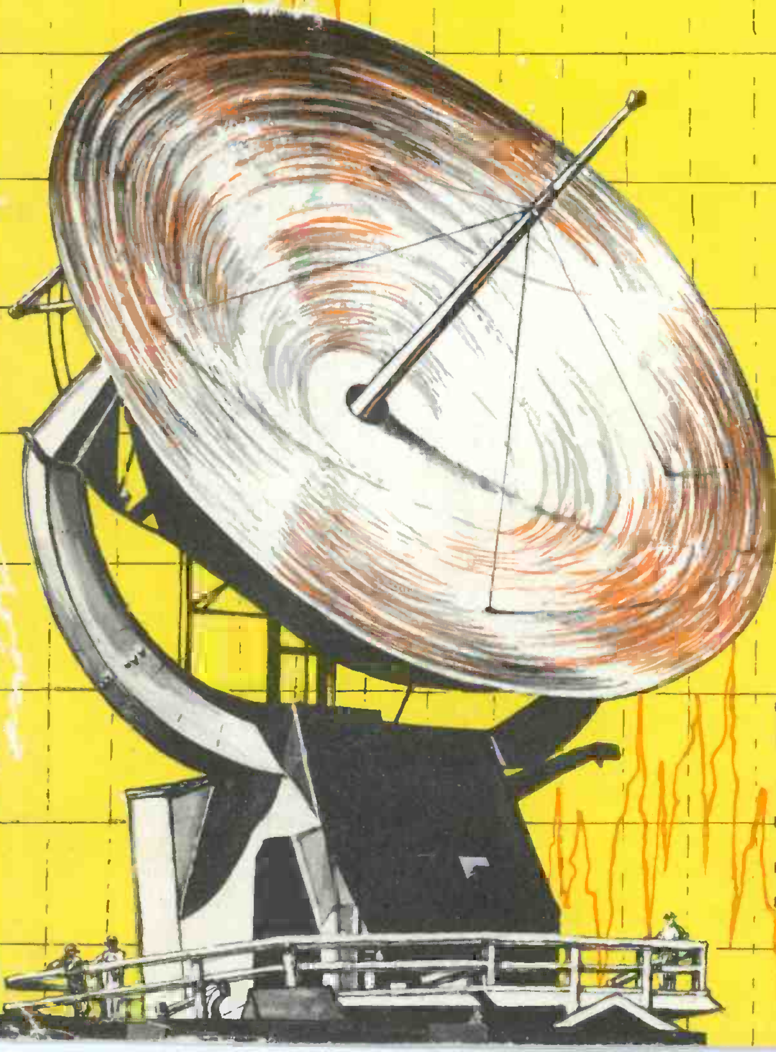
THE BOYS' SECOND BOOK of RADIO and ELECTRONICS



by Alfred Morgan

About the Author

Alfred Morgan is an electrical engineer and has made many valuable contributions to developments in this field. He attended the Massachusetts Institute of Technology and for a number of years he was a radio manufacturer.

His books have been highly successful, for he not only writes from experience and knowledge but also knows how to present facts so that they will interest young people and be easily understood by them. While his own boys were growing up, his home was practically a workshop, and a proving ground for his ideas—with the boys taking an enthusiastic part in it all.

JACKET DESIGN BY LILI RÉTHI

THE BOYS' SECOND BOOK OF RADIO AND ELECTRONICS

By Alfred Morgan

WITH WORKING DRAWINGS AND DIAGRAMS BY THE AUTHOR

This book will be welcomed by readers of THE BOYS' FIRST BOOK OF RADIO AND ELECTRONICS who wish to continue their experiments, and will also be most interesting to those who do not have a wide background of experience in these sciences. In the SECOND BOOK, there is much useful and interesting information about electronic devices, as well as detailed directions and working drawings for easily made radio receivers and such electronic apparatus as transistor amplifiers, a transistor code oscillator, "electric-eyes," electronic phonographs, Geiger counters, capacity operated relays, phono-oscillator, and so forth.

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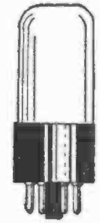

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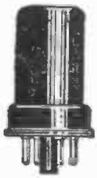

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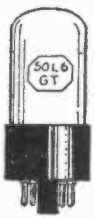
WITH DIAGRAMS BY THE AUTHOR



CHARLES SCRIBNER'S SONS NEW YORK

H-12.63[H]

First printing	May 1957
Second printing	January 1958
Third printing	September 1958
Fourth printing	November 1959
Fifth printing	December 1960
Sixth printing	June 1960
Seventh printing	May 1963
Eighth printing	December 1963

PRINTED IN THE UNITED STATES OF AMERICA

LIBRARY OF CONGRESS CATALOG CARD NUMBER 57-6078

Science Beckons to Youth

Brig. General David Sarnoff
Chairman of the Board
RADIO CORPORATION OF AMERICA

In the guided missiles program and in all fields affecting our national security, research and engineering are of surpassing importance. There is no substitute for brains, or for practical training in a technical age.

Our safety and our industrial strength rest upon our success in expanding the Nation's reservoir of physicists and scientists, trained engineers and technicians. Our economy and national security alike will suffer seriously unless we solve this problem promptly and vigorously.

Science and technology are the very hallmarks of American civilization.

In the not too distant past, science was associated with men of age and experience. Science was moving slowly at that time and its discoveries developed leisurely. The pressure of time was not a vital factor in the birth or use of an invention. Even when a great discovery was made, a skeptical public was slow to accept it because public interest in science was limited and faith in its possibilities was not what it is today.

In contrast with that past, youth today is largely in the forefront of science. Young men and women hold strategic places in its advancement. Young experimenters now enjoy the vast facilities of university and industrial laboratories and a free exchange of knowledge with others.

These young people have noted professors and their libraries from which to draw knowledge from other men's experience. As a result, they may easily learn what has been done before and need not waste their time and energy going over ground already covered by other scientific experimenters.

Science is much like a football game; teamwork is the key to success, but some player trained to take advantage of opportunity will pick up the ball and score a touchdown. That has happened time and time again in science and industry. Science seems to have an affinity for youth. Genius knows no age.

Contents

THE BOYS' SECOND BOOK OF RADIO AND ELECTRONICS

CHAPTER ONE

An Adventure in Science

We live in a complex technological world. Progress in science and engineering is not only desirable but has become an essential part of our civilization. We must look to this progress for the maintenance of our high standard of living. In it is much of our hope for peace and survival. More and more we are dependent on people who are well trained in scientific and technical skills.

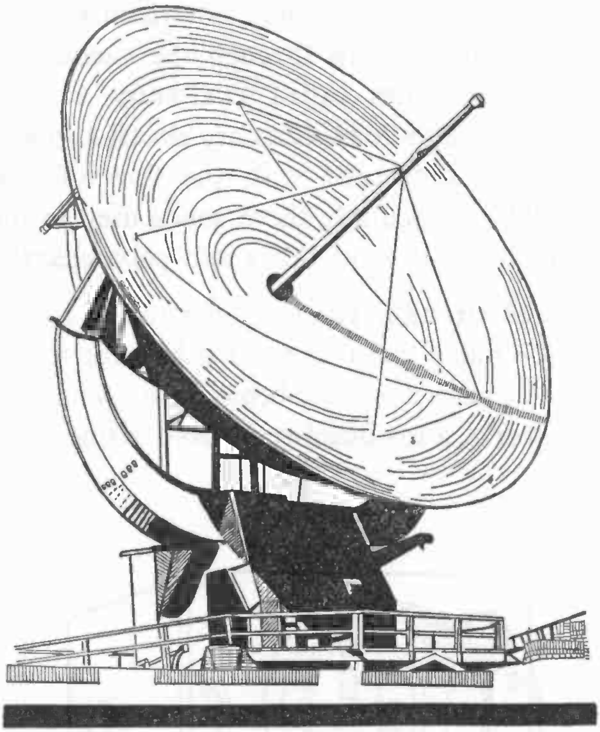
Are you looking for an interesting hobby—a hobby which may lead to a more intelligent understanding of the world in which we live and which may also lead to a scientific career? Are you undecided about your future? Do you still have to make a decision whether you should study law, medicine, engineering, or go into business? You may find an answer in this book. It deals with an intriguing, constantly growing and probably unlimited branch of science and engineering.

America needs twice as many scientists and engineers as we are turning out. By 1960, the U.S.A. will be short at least 100,000 scientists and engineers. Opportunities for employment and advancement in engineering and in the sciences have never been so great or numerous. The best way to discover whether or not you have natural ability for one of these professions is to adopt some branch of engineering or science as a hobby. Electronics is recommened as an enjoyable, engrossing and instructive scientific spare time activity.

An interest in electronics will bring adventures in a scientific wonderland. Radiotelegraphy and radioteleph-ony, television, hi-fi phonographs, sound motion pictures, radar, telephoto transmission of pictures, guided missiles, "electric eyes" and "snooperscopes" for seeing in the dark are only a few of the marvelous things found in the realm of electronics. Apparatus with which you can communicate with other "amateurs" in far away Hawaii or on the other side of the world in Europe is not difficult to construct. Furthermore, a sustained interest in electronics as a hobby will provide the foundation for a professional career as an engineer or scientist. The principles of electronics are basically electrical principles but physics and chemistry are also involved. When this nation's industries are listed according to their size, electronics is No. 9 on the list.

Electronics is a science and an art. A science, you may know, is systematized knowledge obtained by study and practice. What is an art? Well, an art is the practical application of knowledge and skill.

Electronics includes so much of the science of physics and of electrical engineering that it is difficult to state a



RADIO WAVES FROM THE STARS

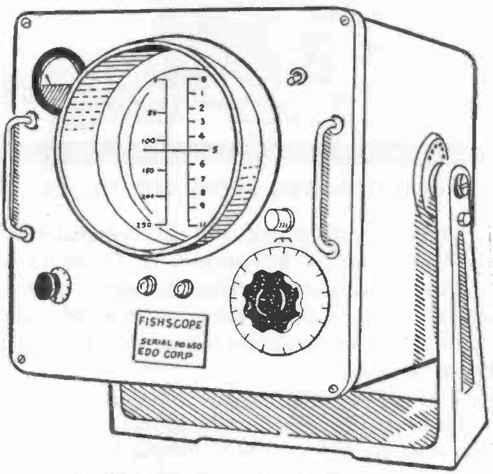
This is the 50-foot radio mirror and 21 centimeter antenna at the Naval Research Laboratory in Washington, D. C. where it is used as a *radio telescope.* Radio radiation reaching the earth from outer space is adding to our knowledge of the physical universe of stars and galaxies. Very large antennas and sensitive electronic recording apparatus are required in the operation of a radio telescope.

Until 1931 all our knowledge of the physical universe of stars and galaxies came from studies made with optical telescopes. Atmospheric absorption limits research with optical telescopes to about 5 octaves of the electromagnetic spectrum. On the other hand, radio telescopes can record radiation for the entire range of wave lengths between 1 centimeter and 30 meters. This is roughly 12 octaves of the electromagnetic spectrum.

brief yet comprehensive definition of what is included in the term ELECTRONICS. A short definition, ample for the purpose of this book, is:

Electronics is the science and art which is concerned with the flow of electrons through the vacuum or gas-filled tubes sometimes called ELECTRON TUBES. The vacuum tubes in a radio receiver are electron tubes. Electronics is also concerned with the flow of electrons through solids, particularly those solids used in the construction of transistors, rectifiers and photoelectric cells.

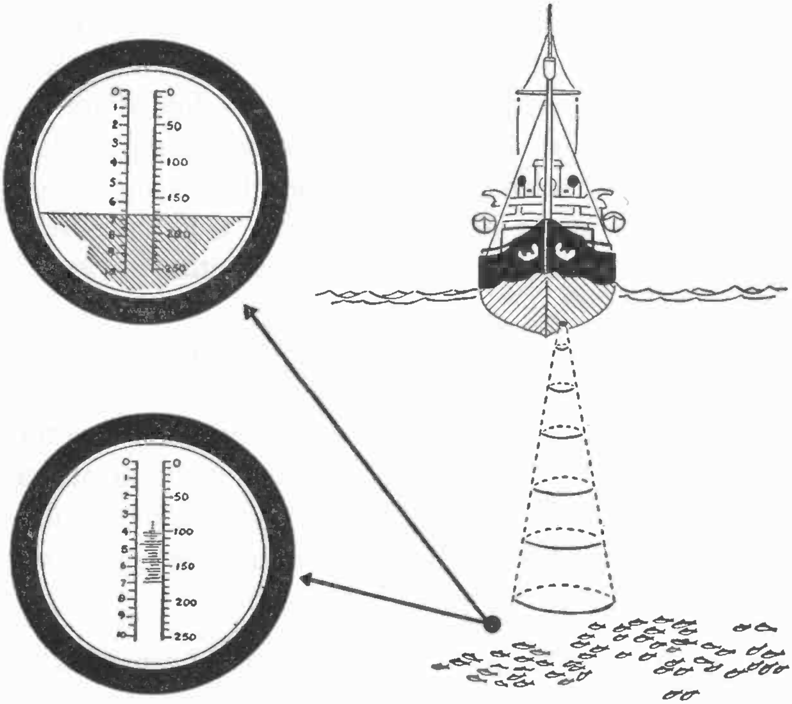
The Word Electronics. The term electronics comes from *electron,* the name the ancient Greeks gave to the pale yellow or sometimes reddish-brown resin which we call amber. Amber is a fossilized resin from extinct pine trees



**THE EDO FISHSCOPE,
AN ELECTRONIC APPARATUS WHICH FINDS FISH WITH SONAR**

The Edo Fishscope employs the principles used in under-water sonar detection gear for the Navy. It gives a clear, accurate picture on an easily readable cathode-ray tube of schooled or even individual fish swimming just below the surface to as deep as 250 fathoms. The Fishscope also serves as a very accurate depth sounder.

which existed many ages ago. Pieces of the resin were worn by ancient people as jewels and decorations. Amber beads which were buried in prehistoric times have been dug up from tombs at Mycenae and Etruria. Amber's



HOW THE EDO FISHSCOPE OPERATES

Sonar signals are sent forth from a transducer located in the bottom of the ship. If the signals strike fish nearby, the signals are reflected back to the transducer and produce "pips" on the screen of a large cathode ray tube in the Fishscope. The right-hand sketch shows how signals from the transducer spread out as they travel toward "bottom." The solid curved lines are the outgoing sonar signals. The dotted curved lines are the sonar signals reflected from the fish. The upper left-hand sketch shows how a school of fish appears on the 0- to 250-fathom scale on the tube. By flipping a switch to the 10-fathom scale, the view is magnified 25 times. The exact depth of the fish is determined by centering the enlarged view on the scope and reading the depth indicated on the scale (*see lower left*).

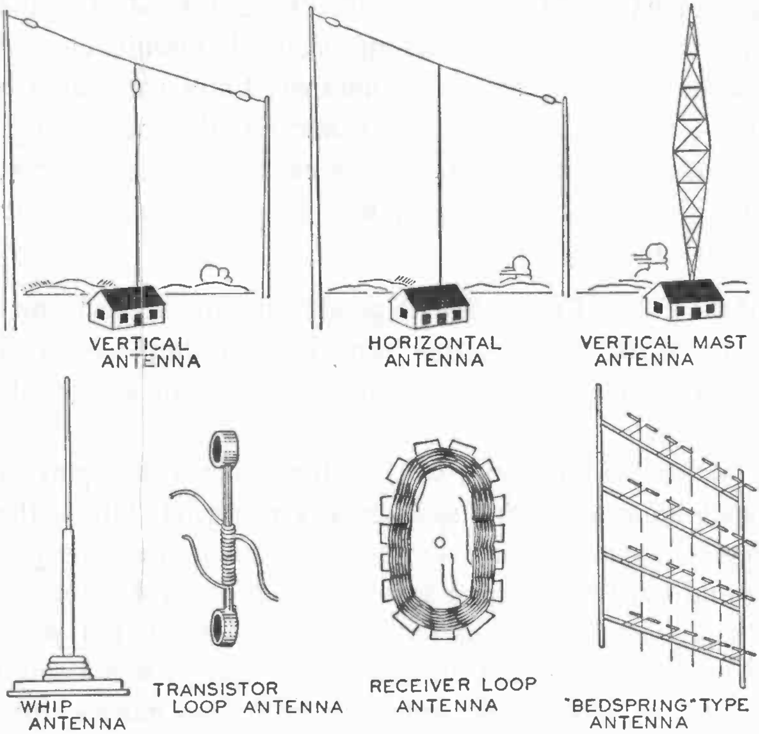
yellow luster must have reminded the Greeks of native gold, for they applied the same name to amber and gold. Amber and gold were both *electron* or "children of the sun" to the Greeks.

There is a reason why the science of electronics derived its name from the Greeks' word for amber. When amber is rubbed or subjected to friction it becomes electrified, or CHARGED WITH ELECTRICITY, so that it noticeably attracts dust, lint and other small light particles. This fact was known in ancient times. Lightning flashes and amber's magic attractive quality, therefore, were probably mankind's first intelligent observation of electrical action.

Present-day scientific opinion is that electricity consists of tiny invisible particles, all alike. They are called ELECTRONS. There are electrons present wherever matter exists. A moving electron is an ELECTRIC CURRENT—a very feeble current for it requires billions of moving electrons to produce a current of sufficient strength to do useful work.

Energy. To be concerned with an electric current is to be concerned with one of the FORMS of energy. Anything which can be converted into work and which can arise from work is ENERGY. Energy can also be the CAPACITY for doing work. Energy takes different forms. The forms of energy of greatest interest in electronics are electricity, heat, light, mechanical energy, electromagnetic energy, radiant energy and sometimes chemical energy.

All of these different forms of energy can be converted into any of the other forms. All electronic equipment con-



ANTENNAS AND RADIO WAVES

Radar, loran, television and radio communications employ electromagnetic waves to carry their signals through space. Electromagnetic waves are commonly called RADIO WAVES. A wire or conductor, or a system of wires or conductors, known as an ANTENNA, is necessary to radiate radio waves into space and to receive them from space.

Antennas are made in many forms and sizes. Portable broadcast receivers are usually equipped with a flat coil of wire called a LOOP ANTENNA. Many home broadcast receivers are provided with a loop antenna inside the cabinet. When not equipped with a built-in antenna, an external wire strung to a mast or tree is used. Automobile radio receivers and transmitters are connected to a WHIP ANTENNA. This is a metal tube about 6 feet long.

Television waves are of much higher frequency than the waves used for broadcasting. For that reason television transmitters and receivers use antennas which are different from those used for broadcasting waves. Radar antennas are of different shapes still. The illustrations show seven types of antennas. The BEDSPRING type is one form of radar antenna.

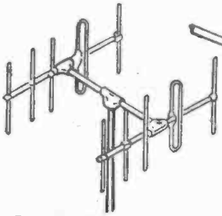
sists of PATHS for electrons called CIRCUITS. Most of the processes which take place in electronic circuits change energy from one form into another. Later we shall see that electrical energy in electronic circuits may change into radiant, mechanical, heat or electromagnetic energy, and electromagnetic energy may change frequently into electrical energy.

Make First a Crystal Set. A good beginning in electronics is to "start at the bottom" and build a simple form of radio receiver, namely, a radio receiver with a "crystal" detector.

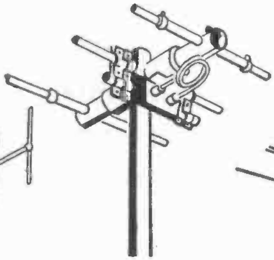
Before radio signals can produce sounds in a pair of headphones or a loud speaker at a receiving station, the signals must first pass through a detector. Perhaps you would hardly expect to secure a good radio detector by digging into the earth for it. Yet, for about ten years prior to World War I the best radio detector was a small crystal of any of the following minerals: galena, iron pyrites, chalcopyrites, zincite, bornite and molybdenite.

For more than a generation uncounted thousands of interested youngsters and adults have constructed radio receivers with mineral or "crystal" detectors. The fascination of this device does not seem to wane.

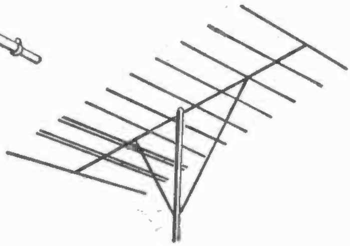
Some amateur experimenters may prefer to put together pieces of equipment without knowing the "whys" of what they are doing. On the other hand, young experimenters with greater curiosity and more analytical minds wish to know the "whys" as well as the "hows" of radio. Here is an explanation of some of the fundamental processes that take place in a radio receiver.



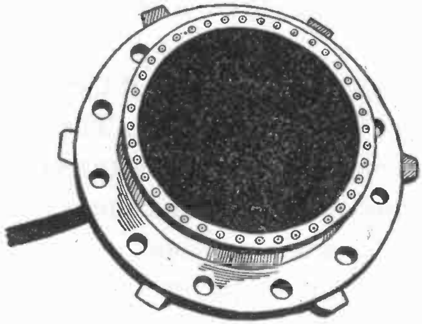
2-METER STACKED ANTENNA



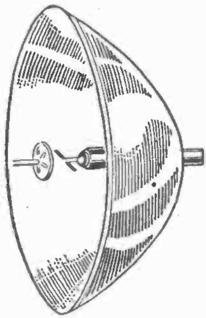
10-METER 3-ELEMENT ARRAY



TELEVISION ANTENNA



SONAR TRANSDUCER



RADAR ANTENNA

A SUITABLE ANTENNA IS IMPORTANT

Best results are obtained only when radio apparatus is connected to a suitable antenna. An antenna that is efficient at one frequency may be entirely unsatisfactory at another frequency. The antenna most suitable for receiving waves of a certain frequency is not always the best antenna for transmitting waves of the same frequency. The higher the frequency, the shorter or smaller the antenna required. At very low frequencies the physical dimensions of the antenna become so great that it is not always practical to employ the vertical type. These are some of the reasons that antennas are of many forms.

The 2-meter and 10-meter antennas illustrated above are types used frequently by amateur or "ham" operators. The television antenna is one of the many kinds for television receivers. The sonar transducer is a form of antenna for propagating and receiving sonar waves in water. The radar antenna at the lower right is the reflector, or mirror, type.

HOW RADIO SIGNALS ARE RECEIVED

Before we can explain how radio signals are received we must first investigate the transmitter.

No matter how complex the various parts of a radio transmitter make it appear, its performance is essentially a simple one. The same fundamental processes occur in its circuits whether it sends forth the dots and dashes of the telegraph code, the music of broadcasting or the pictures and sounds of television.

Two fundamental actions take place at every radio transmitting station.

1. Electrons surge back and forth in some of the transmitter circuits thousands of times per second. The electron surges are termed RADIO-FREQUENCY CURRENTS, a name we give to alternating currents that change their direction more than 20,000 times per second.

2. The electron surges or radio-frequency currents are fed into an overhead wire or wires called an ANTENNA. The surges send radio waves out through space. These radio waves are the CARRIERS of the radio signals.

When a transmitter is in operation there are several changes of energy from one form into another. The principal changes are: electrical energy into magnetic energy, magnetic energy into electrical energy and electrical energy into electromagnetic energy, the latter being a form of radiant energy related to light, heat and x-rays.

When the waves produced at the transmitting station reach an antenna connected to a receiver they set up electron surges in that antenna. The surges in the receiving antenna are of the same frequency as the electron surges in the transmitting antenna which produced the waves. In other words, they occur at the same rate. The electron surges in the receiving antenna, like those in the transmitting antenna, are radio-frequency alternating currents. An alternating current reverses its direction at regular intervals. At one instant the electrons surge through the antenna wire toward the ground. At the next instant, they flow from the ground toward the antenna.

You will hear no signals if you connect an antenna and ground directly to an earphone. Antenna currents, because of their high frequency, are unable to flow through the electromagnets in an earphone. Moreover, when radio frequencies produce sounds, the sounds are ultrasonic—that is, their vibrations are so rapid they cannot be heard by human ears.

However, if you connect a crystal detector to an antenna and ground and connect an earphone to the detector, you will hear signals. The crystal detector makes the signals audible. The crystal does this because it functions as a one-way valve or RECTIFIER. Electron surges in the antenna can pass through it more easily in one direction than in the other. Thus the crystal detector can change or rectify an alternating current into a direct current. A single radio-frequency electron surge does not last long enough to have a useful effect on an earphone. But the surges which produce signals come in groups at an AUDIO frequency, which is to say at less than 20,000 per second, and therefore audible to human ears. Due to the rectifying action of the crystal, the portions of the surges in each group which pass through the crystal ALL FLOW IN

THE SAME DIRECTION. They are pulsating direct currents (currents flowing in one direction only) and can PRODUCE SOUNDS IN AN EARPHONE.

Detection or Demodulation. This process of sorting out the audio-frequency groups of pulses generated in an antenna by radio-frequency carrier waves is called DETECTION OR DEMODULATION. There could be no practical radio communication without detection or demodulation.

First Detectors. In the pioneering days of wireless telegraphy many types of detectors were devised and used but they all lacked dependability and great sensitivity. The use of crystal detectors began in 1906 when General H. H. Dunwoody of the U.S. Army discovered that a small piece of Carborundum would act as a sensitive detector. Carborundum is a crystalline abrasive used in the manufacture of grinding wheels. It is made by heating coke, sand, sawdust and salt in an electric furnace. Its chemical name is silicon carbide. A year later (1907) Greenleaf W. Pickard, an American engineer, developed the first crystal detector of the type which is still in use today.

Dr. Lee DeForest discovered the most practical detector in 1906 when he added a wire grid to the Fleming two-element vacuum tube valve. DeForest thus created not only a stable sensitive detector but also an amplifier which would increase the strength of signals.

Building Your First Radio Receiver

GERMANIUM SEMI-CONDUCTORS

Instructions for assembling a simple radio receiver with a crystal detector, using the circuit diagram shown on page 16, have been printed frequently in pamphlets and magazines. The design of the receiver is based on the use of a crystal diode and the standard antenna coil which is manufactured for superheterodyne broadcast receivers. All parts are factory made except the small wood base. The receiver can be assembled and made ready in an hour or two.

The following parts and materials are required for building the Simple Crystal Receiver:

1 Shellacked wood base
1 1N34 germanium crystal diode
1 Antenna coil with frequency range of 540-1750 kilocycles when used with a 365 mmfd. variable capacitor

1 365 mmfd. midget variable capacitor
1 0.001 mfd. mica capacitor
1 2,000-ohm radio headset
6 No. 2 Fahnestock connector clips
6 ½-in. No. 5 round head wood screws

The 1N34 crystal diode in the list above is used as a detector. A germanium diode of the right type is the modern form of crystal detector. It is sensitive, and unlike the "cat-whisker" detector which was its predecessor in the early days of radio, a germanium diode needs no adjustment and does not get out of order unless mistreated.

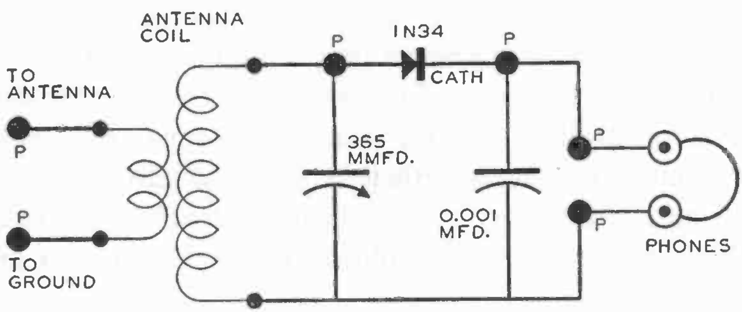


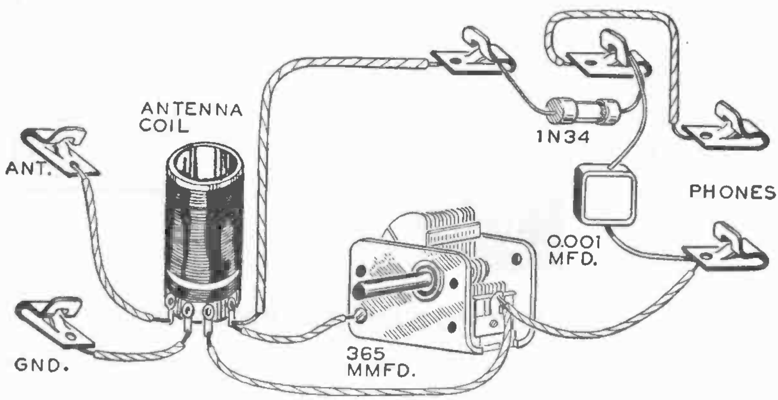
DIAGRAM OF CIRCUIT OF SIMPLE CRYSTAL RECEIVER

This receiver is assembled from standard parts. Nothing is homemade except a 5½ in. x 3¼ in. x ¾ in. wood base. The drawing is a SCHEMATIC diagram. Conventional symbols indicate the various parts or components of the circuit. The symbols used in the circuit diagrams in this book are shown on another page. Memorize them so that you can read any of the schematic diagrams. Schematic diagrams are not as easy at first for the beginner to understand as pictorial diagrams. A pictorial diagram of the same circuit follows this one. Schematic diagrams are more accurate and convey more information than pictorial diagrams. Both kinds appear in this book.

Germanium is of great importance in modern electronics. Since it will be mentioned again in later chapters let's find out what germanium is and what diodes are.

Germanium. Germanium is one of the rare and least known metals of the earth. This grayish-white crystalline substance of great hardness and brittleness was first discovered in 1886 by Clemens Winkler, Professor of Chemistry at the Freiberg School of Mines. He named his discovery germanium in honor of his fatherland. Germanium remained an insignificant metal, merely a laboratory curiosity, for more than half a century. But during the last decade it has become one of the most valuable metallic substances in existence. In 1942 the National Defense Research Council sought metal with certain special properties for use in the field of electronics. Germanium was found to have those properties. Its utility in electronics soon caused it to become five times

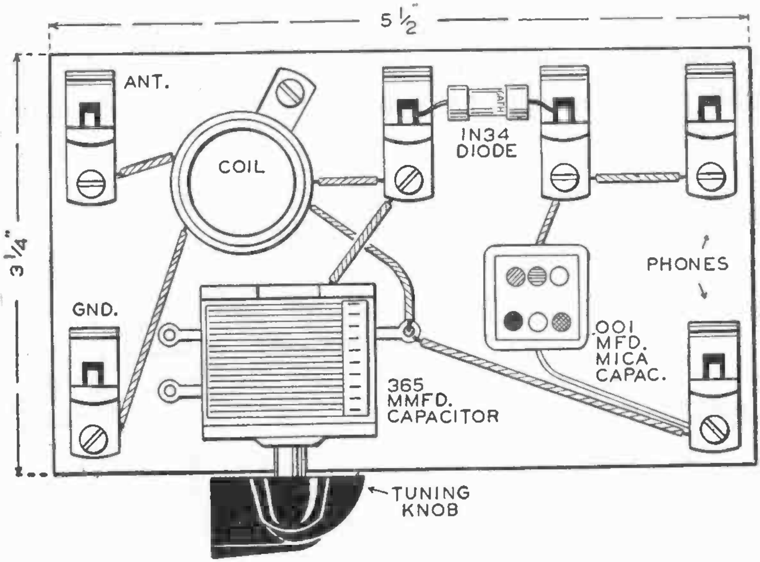
PICTORIAL DIAGRAM OF CIRCUIT
OF SIMPLE CRYSTAL RECEIVER



as valuable as gold. But as more sources of germanium were found and better methods of refining it were developed, the cost was reduced. Pure germanium is worth about $300.00 per pound today. Gold is worth $510.40 a pound.

The useful electrical properties which give germanium its importance in electronics are due to its behavior as a SEMI-CONDUCTOR.

Semi-conductors. The materials through which electrical currents flow easily are called CONDUCTORS. Most of the metals are fairly good conductors, copper and silver being the best. Materials through which electric currents do not



PLAN OF SIMPLE CRYSTAL RECEIVER

This shows the position of the components on the wood base and the arrangement of the wiring.

flow are called NON-CONDUCTORS. Materials such as glass, porcelain, rubber, Bakelite, etc., used to insulate current-carrying wires are non-conductors.

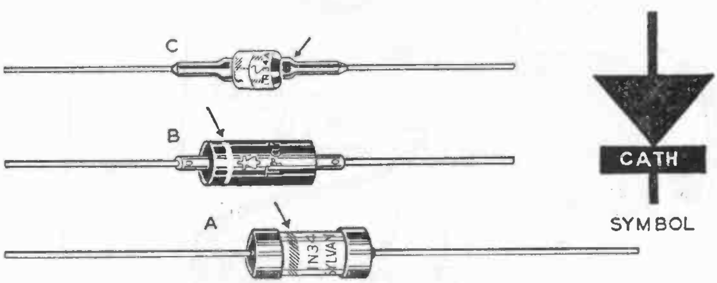
In addition to conductors and non-conductors there are materials called SEMI-CONDUCTORS. A semi-conductor is neither a good conductor like silver or copper, nor a good non-conductor like glass. But under certain conditions germanium acts like copper, and a current will flow through it. Under other conditions it acts like glass and is practically a non-conductor.

One of the useful properties of a semi-conductor is its ability to permit the flow of electricity in one direction and to resist its flow in the other direction. It acts as a sort of automatic electrical valve, opening to electrons passing in one direction and closing to those which try to move the opposite way. Germanium, selenium and silicon, when combined with certain impurities, are the most useful semi-conductors. There are other materials which possess similar properties but they are not used as extensively as the three mentioned.

The first use for semi-conductors in electronics was as RECTIFIERS—devices which change alternating current into direct current. The galena or silicon crystals with an adjustable "cat's whisker," employed as detectors in the early days of radio, represent one of the earliest uses of a semi-conductor as a rectifier *in electronics.* Selenium has long been used as a semi-conductor in power rectifiers and in "self-generating" photocells.

The first use for germanium was in the construction of tiny electronic rectifiers called DIODES, and used to replace the diode vacuum tubes used as detectors in radar, Several small paper-covered books have been published by engineers who helped develop the germanium diode. These books tell how to build more than one hundred electrical and electronic devices using germanium diodes. The books are priced from 25 to 50 cents and can be obtained from any radio dealer that handles the diodes, or from the publisher. The titles of the books will be found at the end of this chapter.

The Antenna Coil. The coil consists of two windings, a primary and a secondary wound on a plastic tube. The secondary has a frequency range of 540-1750 kilocycles when used with a 365 mmfd. variable capacitor. This range slightly more than covers all the frequencies in the standard broadcast band. An antenna coil of this type can be purchased at small cost at almost any radio repair shop. The coils are kept in stock for use as replacements for defective coils.



GERMANIUM DIODES

Several manufacturers produce germanium diodes. The 1N34 (**A**) and 1N34A (**C**) illustrated above are products of the Electronics Division of Sylvania Electric Products, Inc. The arrows in the illustration point to the markings which indicate the cathode end of the diode. On each Sylvania germanium diode the cathode terminal is indicated by a green band and the letters CATH.

Radio Headset. A radio headset consists of two earphones, or telephone receivers, mounted on a headband. The telephone receivers made for radio use are more sensitive to very small currents than the common telephone receiver. Two types of telephone receivers are used in radio. Do not use "crystal" type headphones with a crystal detector. The headset connected to the Simple Crystal Receiver should be the electromagnetic type and have a resistance rating of at least 2000 ohms.

Mica Capacitor. This component of the circuit is not always required. Some headsets have enough of the quality called "distributed capacitance" to make the mica capacitor unnecessary. In some instances the use of the mica capacitor may not improve the strength of the signals heard in the headset but will improve their tone.

Variable Capacitor. The common 365 single gang mmfd. variable capacitors usually have a ¼ inch diameter shaft. When purchasing the capacitor, obtain also a molded knob which can be attached to the shaft with a setscrew. Some variable capacitors are so made that they can be mounted on a base or against a panel. A capacitor for base mounting has threaded holes in the bottom of the frame. The threaded holes are in the front of the frame in capacitors for panel mounting. If the capacitor which you use is of the latter type it will be necessary to mount it on the back of a small ¼-inch plywood panel attached to the front of the wood base.

ASSEMBLING THE SIMPLE CRYSTAL RECEIVER

The base should be a piece of well seasoned wood which has been shellacked or varnished on all surfaces. Mount the components as shown in the plan and perspective sketch. There are four terminals on the antenna coil, and connection is made to them by soldering. Use rosin-core solder NOT acid-core solder. The short coil is the primary. The long coil is the secondary.

Use both the schematic and pictorial circuit diagrams when wiring the receiver, and check each connection carefully to make sure it is correct.

Operating the Receiver. Connect a high-resistance (1000 ohms or more) earphone or a radio headset to the PHONE terminals. Connect an antenna to the ANTENNA terminal and a ground to the GROUND terminal. The antenna should be a wire 50 to 100 feet long and be insulated from its supports. Antennas and grounds are described in more detail in the chapter called "Taking the Mystery Out of Tuning."

Under ordinary conditions the range of the receiver will not be over 25 to 30 miles when listening to a broadcast station. The range of the receiver and the strength of its signals will depend to a great extent upon the height and length of the antenna. If the receiver is located in a metropolitan area where several broadcasting stations are nearby, it may "pick up" more than one program at a time. If two stations are heard at the same time, adjusting the variable capacitor will increase the strength of the signals which you prefer to listen to and weaken those which are causing interference.

All in all, the "simple crystal receiver" is not an entirely satisfactory design. There is no provision for adjusting or tuning the antenna circuit. It has been described here because of its simplicity and because there are no home-made parts required except the wood base.

If you are willing to wind your own coils, build the receiver described in the next chapter. It is much more sensitive and selective. With it, you can perform experiments which will demonstrate the principles of tuning radio circuits.

Books about Transistors

Electronic Shortcuts for Hobbyists, Sylvania Electric Products, Inc., 1740 Broadway, New York 19, N. Y. 25 cents.

Forty Uses for Germanium Diodes, Sylvania Electric Products, Inc., 1740 Broadway, New York 19, N. Y. 25 cents.

Transistor Manual, General Electric Co., Electronics Park, Syracuse, N. Y. 50 cents.

Transistor Applications, Raytheon Mfg. Co., Newton 58, Mass. 50 cents.

Popular Electronics, Ziff-Davis Publishing Co., 366 Madison Avenue, New York 17, N. Y. 35 cents. A magazine published monthly for electronic experimenters.

CHAPTER THREE

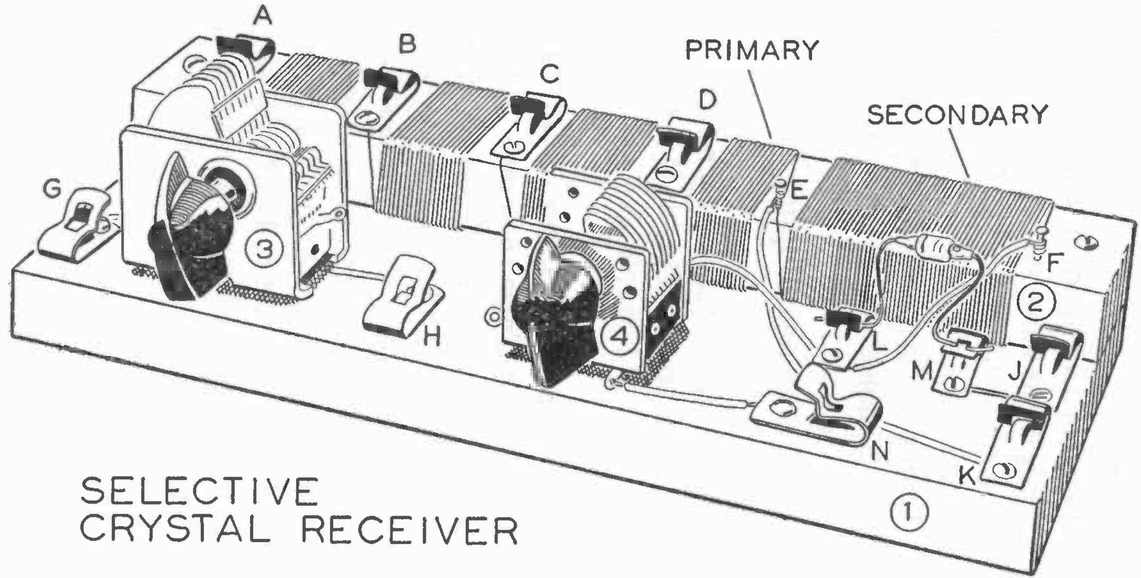
How to Build A More Selective Crystal Receiver

The crystal receiver described in the last chapter is popular because all the parts can be purchased ready-made. It is used in many high schools to demonstrate elementary principles of a radio receiver.

Unfortunately, the advantage of being able to assemble quickly a working receiver sacrifices sensitivity and selectivity. You can build a much better receiver if you wind a special coil to be used in place of a standard antenna coil which, after all, was not originally designed for use in a crystal receiver.

The following parts and materials are required:

1	Shellacked wood base, 10 in. x 4 in. x ¾ in. **(1)**
1	Shellacked pine coil form 10 in. x 1½ in. x ¾ in. **(2)**

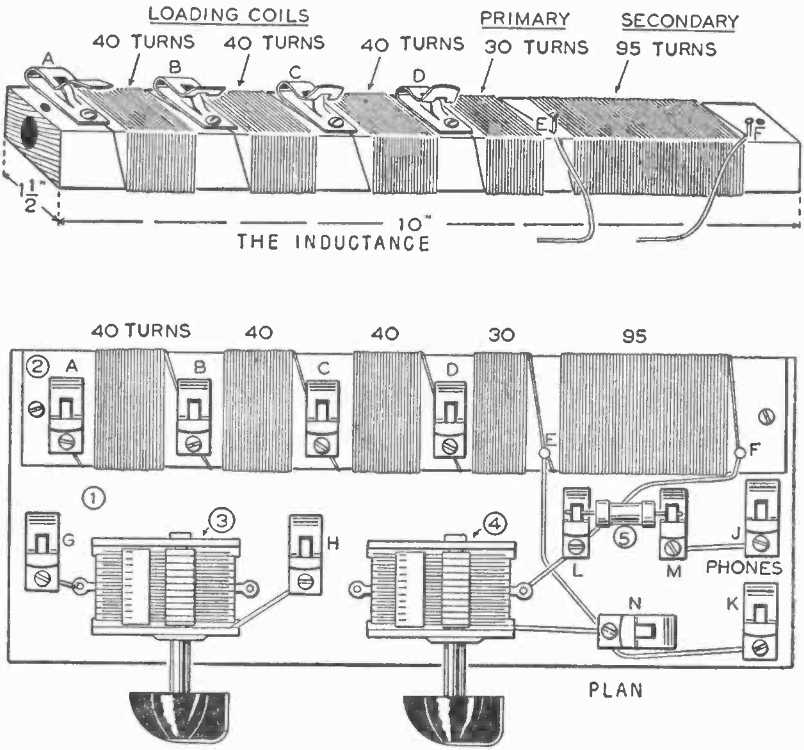


A MORE SELECTIVE CRYSTAL RECEIVER

100	feet No. 24 B.S. gauge enamelled magnet wire
1	Sylvania 1N34 germanium diode (5)
2	Midget one-gang TRF receiver variable capacitors with capacity from 10 to 365 mmfd. (3 and 4)
2	Knobs for the variable capacitors
9	No. 2 Fahnestock spring contact clips (1 in. x ⅜ in.)
2	No. 10 Fahnestock spring contact clips (¾ in. x 5⁄16 in.)
2	¾ in. brass escutcheon pins
	Hook-up wire, 2-1¼-in. No. 6 R. H. wood screws, 11-½-in. No. 5 R. H. wood screws

The Coil. This consists of 245 turns of No. 24 B.S. enamelled magnet wire in a single layer on a 10 inch x 1½ inch x ¾ inch pine (or other soft wood) core. Much common lumber is ¾ inch thick and there should be no difficulty in finding a piece of this thickness from which to saw a 10 inch x 1½ inch strip. The wood should be seasoned and dry. Plane or sandpaper the piece smooth and apply two coats of shellac to all surfaces. The shellac will seal the wood against moisture, help to prevent swelling or shrinkage of the core and consequent loosening of the winding.

The winding starts and ends about one inch from the ends of the core and is divided into five sections. There is a space between each section but from the electrical standpoint the winding is continuous. There is no break in the wire between sections. The spaces between the sections and at the ends of the core provide the room for "taps." Four of the taps are No. 2 Fahnestock connector clips so that a wire can be easily and quickly connected to any one of them and disconnected with equal facility. Two of the taps are brass escutcheon pins. Escutcheon pins are round headed brass nails obtainable at a hardware store and used for fastening small name



PLAN OF THE CRYSTAL RECEIVER AND DETAILS OF THE TUNING INDUCTANCE

Note the letters identifying each contact clip and the two pins. These letters also appear in the circuit diagram.

plates. The connections made to the brass pins are permanently soldered. The Fahnestock clips are fastened to the wood core with ½-inch No. 5 round head wood screws. The escutcheon pins are driven into the core.

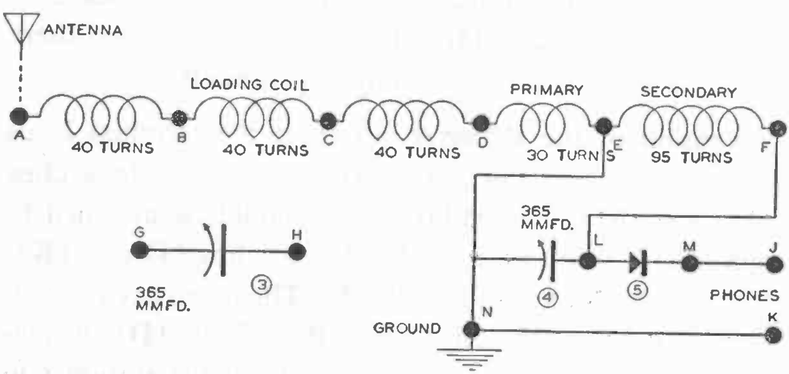
The first three sections of the winding each contain 40 turns of wire and comprise the ANTENNA LOADING COIL. The fourth section consists of 30 turns and is the PRIMARY. The last section contains 95 turns and is the SECONDARY.

The wire must be wound tightly in a smooth, even layer and the turns counted carefully as they are wound on so that there will be the correct number in each section of the coil. Scrape the enamel off the "beginning" end of the wire with fine sandpaper and clamp it under Fahnestock clip (**A**) and once around the screw which holds the clip. Tighten the screw so that the wire is secure. Wind on 40 turns. Hold the wire taut so that the turns will not loosen, and clean the insulation off the wire at the right place so that it will make a good electrical connection with Fahnestock clip (**B**) when placed under the latter and the screw is tightened. Then wind on 40 more turns and connect the wire to clip (**C**). Continue in this manner until the winding is complete. The insulation should be cleaned off the wire where it is wrapped around the pins (**E**) and (**F**).

Winding the coil is not difficult when some sort of a winding device is used. Perhaps some one with a lathe-equipped home workshop will wind the coil for you. Or perhaps you can do this yourself on a lathe in the shop at your school. If a metal-turning lathe is used, one end of the wood core is placed in a four-jaw chuck on the headstock of the lathe. The other end is supported on the center in the tailstock. The lathe should be turned slowly by hand by pulling on the belt. If a wood-turning lathe is used, the wood core is mounted between the head and tail centers as if it were a piece of wood to be turned. Turn the lathe by hand by pulling on the belt. Do not use power. Those who are not fortunate enough to have a lathe available should build the winding machine described at the end of this chapter. It will not require much time to make and the machine will make winding the coil easy.

When the winder is in use it should be held firmly to the top of work bench or table with a C clamp. Coil forms of various lengths can be wound with this same winder by moving the uprights so that the distance between them is $\frac{1}{16}$ inch longer than the coil form.

The Variable Capacitors. Both variable capacitors should be the type which can be mounted on a base and be provided with two threaded holes in the bottom of the capacitor frame for that purpose. If the threaded holes are



CIRCUIT DIAGRAM OF THE CRYSTAL RECEIVER

in the front of the frame, the capacitor is designed for panel mounting. In that case it will be necessary to attach a small plywood panel (6 in. x 3 in. x ¼ in.) to the front edge of the wood base and mount the capacitors on the back of the panel.

Fixed Capacitor. You may notice that an 0.001 mfd. fixed capacitor to be connected across the headset is not included in the list of parts. Such a capacitor is usually shown in circuit diagrams of crystal receivers. If a standard radio headset is connected to the receiver the 0.001 mfd. capacitor is not necessary. The purpose of the capacitor is to provide a path for radio-frequency currents around the headset. There is sufficient capacitance in the windings and connecting cord of a standard radio headset to provide such a path.

Assembling. Assemble the parts on the base according to the plan in one of the illustrations. To connect the parts, consult the wiring diagram. Notice that the variable capacitor (**3**) to the left on the base is not included in the circuit but is connected only to two Fahnestock connector clips (**G**) and (**H**). This capacitor is placed there to be used later in some tuning experiments.

Operation of the Receiver. Connect the terminal leads attached to the 1N34 diode (**5**) to the Fahnestock clips (**L**) and (**M**). The cathode lead should be attached to clip (**M**). Connect a radio headset to clips (**J**) and (**K**). Connect a good ground to clip (**K**). The antenna can be attached to any of the clips (**A**) (**B**) (**C**) or (**D**), whichever one will bring in signals best from the station you wish to listen to. For instructions regarding the antenna and ground connection consult the chapter devoted to those subjects. Adjusting the variable capacitor (**4**) will tune the secondary winding and enable you to tune out unwanted signals.

With this receiver you should be able to hear more stations and get louder signals without interference than is possible with the simple receiver described in the previous chapter. The primary of the antenna coil used with that receiver does not contain enough turns to tune in signals efficiently over the entire broadcast band when used with a crystal detector. The coils (**A**) (**B**) (**C**) and (**D**) provided in the more selective receiver are loading coils. They enable you to tune or adjust the antenna circuit to suit the length of the waves which produce the signals you wish to listen to.

Perhaps you will understand how the loading coil improves the receiver after you have read the next chapter.

HOW TO BUILD A WINDING MACHINE FOR WINDING THE TUNING INDUCTANCE

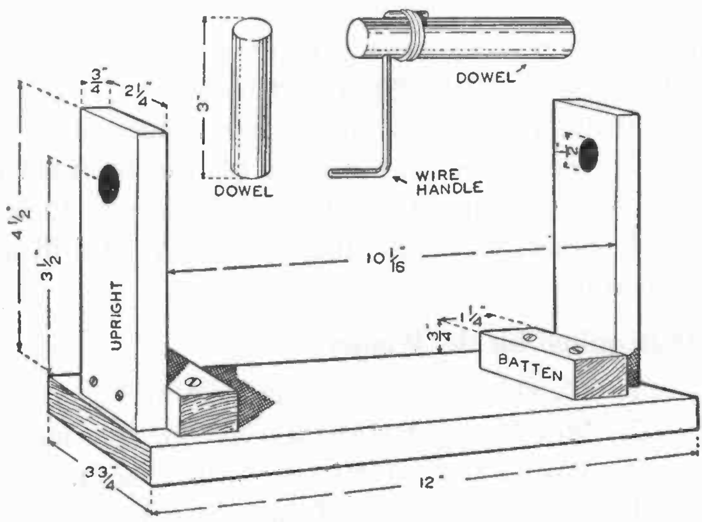
The materials required are several pieces of wood, screws, ½-inch dowel rod, a piece of wire from a coat hanger and a clamp. A handsaw, screwdriver, ½-inch auger bit, brace, hand drill and a No. 28 twist drill will be needed for making the parts.

Parts Required for the Winder

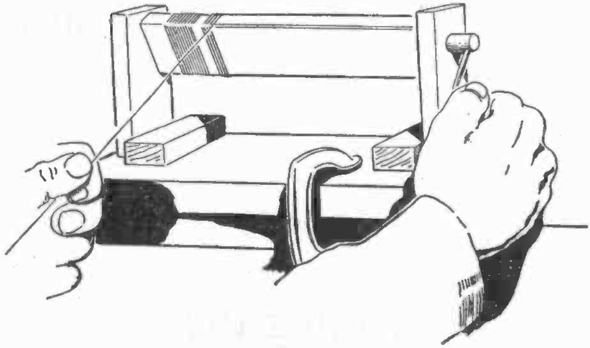
1 Wood base 8 in. x 3¾ in. x ¾ in.
2 Wood uprights 4½ in. x 2¼ in. x ¾ in.
2 Wood battens 3½ in. x 1¼ in. x ¾ in.
1 Piece of steel wire from a coat hanger
8 No. 6 wood screws 1¼ in. long

Cut the wooden parts to the dimensions shown in the illustration. Give them one or two coats of shellac or varnish. Bore a ½-inch diameter hole through both uprights on their center line and 3½ inches from the lower end.

Bore two holes in each upright with a No. 28 twist drill. The holes should be ⅜ inch from the end, and at the end opposite the ½-inch hole. Slip a No. 6 wood screw through each of the small holes in the uprights and fasten each upright to a batten. Fasten each batten to the base, using two screws. The battens should be located so that the distance between the uprights is $\frac{1}{16}$ inch longer than the wood core of the inductance. The ½-inch holes in the uprights are bearings and must be in line so that a piece of ½-inch diameter dowel will pass through both



PARTS FOR THE COIL WINDER



WINDING THE TUNING INDUCTANCE

holes and turn without binding. To align the holes, first fasten one upright and batten to the base. Then slip a long piece of ½-inch dowel through the bearing holes in both uprights, and fasten the second batten and upright to the base at the proper distance. Assembling the winder with a long dowel in the bearing holes should bring the holes in alignment.

Two pieces of ½-inch dowel 3 inches long are used as a shaft for the wood core which is to be wound. Bore a ½-inch diameter hole in each end of the core along its axis. Make the holes 1½ inches deep. A piece of steel wire (from a coat hanger) is slipped through a hole near the end of one of the 3-inch dowels and bent to form a crank. This wire handle is used to turn the core when winding it. The two pieces of dowel used as a shaft should fit tightly into the holes in the end of the core. It may be necessary to wrap them with a layer or two of paper to make a snug fit. The dowel shafts must turn freely in the bearing holes in the uprights. If they are too tight in the bearing holes, free them by sandpapering the dowels to make them slightly smaller.

CHAPTER FOUR

Taking the Mystery Out of Tuning

Hundreds of radio stations are transmitting at the same time. Many of them are in the same neighborhood. They transmit at many different frequencies. For example, broadcasting stations transmit over a "band" ranging from 550 kilocycles to 1700 kilocycles. This means that the alternating currents produced at broadcast transmitters and fed into the antenna alternate from 550,000 to 1,700,000 times per second. Each transmitting station sends at a frequency which has been assigned to it by the Federal Communications Commission. Each transmitter is equipped with automatic controlling apparatus which holds it within narrow limits to the frequency assigned to it.

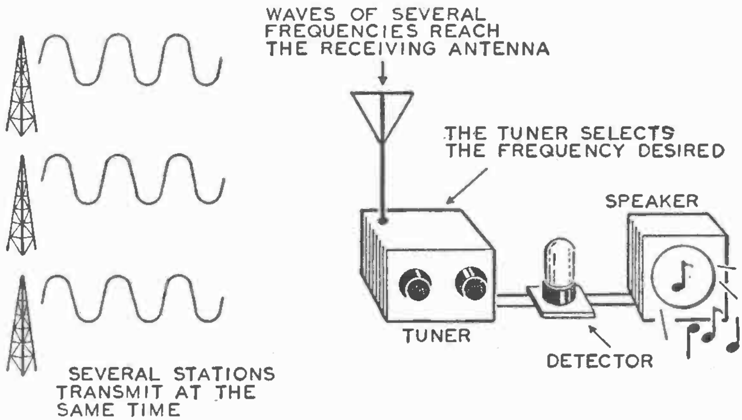
Every receiving antenna is constantly intercepting waves of many different frequencies, but with a selective receiver signals from only one transmitter can be heard at a time. A process called TUNING makes this possible.

Tuning a receiver adjusts it so that it selects signals of one frequency only and rejects the signals of all other frequencies. Tuning is accomplished by adjustable coils and capacitors.

A radio engineer thinks of tuning in mathematical terms. By using analogies instead of technical terms and by comparing radio circuits to a rope clothes-line, tuning can be freed of some of its mystery for the novice.

EXPERIMENTS IN "TUNING" A ROPE

Try these experiments. Hang a light rope or clothes-line between two supports 30 to 40 feet apart. The rope



TUNING

An agreement among the nations of the world requires all radio transmitters to be licensed. Under this agreement, each transmitter is licensed for operation only on the frequency (or frequencies) assigned to it. Consequently it is necessary to adjust or TUNE a transmitter so that it will produce waves only of the frequency or frequencies assigned. Tuning a receiver strengthens the desired signals and bars out signals from other stations which are unwanted at the time.

should not be stretched taut or allowed to hang very slack.

The rope can be made to behave in a mechanical manner somewhat as a radio circuit behaves in an electrical manner, and thereby illustrate some of the principles of tuning.

With your forefinger or a stick, strike the rope a sharp, quick blow near one end. If the rope is properly hung and you use the right amount of force, a visible wave in the rope will move along its length. Some of the energy in your arm has been transferred to the rope. The energy travels along the rope to the opposite end in the form of a wave. When it reaches the end of the rope the wave reverses its motion and travels back toward you. The wave will move back and forth along the rope several times, becoming weaker and weaker until all its energy is exhausted and it disappears.

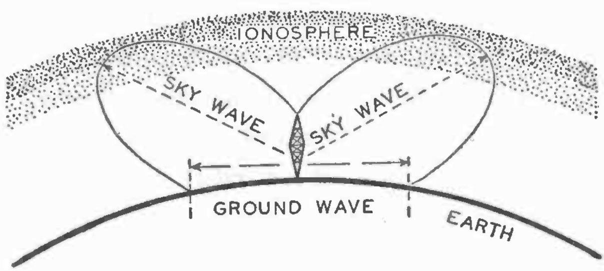
One of the most important observations that you could make during this experiment is: if you could measure accurately the length of time required for the wave to travel from one end of the rope to the other end and back, you would find that the time is always the same no matter whether you hit the rope hard or gently—PROVIDED YOU DO NOT CHANGE THE LENGTH OR TAUTNESS OF THE ROPE.

A wire or antenna which is struck by an electromagnetic (radio) wave from a transmitter can be likened to the rope struck by your hand. Energy runs along the wire or antenna, not in a visible wave which can be seen, but as a moving group of invisible electrons called a pulse of electric current. The electrons travel along the wire or antenna to one end and then reverse their direction.

They travel back and forth until the energy that moves them is exhausted. Since the electrons reverse their motion they are an ALTERNATING electric current.

Now try another experiment. Tighten the rope slightly so that there is less slack. Tap it again once near one end. A wave will travel from one end of the rope to the other and back as it did before but this time it will travel MORE RAPIDLY. Shortening the rope will produce the same effect as tightening it. The wave will move from one end to the other and back in less time. Lengthening or loosening the rope will INCREASE the time required for the wave to travel back and forth. By this experiment you have demonstrated a method of "tuning" a rope.

A wire or an antenna can be ELECTRICALLY shortened, lengthened, tightened or loosened just as a rope can be MECHANICALLY shortened, lengthened, tightened or loos-



RADIO WAVES—GROUND WAVES AND SKY WAVES

Normally a vertical antenna is more efficient for transmitting radio waves than a horizontal antenna. When a radio wave leaves a vertical antenna, if it were visible, its pattern would resemble a huge doughnut lying on the ground with the antenna in the hole at the center. Part of the wave moves away from the antenna but remains in contact with the earth and is called the GROUND WAVE. The rest of the wave moves upward and outward to form the SKY WAVE. It is the surface part of the ground wave that reaches most receivers tuned to daytime broadcast programs.

ened. In other words, it can be TUNED. If a wire or circuit is either shortened or electrically "tightened," alternating electric currents will travel back and forth in it in less time than before. From a radio or electrical standpoint, the currents will alternate at HIGHER FREQUENCY. Lengthening or electrically "loosening" a wire or circuit will produce the opposite effect. This will increase the time required for an alternating current to travel back and forth therein. The currents will alternate at a LOWER FREQUENCY.

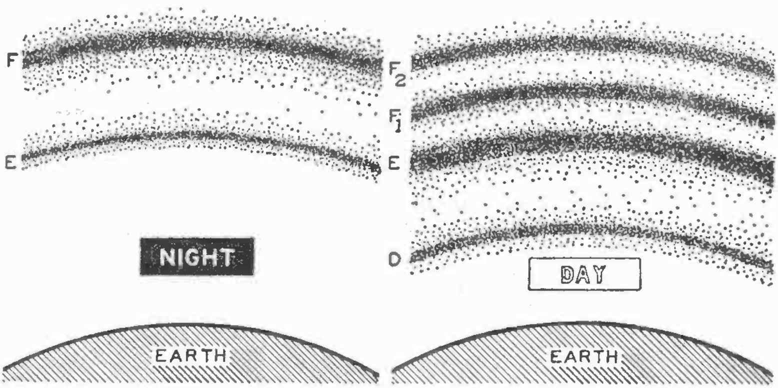
NATURAL FREQUENCY

The number of little waves that run back and forth along a rope in a second are called the NATURAL FREQUENCY of the rope. The number of times that an alternating electric current will surge back and forth along a wire or through a circuit NATURALLY, that is, without being forced is the NATURAL FREQUENCY of the wire or circuit. This explanation is not a literal definition of natural frequency as it is understood by a radio engineer, but it will serve to give you a concept of the meaning of the term natural frequency as it is used in electronics. Whenever we tune a radio circuit, we change its natural frequency.

Changing the physical length of a wire or circuit, that is its length in feet and inches, changes its natural frequency. There are other ways of changing the natural frequency of a wire or circuit besides changing its physical length. It may be ELECTRICALLY tightened or shortened, or lengthened or loosened by changing its INDUCTANCE and CAPACITANCE. A wire wound in the form of a coil has a different "tension" and a different "electrical length" from the same piece of wire when it is stretched out straight.

ANOTHER EXPERIMENT WITH THE ROPE

Let us consider the rope again. Suppose, for the moment, that your finger is an electromagnetic wave carrying energy from a transmitting station and that the rope is an antenna connected to a radio receiver. You are the transmitter. Your frequency is three. You tap the rope three times per second. At the first tap the energy induced in the rope surges outward toward the far end. It reaches



RADIO WAVES AND THE IONOSPHERE

The rarefied atmosphere approximately 40 to 350 miles above the earth contains many more positive and negative ions than the lower atmosphere. This ionized layer is called the IONOSPHERE. It has a marked effect upon the transmission and reception of radio signals. The ions in the ionosphere are produced by ultra violet and particle radiation from the sun. The ionosphere is thicker and closer to the earth in the daytime than at night. Consequently sunshine limits radio transmission. Radio transmission and reception are better at night than in daytime. Much long distance radio transmission is accomplished by receiving sky waves reflected from the ionosphere. The reflected waves come back to earth closer to the transmitter in daytime than at night (*See next illustration*).

the far end and is returning when it meets the second outward traveling surge induced by the second tap of your finger. One surge cancels another when they meet coming from opposite directions. Your waves (taps) do not have much effect on the rope antenna after the first surge because the antenna is NOT IN TUNE with the frequency of the surges.

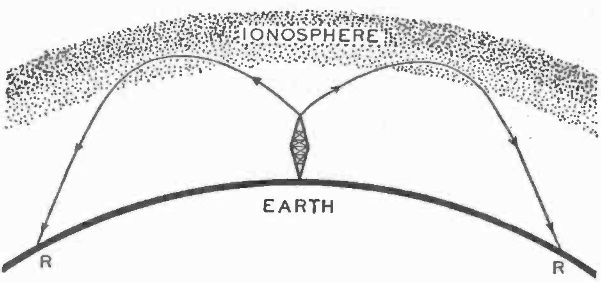
But wait a moment. Suppose that you lengthen, shorten, loosen or tighten the rope. In other words, tune the rope so that each new outgoing surge set up by the three taps per second of your finger falls in step with the one already travelling back and forth on the rope. Your waves will have great effect on the rope antenna. The surges will move to and fro, or OSCILLATE, without interference.

RESONANCE

A radio engineer would say that the surges are now IN PHASE, and the rope antenna is tuned to RESONANCE with the incoming waves.

Similar conditions and similar events occur in a radio antenna and in radio circuits. The condition called resonance enables tuning to select the signals of one station from the others which are transmitting at the same time. In order for incoming waves to have the most effect in producing alternating currents in a receiving antenna or in radio circuits, the antenna and circuits must be tuned until they are in resonance wih the incoming waves. They must be tuned to suit the frequency of the waves coming from the station to which it is desired to listen.

Every receiving antenna includes a small coil which couples it to the detector and other receiver parts. A coil is also used to couple transmitting apparatus to its antenna. These antenna coupling coils increase the electrical length of the antenna. A capacitor placed in series with the coil shortens the electrical length of the antenna. These two devices, a coil and a capacitor, are a simple means of increasing or decreasing the ELECTRICAL LENGTH of an antenna or radio circuit or bringing it into resonance with the frequency of the alternating currents which surge in it. In actual practice that is the way most tuning is done. A coil and a capacitor connected to a tuning knob tune the antenna and other circuits.



RADIO WAVES—REFLECTION OF THE SKY WAVES BY THE IONOSPHERE

The ionosphere acts as a conductor and absorbs part of the energy in the sky waves radiated from an antenna. It also acts as a radio mirror and bends the sky wave back to the earth as illustrated above. Receivers located at or near either of the points **R** in the illustration will receive signals transmitted from the antenna at point **T**. This explains why low-powered amateur stations can sometimes be heard at night halfway around the world. Their sky waves are bent by the ionosphere and returned to earth in a distant land. It also partly explains the fading of signals. The ionosphere is constantly shifting and changing. Occasionally sudden disturbances in the ionosphere cause absorption of all sky-wave radiations. At other times the reflected sky waves alternately strike and skip over areas.

EXPLANATION OF INDUCTANCE AND CAPACITANCE

One of the first things to be learned about electricity is that in order for a direct current to flow in a circuit, the circuit must be complete—that is, the wire must form a loop so as to provide a return path. How then can an alternating current flow back and forth in a straight wire without a return path, as it does in an antenna?

Here is the explanation. A single wire stretched out straight or in the form of an open coil has two remarkable properties. One of these is its INDUCTANCE. The inductance of a wire or a coil is the property that allows it to store up energy in the form of an electromagnetic field. The other is its CAPACITY or ability to store up a certain amount of electrical energy by stressing or straining the space about it or substances nearby. This "distributed capacitance," as it is called, acts like a tiny invisible capacitor connected across the ends of an antenna, across a wire or across the terminals of a coil.

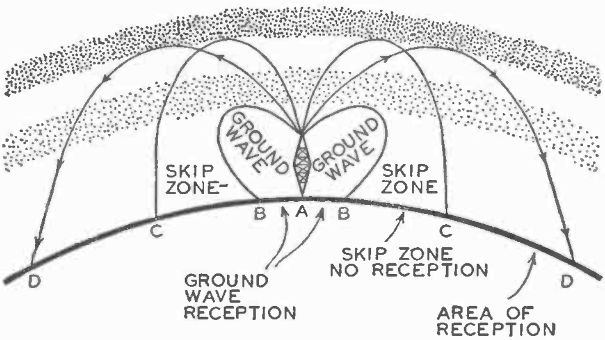
When there is not too much resistance in a wire or open coil in proportion to their inductance and capacitance, radio-frequency currents can surge back and forth in the wire or coil because of the distributed capacitance present. Low-frequency or direct currents can flow in an open circuit for the merest infinitesimal fraction of a second only while the open coil or wire is storing up energy in electromagnetic or electrostatic form.

The antenna is not the only part of a radio transmitter or receiver that must be tuned. Other circuits in both transmitters and receivers must be adjusted until they are in resonance. The transmitter circuits are tuned to be in resonance with the frequency at which IT IS DESIRED TO TRANSMIT. The receiving circuits are tuned to resonance with the frequency of the transmitter whose signals IT IS DESIRED TO RECEIVE.

When an antenna or radio circuit is tuned to resonance with any certain frequency, for example 550 kilocycles, the maximum amount of 550 kilocycle current will flow in the circuit. Very little, if any, current of other frequencies will flow.

Tuning therefore, is ADJUSTING CIRCUITS TO RESONANCE at a desired frequency so that the circuits give the maximum response to currents of that frequency.

Tuning can be done by varying the inductance of a



RADIO WAVES—SKIP ZONES

Signals from a transmitter can always be heard over the considerable area (**A** to **B**) surrounding the transmitter where the ground waves reach. Surrounding this area is a SKIP ZONE where there are no ground waves and where the transmitter's signals cannot be heard. Beyond the skip zone there are distant points where the signals can be heard. The illustration helps to explain this. The skip zone is the area beyond the limits of the ground waves. The area beyond the skip zone where signals can be heard again is the area where the sky waves reflected from the ionosphere return to earth (**D**).

coil. Usually it is easier to do it with a capacitor and most tuning is done with a variable capacitor.

The majority of modern receivers employ the superheterodyne circuit invented by E. H. Armstrong. In this circuit, there are tuned radio-frequency amplifiers. They consist of electron tubes, coils and variable capacitors. There is more than one tuned circuit in a superheterodyne receiver. For convenience in tuning, so that there is only one knob to turn, the rotors of two or more identical variable capacitors are mounted on one shaft. Such capacitors are called ganged capacitors.

EXPERIMENTS IN TUNING A CRYSTAL RECEIVER

Now that tuning has been explained it will be more interesting to experiment with the crystal receiver described in Chapter Three. By moving the antenna connection to clip **A**, **B**, **C** or **D** (whichever will bring in the station the loudest) you can tune the antenna circuit of the receiver. Shifting the antenna connection to the various clips varies the inductance in the antenna circuit and the frequencies to which it will respond best.

Find out the frequencies of the broadcasting stations which you can tune in, by looking them up in a printed radio program. Listen to each station until its name is announced. Then jot down its call letters and frequency. You will find that by tuning the antenna circuit you can bring in more frequencies than is possible with the simple receiver with an untuned antenna circuit described in Chapter Two.

The variable capacitor marked (**3**) to the left in the plan was purposely not made a permanent part of the receiver circuit so that it could be used for experiment. The terminals of capacitor (**3**) are connected to the Fahnestock clips **G** and **H**.

Let us suppose that you have tuned in a station which you wish to listen to and get the best signal when the antenna is connected to clip **B**. Perhaps you will get an even better signal if you connect capacitor (**3**) across the primary and that portion of the loading coil which is in the antenna circuit. To do this connect clip **B** to clip **C** with a short piece of wire and connect clip **H** to escutcheon pin **E** with another piece of wire. Adjusting capacitor (**3**) may improve the signals. Perhaps you will get even better signals if you connect the antenna to clip **C** and disconnect clip **G** from clip **B** and connect **G** to **C**.

If the antenna you are using is a very long one, it may be necessary to connect the antenna to clip **G** and connect clip **H** to clip **A** in order to receive the higher frequencies in the broadcast band.

Remember that in order to tune you do not merely shift the capacitor connections. You must also adjust both capacitors by turning the knobs to the position that produces the loudest signals.

CHAPTER FIVE

A Simple Outdoor Receiving Antenna . . . STATIC AND STRAYS

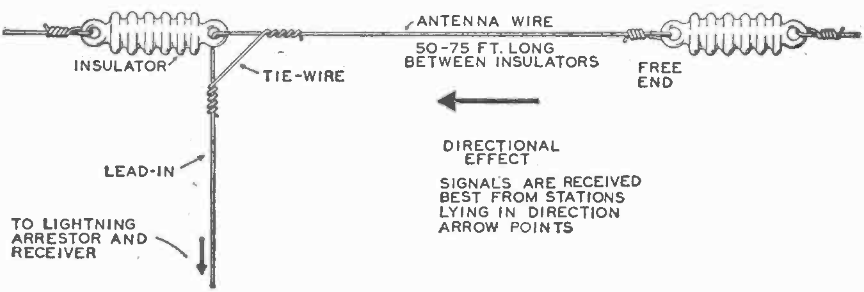
The simplest outdoor antenna for receiving signals from the broadcasting stations which are in the standard frequency range is a single horizontal wire having a lead-in wire connected to one end. A wire 50 to 100 feet long, properly insulated and as high and clear of surrounding objects as possible, with a height of 30 to 50 feet is desirable. It is important to provide rigid supports for both ends of the antenna. Tree branches are not desirable supports because they sway in a wind. When a tree trunk must be used as an antenna support, the antenna wire should hang slack so that the tree can move without straining the wire.

It is important to keep an antenna wire as far away as possible from chimneys, metal roofs, gutters, drain pipes, telephone and power wires, other antennas and tree branches.

The antenna and lead-in should be one continuous piece of wire. If they are not, all splices should be soldered. Use stranded copper antenna wire, obtainable at any radio store. Use a 3-inch glass insulator at each end of the antenna.

The lead-in wire should not approach the side of a building closer than six inches except at the point where it enters. An antenna lead-in strip will insulate the lead-in and bring it into a building without permitting much leakage of energy. The lead-in strip is a thin copper strip covered with waterproof lacquered webbing. It is thin enough so that it may be laid on the sill and the window sash will close upon it.

An antenna on an apartment building or on a city house brings problems not encountered if you live in a detached house in the country or suburbs. Telephone wires over the rooftops, other antennas close by, steel framework in buildings, and man-made static are some of the difficulties to be met in the city. Preferably the antenna



AN ANTENNA FOR YOUR HOMEMADE RECEIVER

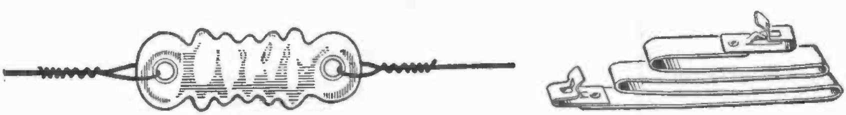
A single hard drawn No. 14 B.S. copper wire or stranded copper wire 50 to 75 feet long insulated at both ends from its supports.

wire erected on an apartment house or city dwelling should be supported from two wood poles at least ten feet above the roof. The wire, if possible, should be erected at right angles to neighboring wires or antennas.

A horizontal antenna wire whose length is greater than its height above ground will receive signals slightly better in one direction than in others. It will receive best from stations lying in the direction OPPOSITE to which the free end points. The free end is the one opposite to that the lead-in is attached to.

If you can arrange your antenna to point in any desired direction, erect it so that its position will be an advantage in bringing in signals from the station you prefer to listen to.

The single, horizontal wire antenna which has just been discussed is recommended only as the SIMPLEST form of antenna for use with a broadcast band receiver used solely for the reception of comparatively local programs. Receiving antennas of this type were in wide use in the early days of broadcasting. Today they are not considered desirable unless used in a location free of man-made static.



ANTENNA INSULATORS

At the left is a corrugated glass insulator suitable for supporting a 50- to 75-foot receiving antenna. The right-hand sketch shows an insulated lead-in window strip which makes it easy to lead in the antenna over a window sill and under the sash without interfering with the opening or closing of the window.

Static. There are two kinds of objectionable noises called STATIC produced in radio receivers. One is due to nature's electrical disturbances in the atmosphere and the other is "man-made."

Lightning discharges are the cause of the loud crashes and rattling sounds sometimes heard coming from a loud-speaker or headset. Snowflakes often carry minute electrical charges and produce noises in a receiver when they strike the antenna.

Another name for atmospheric electricity which disturbs a radio receiver is STRAYS. Natural static does not affect a frequency-modulated or FM receiver but it cannot be tuned out of an AM receiver. All of the receivers described in this book are the AM type. An FM receiver cannot be assembled by the young novice at radio building.

Man-made static is usually due to induction and sparking by various electrical devices such as elevators, vacuum cleaners, oil burners, sewing machines, electric refrigerators, etc. Apartment houses are fairly alive with these radio disturbers. When a receiver is disturbed the source of the trouble is usually not far away. Nowadays many electrical appliances are equipped with interference prevention devices at the factory. When not equipped, a line filter connected to the power wires near the source of interference will often eliminate man-made static from electrical appliances.

CHAPTER SIX

Components of Electronic Circuits . . . CAPACITORS AND CAPACITANCE • RESISTORS AND CONTROLS

It would be difficult to find an electronic circuit in which there is not at least one capacitor. It is important for the experimenter with electronics to know about capacitors and their quality of CAPACITANCE.

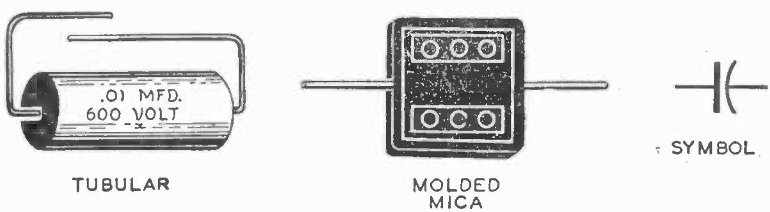
Capacitors were formerly called condensers. But thousands of young men who were trained to handle radio and electronics equipment by the U. S. Navy in World War II learned to use the better and now correct term CAPACITOR. In engineering, the term "condenser" now refers only to certain hydraulic, chemical and engineering devices.

What is a Capacitor? A capacitor is not a complicated device. There are few useful contrivances as simple as a capacitor. It is not much more elaborate than a resistor.

A capacitor consists of two conducting metal plates separated by a layer of insulating material. The conducting plates are called the PLATES and the insulating separator is called the DIELECTRIC. If the plates are separated by air, air is the dielectric. If they are separated by oil, oil is the dielectric. The plates are usually made of sheet aluminum or aluminum foil. The common dielectrics used in capacitors are air, mica, paper, oil and a thin layer of non-conducting aluminum oxide.

The behavior of capacitors when connected to a source of electric current makes them a necessary part of almost every electronic circuit. For example, capacitors will store energy. In addition, when included in a circuit, an efficient capacitor will IN EFFECT allow an alternating current to pass but block a steady direct current. See further explanation on page 69.

How a Capacitor Performs. Let's see what happens when a capacitor is connected to a direct current voltage source, as, for example, to the terminals of a battery. Since the dielectric between the plates is a non-conductor, a capacitor might be expected to behave as a break in the circuit. When connected to a source of steady direct current, it does act as an open circuit except for a very short time



SMALL FIXED CAPACITORS AND THEIR SYMBOLS

The capacitor at the left is a paper by-pass capacitor. That at the right is a molded mica capacitor.

while it is CHARGING. But it does other things as well.

As soon as a capacitor is connected to a source of direct current voltage, electrons start to flow from the plate connected to the positive terminal of the battery. The electrons move through the battery and up to the plate connected to the negative terminal. They collect there. When the capacitor is first connected to the battery, the electrons rush along quickly. Then they slow down. When the charging continues to the point where the voltage across the capacitor terminals equals the voltage across the battery terminals, the electrons no longer move. At this stage the capacitor is fully charged insofar as the voltage of that particular battery is able to charge it. When in this condition, one plate has a positive charge, which is to say it is deficient in electrons. The other plate is negatively charged, that is, has a surplus of electrons. While the electrons were in motion during the charging process, there was a current flow. When the electrons are not moving, there is no current flow.

If the charged capacitor is disconnected from the battery it will remain charged unless the electrons leak across the dielectric or are released by an outside conducting path. Given the opportunity, the excess of electrons on the negative plate will move back to the plate (positive) which is deficient in electrons. If the charged capacitor is disconnected from the battery and a resistor is connected across the terminals of the capacitor, electrons will move—a current will flow through the resistor.

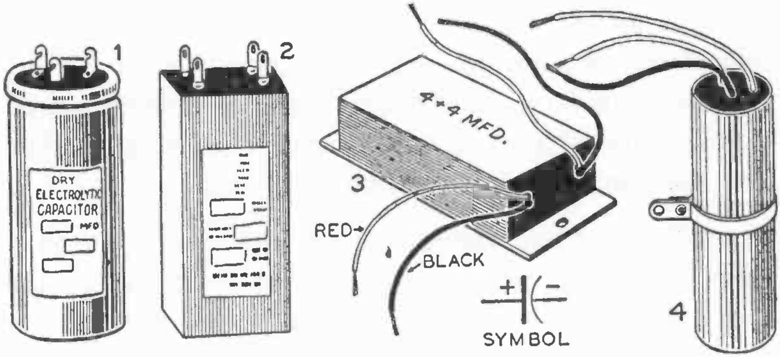
The Meaning of Capacitance. The CAPACITANCE of a capacitor refers to the amount of charge—that is, the number of electrons required to build up a certain potential difference. Increasing the area of the plates, or decreasing the distance between the plates increases the capacitance. The unit of measurement for capacitance is the FARAD (a shortened form of Faraday in honor of Michael Faraday).

The plates of a capacitor with a capacitance of one farad would be raised to a potential difference of one volt if charged for one second with electrons flowing at the rate of one ampere. When current flows at a rate of one ampere 6 quintillion, 281 quadrillion electrons flow past a given point in the circuit in one second. That is a lot of electrons and you can see what a staggering quantity is involved if you write 6,281 and place fifteen zeros after it like this: 6,281,000,000,000,000,000. A capacitor having a capacitance of ONE FARAD is extremely large and there is little use for so much capacitance in a single unit. The capacitors which are most widely used are much smaller. A more practical unit than the farad for measuring capacitance is the MICROFARAD, this being one millionth of a farad or .000001 farad. The abbreviation for microfarad is mfd. In electronic circuits some of the capacitors are so small that their capacitance is measured in micro-microfarads or millionths of a microfarad. The abbreviation for micro-microfarad is mmfd.

The Effects of the Dielectric. Different dielectrics in a capacitor create different capacitances even though the area of the plates and the space between them is the same. If a capacitor with air as the dielectric has a certain capacity, for example, .001 mfd., the same plates, spaced the same distance apart but with mica as the dielectric will have from 2½ to nearly 7 times the capacitance. In other words, the capacitance will be from .0025 to .0065 mfd. depending upon the variety of mica. Paper substituted for air will increase capacitance from 2 to about 2½ times. The capacitance of .001 mfd. is increased to .002 to .0026 mfd. by paper.

Some dielectrics are stronger than others in respect to the amount of voltage they will withstand without breaking down or puncturing. A mica dielectric .005 inch thick will withstand several times the voltage that would puncture holes in a paper dielectric. Oil substituted for air between the capacitor plates will not only increase the capacitance from 2.2 to 4.7 times but will withstand a much higher voltage before breaking down.

When an electric current flows into a capacitor, a certain amount of energy is lost in the dielectric. Some dielectrics produce greater losses than others.



ELECTROLYTIC CAPACITORS

These are fixed capacitors of large capacitance.

For all of these reasons and also because of the requirements of limits in size, weight and cost, capacitors are manufactured in great variety. Those which we will utilize later in carrying out the plans in this book are described here in detail.

Capacitors are an essential part of most electronic circuits. They are also used in automobile ignition equipment, telephone, telegraph and railway signaling apparatus and other electrical devices.

There are two general classes of capacitors used in radio and electronics. They are called FIXED and VARIABLE, accordingly, as the capacity may be varied or not.

FIXED CAPACITORS

Of fixed capacitors there is no end of varieties and sizes. The catalogs of supply houses dealing in electronic components list hundreds of fixed capacitors. Some have mica dielectrics, some have paper, some have oil. They may be enclosed in molded Bakelite, waxed cardboard tubes or sealed in metal cans.

Fixed capacitors may be used to block a direct current from flowing in a circuit and let an alternating current pass. Their purpose in a circuit gives them various names such as BLOCKING CAPACITOR, BY-PASS CAPACITOR, etc.

Capacitors of small capacitance will pass radio-frequency alternating currents but block audio-frequency currents. Capacitors of greater capacitance pass radio-frequency and audio-frequency alternating currents and stop only direct current. By controlling the capacitance of a capacitor, it is possible to permit radio-frequency currents to pass and stop audio-frequency currents that try to flow through the same path. Capacitors used for such purposes are termed BY-PASS capacitors. They are used to by-pass radio-frequency currents in the detector circuits of radio receivers and in amplifiers for radio-frequencies; also to by-pass audio-frequency currents in both detector circuits and audio amplifiers.

Generally speaking, the capacitances used for by-passing radio-frequencies in broadcast receivers usually range from 0.1 to .006 mfd. (depending upon frequency to be passed). Those for by-passing audio frequencies generally range from 0.25 to 1 mfd.

Mica Fixed Condensers. The size and form of small mica fixed condensers varies but the principle of two conducting surfaces separated by a thin layer of mica never changes. Mica fixed condensers are usually enclosed in moulded Bakelite. Two tinned wire terminals are provided. Mica fixed condensers withstand higher voltages and have less energy loss in their operation than paper condensers. They are usually of smaller capacitance than paper condensers. The capacitance may be indicated by color code markings, or numerals showing the actual value may be stamped on the capacitor. If the numerals are a decimal, for example, .002, the capacitance is indicated in microfarads. If it is a whole number, for example, 2000, the figure represents micro-microfarads.

Tubular Paper By-Pass Capacitors. These are cylindrical shaped paper dielectric capacitors with two tinned wire terminals. They are plainly marked to show the capacitance and safe working voltage.

Ceramic Capacitors. The dielectric in this type is a ceramic, that is, special baked clay. The plates are a film of metallic silver baked on the surface of the ceramic. Ceramic capacitors are often used for the same purposes as mica capacitors. They are made only in small capacitances.

Electrolytic Capacitors. This form of capacitor is commonly used in the power supply of electronic circuits where large capacitance is required. An electrolytic capacitor can provide large capacitance in small space. It can also be manufactured at much lower cost than a paper capacitor of equal capacitance.

Electrolytic capacitors may be either wet or "dry." Both types are actually wet inside but the so-called dry type contains no free liquid, whereas the wet type does. The wet capacitor consists of sheets of aluminum foil immersed in a solution of borax in water. The borax solution is an electrolyte. All electrolytes are conductors of electricity. The borax solution serves as one of the conducting surfaces in the capacitor. Chemical action forms a thin film of aluminum oxide on the surface of the aluminum foil immersed in the borax solution. Aluminum oxide is an insulator and the film serves as the dielectric between the aluminum foil and the solution. Wet type electrolytic capacitors are usually enclosed in an aluminum can.

The dry type of electrolytic capacitor also consists of aluminum foil and a solution of borax. However, the electrolyte is contained in wet gauze or paper or in a thick jelly so that there is no free liquid. There is nothing in the dry type to spill.

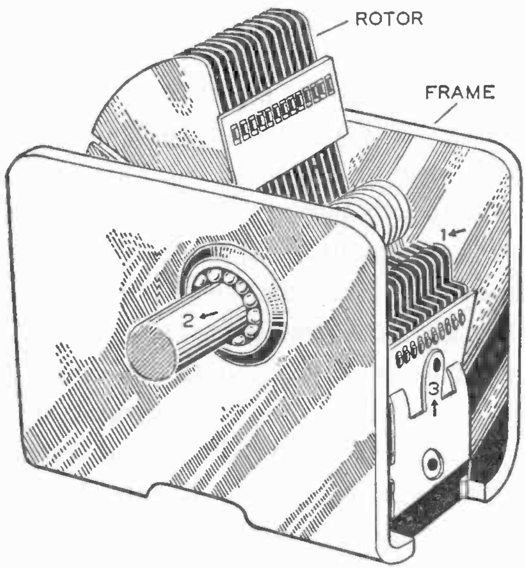
Electrolytic capacitors are manufactured in many sizes, ranging in capacitance from 1 to 1000 microfarads. The capacitance, polarity and working voltage is usually indicated. The terminals are always marked with a plus and minus sign or the polarity is indicated by red and green or by red and black terminal wires. Red indicates positive; so does a plus sign. The electrolytic capacitors shown in circuit diagrams are always marked to show the location of the positive and negative terminals. The circuit will not function unless the capacitors are connected as indicated. If an electrolytic capacitor is accidentally reversed in a circuit it forms a short circuit and the capacitor usually is ruined. Electrolytic capacitors are manufactured in single, double and triple units—that is, one, two or three capacitors within one case. Double and triple units usually have a common negative terminal.

The working voltage marked on an electrolytic capacitor is important. A capacitor marked 25-v D.C. should be used only in a circuit where the voltage is never above 25 volts. It is well to allow more margin of safety than this. A capacitor which is to be used on 117-v A.C. circuit should be one marked for 150 or 250 working volts.

Although electrolytic capacitors furnish large capacity in small space and at low cost they are inefficient and have a high power loss compared to paper, mica, air and oil dielectric capacitors. The electrolytic film between the aluminum foil and the electrolyte deteriorates with age. Consequently a breakdown in the electrolytic capacitors in commercial radio receivers is one of the most frequent causes of receiver failure. Because of deterioration with age or while in storage, electrolytic capacitors seldom are used in army and navy equipment.

VARIABLE CAPACITORS

Variable capacitors are used for tuning. They are sometimes called tuning capacitors. The knob on your radio receiver which you turn to tune in different broadcasts is attached to a variable capacitor. The most common type is constructed so that the capacitance may be gradually and continuously increased or decreased by turning a



VARIABLE TUNING CAPACITOR

This is the 365 mmfd. variable tuning capacitor used in building the receivers described in this book. It is designed for mounting on a base and has two threaded holes for 6-32 machine screws on the under side. Connection to the frame and rotor is made by a wire placed under the head of one of the mounting screws. The numerals identify: **1**, the stator, **2**, the shaft and **3**, the stator terminal.

knob. It consists of a number of movable, semi-circular aluminum plates which rotate between another group of nonmoving plates so as to interleave. The group of movable plates is called the ROTOR. The group of nonmoving plates is called the STATOR.

The air between the plates is the dielectric. When the movable plates (rotor) are turned so as to mesh with the nonmoving plates (stator) the capacitance increases. The capacitance is greatest when the plates are completely meshed. When the rotor is turned so that the movable plates move out from between the stator plates the capacitance is reduced. A variable capacitor has comparatively small capacitance when the plates are separated.

Several variable capacitors mounted so that all the movable plates are on a common shaft is called a "gang" capacitor. Gang capacitors are used to tune more than one circuit simultaneously. They will be found in modern superheterodyne and tuned radio-frequency receivers.

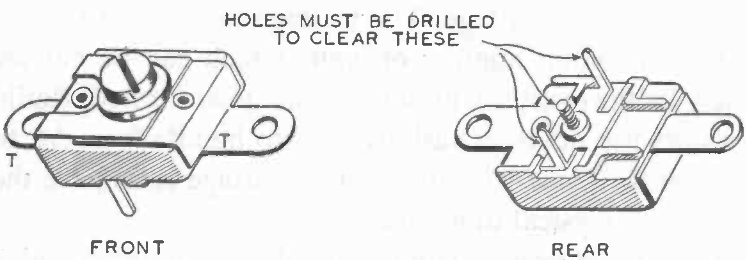
Variable capacitors are constructed so that the metal frame is electrically connected to the rotor. When the capacitor is properly connected in a circuit, this construction helps to eliminate "body effect," or disturbance of the circuit due to the presence of the fingers close to the rotor shaft while grasping the tuning knob.

Variable capacitors are made and adjusted by experts at the factory. Bending the plates may throw them out of alignment or cause them to short circuit. When handling or working with a variable capacitor in the construction of a project, keep the capacitor closed—that is, plates fully meshed.

Trimmer and Padder Capacitors. The most common variety of this type of capacitor consists of two small metal plates mounted on a ceramic base. A thin sheet of mica between the plates acts as the dielectric. The capacitance can be changed by using a screwdriver to turn a screw which moves the two plates closer together or farther apart. Trimmers and padders are "adjustable" capacitors rather than variable condensers.

Trimmers are usually mounted on the side of variable capacitors for "trimming" or adjusting the capacitors. Padders are commonly used in the oscillator circuit of superheterodyne receivers.

Modern radio receivers employ from two up to ten or even more circuits in order to obtain selectivity. These circuits are useless unless all of them are working at their proper frequencies simultaneously. In order to tune several circuits simultaneously, tuning capacitors with several individual capacitor sections on one shaft are employed.



A TRIMMER CAPACITOR

The terminals are marked **T** in the illustration. When the capacitor is mounted on a base or panel, holes must be drilled to provide clearance for the lugs and adjusting screw.

Trimmer capacitors mounted on the variable capacitor and also, in some instances, on the transformers and other coils make it possible to "align" the coils and capacitors so that several circuits can be tuned simultaneously by turning a single tuning control knob.

RESISTORS

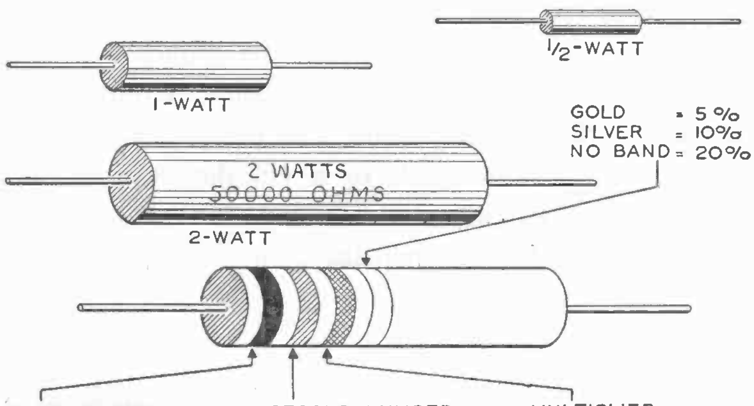
Radio men commonly use the term RESISTOR to indicate the small cartridge-shaped fixed resistances which are included in the circuits of radio receivers and amplifiers. A resistor is a device intentionally placed in an electric circuit to provide resistance in the circuit. The term resistor applies also to the various forms of voltage dividers, rheostats, potentiometers, volume controls and ballasts used in electronic circuits. Resistors are utilized in electronic circuits to:

1. Reduce or control the amount of current flowing.
2. Cause differences of potential at certain points.
3. Reduce the voltage applied to a device.

Resistors are rated according to their resistance in ohms and their wattage. The wattage rating of a resistor is the maximum number of watts which can be carried safely by the resistor without becoming overheated. Radio resistors are made in various sizes to handle from ¼ to 100 watts. Those with the highest wattage rating are the largest in physical dimensions.

Some resistors are plainly marked with numerals which show their resistance measured in ohms. Those which are not so marked employ a color code to indicate their resistance. The most common method is to use colored bands.

When the resistor is turned so that the bands are at the left hand end, the first two bands (reading from left to right) indicate the first two figures. The third band is the multiplier, used to multiply the first two figures. If there is no fourth band, the resistance may vary plus or minus one-fifth (20%). A gold fourth stripe indicates a variation of plus or minus one-twentieth (5%) and a silver fourth stripe indicates a variation of plus or minus one-tenth (10%).



FIRST NUMBER		SECOND NUMBER		MULTIPLIER	
BLACK	0	BLACK	0	BLACK	1
BROWN	1	BROWN	1	BROWN	10
RED	2	RED	2	RED	100
ORANGE	3	ORANGE	3	ORANGE	1,000
YELLOW	4	YELLOW	4	YELLOW	10,000
GREEN	5	GREEN	5	GREEN	100,000
BLUE	6	BLUE	6	BLUE	1,000,000
VIOLET	7	VIOLET	7		
GRAY	8	GRAY	8		
WHITE	9	WHITE	9		

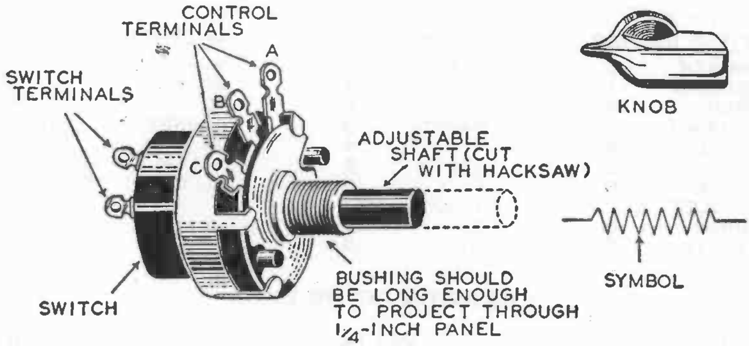
RESISTOR COLOR CODE

To interpret the color bands hold the resistor so that the end bearing the bands is at your left. Each band is code for a numeral. Follow the instructions in the text to determine the resistance. You can identify the capacity of a resistor by its size. The resistors illustrated above are full size.

For example, if a resistor has a blue first band, a gray second band, an orange third band and a silver fourth band, the first number is 6, the second is 8, the multiplier is 1000 and the variation may be plus or minus 10%. Therefore the resistor is a 68,000 ohm unit whose actual resistance in ohms may be somewhere between 61,200 and 74,800 ohms.

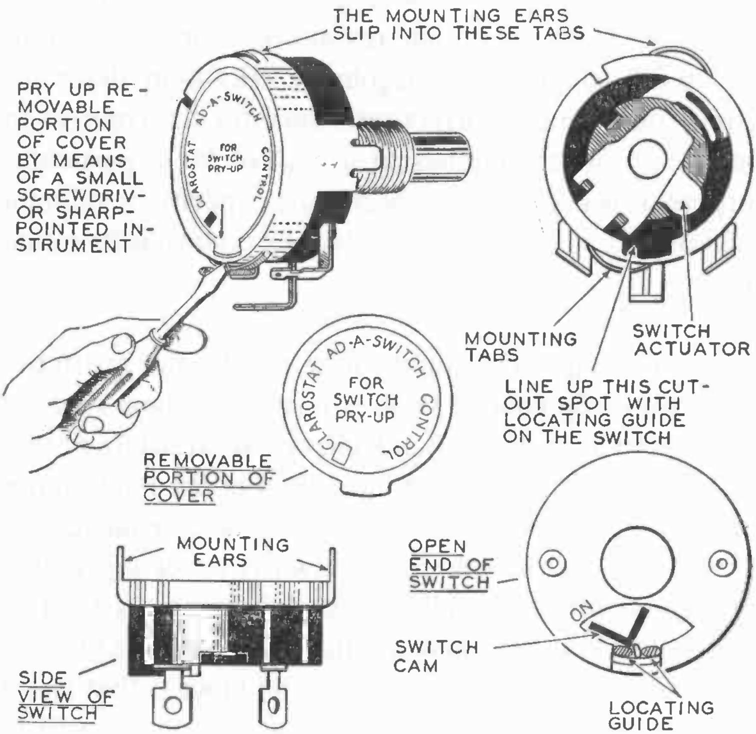
CONTROLS

Many of the adjustments required in electronic circuits are made by means of variable resistors called controls. The volume control which adjusts the sound volume of a radio receiver is a variable resistor. Controls are equipped with three terminals. The two outer terminals are connected to the ends of a circular resistor. The center terminal is connected to a movable contact which slides over the resistor when the control knob is turned.



CONTROLS

Controls are resistors whose resistance can be varied by turning a knob. Controls are used in some of the apparatus described in this book.



HOW TO ATTACH AN "ON-OFF" SWITCH TO A CONTROL

Pry off the removable portion of the cover on the control. Hold the control in your left hand with the shaft pointing toward you. Use your right hand to turn the shaft in a clockwise direction as far as it will go.

There are two projecting metal tabs or "ears" on the metal rim of the switch—there is also an opening in the switch cover. Inside the switch and visible through the opening is a "V"-shaped cam. Moving the cam operates the switch. Move the cam until it is in the center of the opening. Line up the projecting ears on the switch housing with the metal guides in the control case. Then press the switch firmly against the control and while holding it in that position bend the ears so that the switch cannot slip away from the control.

The shaft on the control will probably prove to be longer than necessary and it should be cut off. If the shaft is the notched type, it can be shortened by holding it in a pair of pliers and breaking it at the notch which will reduce it to the correct length. If the shaft is not notched, cut off the surplus length with a fine tooth hacksaw.

Electronic-equipment catalogs list controls of many sizes ranging in maximum resistance from ½ ohm to 10,000,000 ohms (ten megohms). Hook-up diagrams usually indicate the correct resistance for the controls in the circuit. When purchasing a control for a particular purpose, it is necessary to specify the capacity, maximum resistance and taper. The capacity of a control is its rating in watts.

Taper. The taper determines how rapidly the resistance varies when the control knob is turned. In some types of taper there may be a rapid change in resistance near either the right hand or left hand limit of the knob movement; in another type the greatest resistance change may take place near the center. The two types of taper used most frequently in building electronic appartus such as that described in this book are the AUDIO and the LINEAR. The scientific description of the audio taper is that it is a left-hand true logarithmic taper. You will not be able to understand that definition unless you are an engineer or a mathematician.

The linear taper is not really a tapered control even though it is commonly referred to as such. It has a uniform resistance change from either end. A "linear taper" is used wherever a control should be such that the change in resistance is proportional to the degree of rotation over the entire range of adjustment.

A control can be connected in a circuit so as to regulate either current flow or voltage. When used to regulate current it is a RHEOSTAT and only two terminals are used. When used to regulate voltage the control is a

POTENTIOMETER and all three terminals are utilized. Potentiometers usually have a linear taper.

It is sometimes desirable to attach an on-off switch to a control so that the same knob operates both the control and the switch. SPST, SPDT and DPST switches for this purpose are manufactured. One of the illustrations and its caption explains how to attach a switch to a control.

Further Explanation about Capacitor Action. It is customary for electronic technicians to use the word "pass" as if alternating current actually passed THROUGH a capacitor. The word pass may mislead students who are interested in the physics of a capacitor's action. Alternating current does not actually pass THROUGH a capacitor unless the capacitor "leaks." A capacitor may leak because of a defect, low resistance dielectric or other reasons and permit an alternating current to pass through. Without a long explanation of capacitor action, it is more accurate to say briefly that an efficient condenser, in good condition, blocks a steady direct current but permits an alternating current to surge back and forth in a circuit without in reality passing THROUGH the capacitor.

Transducers—Components of an Electronic Circuit: EARPHONES, LOUDSPEAKERS, MICROPHONES AND PICKUPS

There is a word in our language which once belonged only to physicists and the dictionary but now is coming into more common usage. It is the term TRANSDUCER and it means CONVERTER OF ENERGY. You hold two transducers in your hand when you make a telephone call. The microphone into which you direct your voice converts sound energy into electrical energy. The receiver into which you listen converts electrical energy back into sound energy.

There are many kinds of transducers. Some of them, such as the bolometer, glass electrodes and electrical strain gages, are used only in laboratories. A bolometer is an electrical instrument for measuring minute quantities of radiant heat by changes in the resistance of a blackened platinum strip exposed to the radiation. The development of transducers in recent years and their combination with the electronic amplifier and recording instruments brought a revolution into the broad field of scientific measurements. Practically any physical or chemical property of matter can be made to give an electrical signal by means of transducers. They are invaluable in industrial research and development laboratories.

All of us have at least a nodding acquaintance with a few transducers. Two of these, the telephone receiver and telephone transmitter, have been mentioned. Others in this class are the loudspeaker, microphone, phonograph pickup and photocell. This chapter describes some of them.

TELEPHONE RECEIVERS AND HEADSETS FOR RADIO AND ELECTRONIC CIRCUITS

In the early days of radio, there were no loudspeakers. Loudspeakers had not been developed because they required more energy than a radio receiver could furnish without amplification and there were no amplifiers. A telephone receiver requires very little energy in order to produce sounds in comparison to the energy required for a loudspeaker. Telephone receivers made the signals audible. They were the transducer used to convert small amounts of electrical energy into audible sounds.

Telephone receivers still are used in aircraft, military and communications service, by experimenters and by "ham" (amateur) radio operators. The hams call a telephone receiver a "can."

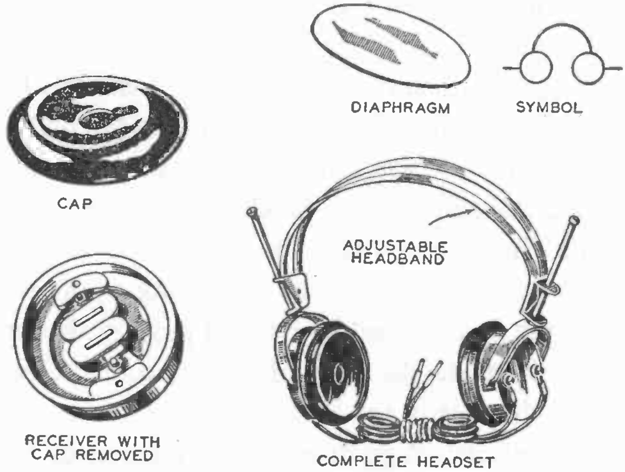
A telephone receiver is one of the most sensitive of electrical instruments. A few millionth parts of the energy required to light a small flashlight lamp will produce sounds in a telephone receiver. A good radio headset is so sensitive that it will produce audible sounds in response to changes in the almost infinitesimal amount of current generated when the cord tips are touched to the moist tongue and one tip is tapped against the other.

The telephone receivers or ear-phones used in radio and electronics are the small light-weight variety known as "watch case" or headphones. A complete headset consists of a pair of receivers, a connecting cord and a head band which holds the receivers snugly against the ears.

Electromagnetic Telephone Receivers. The most common type of earphone used in headsets is an electromagnetic device which consists of a case and cap enclosing a permanent magnet, a sheet-iron diaphragm and two small electromagnets wound with very fine wire. The parts are assembled so that the space between diaphragm and the iron cores in the electromagnets is small—usually about .002 inch.

It has been explained that there is always a magnetic force or flux at the poles of an electromagnet and that there is also a magnetic force or flux through the core of an electromagnet when an electric current flows through the winding. It has also been shown that a magnetic flux exerts an attractive or pulling force upon iron.

The magnetic flux from the poles of the permanent magnet in a telephone receiver passes through the cores of the electromagnets and exerts a pull upon the iron diaphragm. The pull of the permanent magnet places the



ELECTROMAGNETIC TELEPHONE HEADSET FOR RADIO USE

Telephone receivers make radio signals audible by changing the energy of the rectified high-frequency currents delivered by the detector into sound waves. For radio, it is desirable to have the telephone receivers held firmly to the listener's ears and leave both hands free. A complete radio headset consists of two receivers equipped with a headband so that a receiver is firmly held to each ear. When used for radio work, telephone receivers are wound with much finer wire than is used in the Bell telephone receiver. This makes it possible to wind a large number of turns in small space so that the receiver is more sensitive to weak currents. Incidentally, it also increases the resistance. The Bell telephone receiver has a resistance of approximately 75 ohms but the resistance of a radio headset is 2,000 to 3,000 ohms.

A telephone receiver is one of the most sensitive of electrical instruments. An amazingly small amount of energy flowing through a sensitive telephone receiver will produce sounds audible to human ears. There are two kinds of telephone receivers used in radio, the crystal and the electromagnetic types. Electromagnetic receivers are the "best all around" for amateur experimenters. An electromagnetic telephone receiver consists of a pair of small electromagnets, a permanent magnet and a thin sheet-iron diaphragm. The electromagnets are mounted close to the diaphragm but do not touch it. The permanent magnet exerts a constant pull on the diaphragm. The diaphragm acts like the head of a drum. Only a very small disturbance is required to make it respond. When current flows through electromagnets, the magnetic pull on the diaphragm varies. It becomes stronger or weaker, depending upon whether the current in the windings is aiding or is bucking the pull of the permanent magnet. Each quick change in the pull produces a sound wave.

diaphragm under a tension like the head of a drum. If the tension on the diaphragm is increased or decreased the diaphragm will move and produce a sound. Only a very small disturbance is required to make the diaphragm produce a sound. When current flows through the coils on the electromagnets they produce a magnetic flux of their own. The force pulling the diaphragm then varies, becoming stronger or weaker, depending upon whether the pull of the flux created by current passing through the coils aids or bucks the pull of the permanent magnet. Very small changes in the strength of the current flowing through the electromagnets alter the tension of the diaphragm and cause it to move. Its motions force sound waves out through the hole in the cap.

The strength of the magnetic flux produced when a weak current flows through the electromagnets is greater if the coils consist of many turns of wire than when the same weak current flows through electromagnets having few turns of wire.

The electromagnets in an earphone are wound with hundreds of turns of wire in order to make the phone sensitive to weak currents. The wire must be very small in diameter in order to wind a large number of turns on a small electromagnet. Fine wire has much greater resistance than larger wire. Earphones used in radio headsets usually have a resistance of 1000 to 1500 ohms each. Although radio headsets are rated according to their resistance in ohms, resistance itself is not always the quality which is most desired and it is specified only to give an indication of the turns on the electromagnets. The number of turns of wire wound on the bobbins is more important than the resistance except in special instances. Headsets having a resistance of 8,000 to 10,000 ohms are manufactured for use in circuits where the high resistance is a desirable quality.

A radio headset requires care to preserve its sensitive condition. Do not drop it and do not unscrew the caps and lift up the diaphragms to see inside. A diaphragm is easily bent and the receiver thereby thrown out of adjustment. Keep the caps screwed tightly in place.

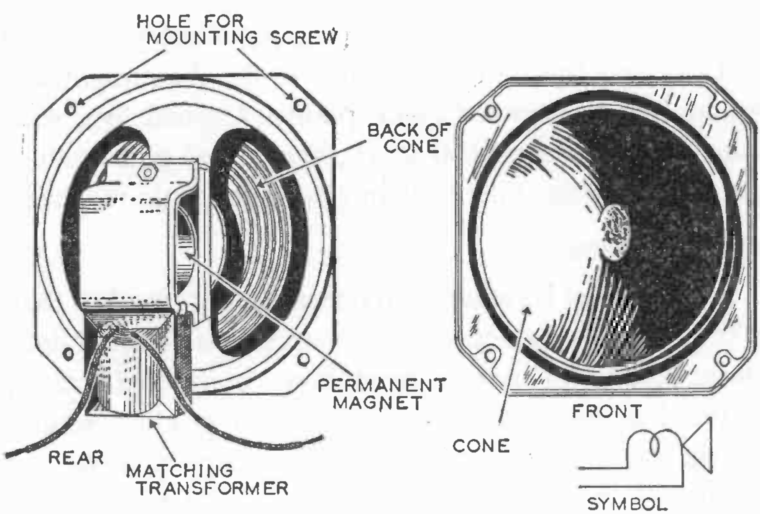
Crystal Telephone Receivers. The fact that certain crystals will be distorted mechanically if a voltage is impressed upon them is used in the construction of "crystal phones." No coils or magnets are used. The crystal is mounted between two electrodes. One electrode is connected to a circular diaphragm. When the electrodes are connected to a source of varying potential the crystal vibrates and transmits its motion to the diaphragm and sounds are produced. Crystal phones respond to a wide range of frequencies (60 to 10,000 cycles) and produce sounds of greater fidelity than electromagnetic receivers.

LOUDSPEAKERS

More energy is required to operate a loudspeaker than is required to produce audible sounds in a sensitive telephone receiver. A pair of headphones connected directly to the detector of a radio receiver will produce sounds which are plainly audible to the person wearing the headset. A loudspeaker connected to the detector under the same conditions would not produce audible sounds. The currents from a detector must be amplified before they will operate a speaker satisfactorily. A loudspeaker connected to the right amplifier will produce sounds which can be heard by a group of people. When used to reproduce voice and music, the sounds from the speaker are a more faithful reproduction of the original than the sounds from a telephone receiver.

The type of speaker used most widely is the dynamic moving-coil PM speaker. PM is an abbreviation for permanent magnet. The mechanism of a PM dynamic speaker is a small coil of wire called the voice coil, a cone-shaped paper diaphragm and a permanent magnet assembled on a metal frame.

The voice coil is a single layer of fine wire wound on a small paper tube and attached to the small end of the paper diaphragm. The diaphragm is mounted on the

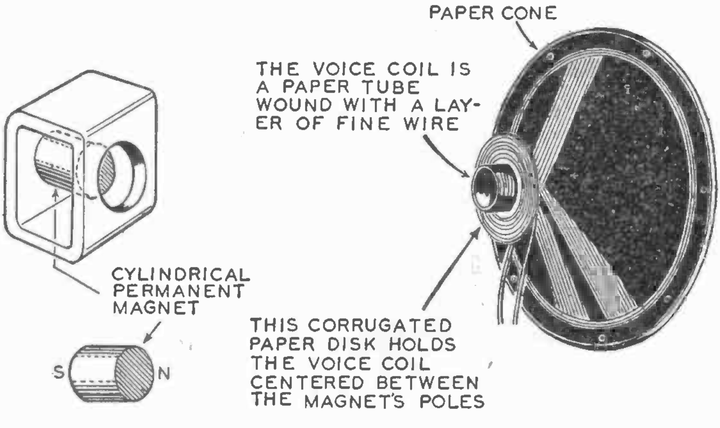


FRONT AND BACK OF A SMALL PM LOUDSPEAKER WITH TRANSFORMER

All speakers do not come equipped with a matching transformer.

speaker frame so that the coil attached to its apex "floats" in the narrow space between the poles of the permanent magnet. The coil is close to the magnet poles but does not touch them. The coil is supported so that it is free to move back and forth along its axis but not sideways or up and down. Its movements are like the to and fro motion of a piston in an engine cylinder.

When an electric current is passed through the voice coil it produces a magnetic field. The reaction of the coil's magnetic field produces forces which move the coil. A current flowing through the coil in one direction will cause the coil to be pulled farther into the field of the permanent magnet. A current in the opposite direction

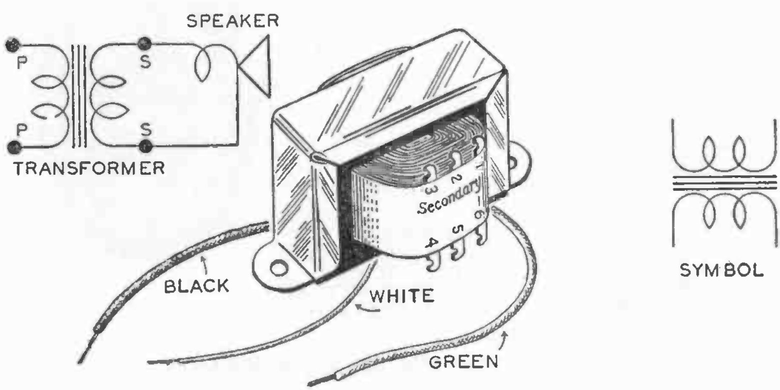


THE MECHANISM OF A PM SPEAKER

The permanent magnet in a PM speaker is usually a small cylinder of Alnico or similar alloy steel. It is mounted in an iron frame with a circular opening in the front. The magnetic path is arranged so that one end of the cylinder is one pole and the edge of the opening in the frame is the other pole. The voice coil moves back and forth in the magnetic field between the poles.

will cause the coil to be pushed away from the permanent magnet. A fluctuating direct current or an alternating current causes the coil to move to and fro. Since the coil is attached to the diaphragm, the diaphragm moves when the coil moves. Movements of the diaphragm push the air and produce sound waves. If the fluctuations in the direct current or alternations of the alternating current occur between approximately 40 to 10,000 per second, the movements of the ordinary PM speaker is able to follow them and produce sounds of corresponding frequencies.

A speaker is rated in size according to the diameter of its cone-shaped diaphragm. A 6-inch speaker has a 6-inch diaphragm; a 12-inch speaker has a 12-inch diaphragm, etc. Speakers smaller than 8 inches are noticeably partial to high-pitched sounds. They do not reproduce base tones



OUTPUT TRANSFORMER AND CIRCUIT CONNECTING A SPEAKER TO AN AMPLIFIER

The black, white and green wires are primary or input terminals.

as well as higher tones. No speaker is equally efficient over the full range of pitch audible to human ears. A 12-inch speaker gives more faithful reproduction than the smaller sizes, but it too favors some tones more than others and does not reproduce faithfully some of the higher pitched sounds. When high fidelity is desirable, three speakers of different size are often used in order to cover the audio-frequency sound range more efficiently.

Speakers are rated in capacity according to the number of watts they will carry. The 12-inch speakers built for home hi-fidelity phonograph installations have a rating of 10 to 25 watts. Some of the 12-inch speakers designed for public address systems have a rating of 35 to 50 watts.

The impedance of the voice coil in a speaker must be taken into consideration before it is connected to an amplifier. The impedance of standard speakers ranges from 3 to 50 ohms. Those used in ordinary radio receivers usually have an impedance of 3 to 4 ohms. Speakers designed for public address systems have an impedance of 6 to 8 ohms. The impedance of speakers manufactured for intercom systems is the highest, usually 45 to 50 ohms.

If the voice coil of a speaker is connected directly to an amplifier, it will not operate satisfactorily. The reason is that the impedance of the plate circuit in the amplifier output tube is much greater than the impedance of the voice coil in a PM speaker, and for efficient operation the impedance of the speaker should match the impedance of the tube. The problem is solved by the use of a small closed core transformer called a "matching" transformer.

The primary of a matching transformer is wound so that its impedance nearly matches the impedance of the plate circuit in the amplifier. It may have an impedance of 14,000 ohms. The secondary of the transformer is wound so that it has about the same impedance as the speaker voice coil. When the primary of the transformer is connected to the output of the amplifier and the secondary is connected to the voice coil, the speaker is "matched" to the amplifier.

Some matching transformers are built with taps on both the primary and secondary so that different impedance values are available. Matching transformers are made in several sizes having a capacity of 3.5 to 35 watts. The proper procedure is to select a transformer which will match most nearly the impedance of the signal source. A difference of 10% is usually of no great importance. If a close match cannot be secured, it is best to select an impedance value which will present a higher rather than a lower impedance to the output tube.

Cabinets for Loudspeakers. The common loudspeaker with a paper "cone" or diaphragm radiates sound waves directly into the air. Normally sound waves will be radiated from both sides of the cone. Those from the back of the cone combine with those from the front of the cone. Under these conditions the waves of low-pitched sounds tend to combine so as to mutually cancel each other. Therefore a loudspeaker is usually placed in an enclosure open to the front of the cone but closed at the back so that no sound waves can be radiated from the back of the diaphragm.

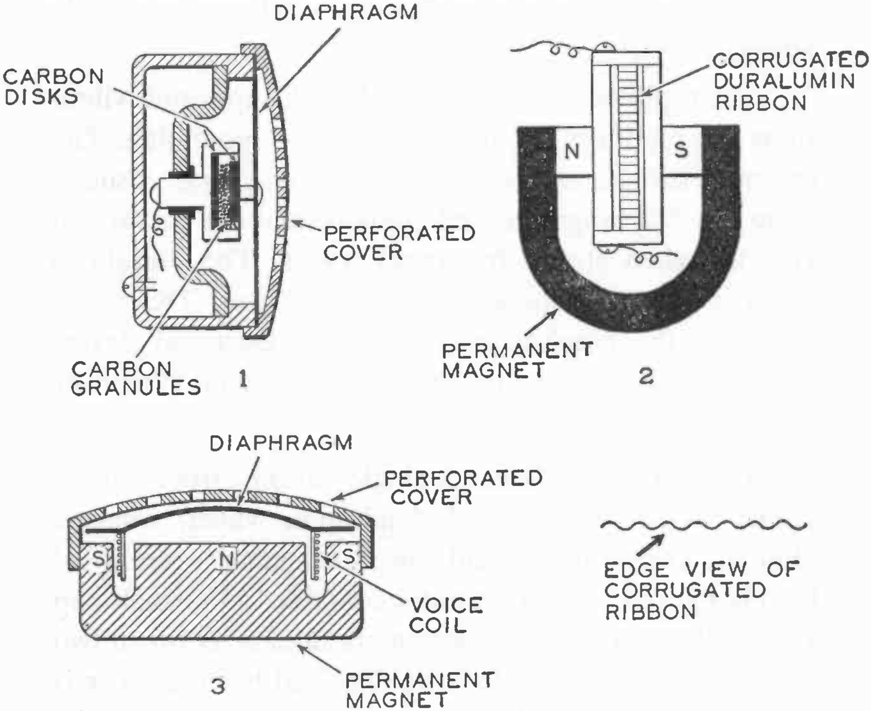
MICROPHONES

A microphone is a device which picks up sound vibrations and produces fluctuating currents or potentials. The ordinary telephone transmitter is a microphone. Usually there is a diaphragm in a microphone and the diaphragm vibrates when struck by sound waves. The vibrations occur in step with those of the sound waves. The movements of the diaphragms actuate an electrical device which may be a carbon button, a small metal ribbon or a piezo-electric crystal.

The Carbon Microphone. A single-button carbon microphone consists of a metal diaphragm which, when it vibrates, exerts mechanical pressure against a group of loosely packed carbon granules contained in a small cup (called the button). The carbon granules lie between two electrodes. One electrode is rigidly fixed but the other is attached to the diaphragm and moves when the diaphragm moves. The electrodes make electrical contact with the granules but there is a certain amount of resistance to the flow of current from one electrode and through the granules to the other electrode. This resistance changes if the granules are disturbed. Vibrations of the diaphragm disturb the granules. If a carbon microphone is made part of an electrical circuit, the resistance of that circuit will fluctuate when sounds strike the microphone.

Single-button carbon microphones are more sensitive than two-button microphones but their tone quality is not as high.

A carbon microphone itself does not generate any cur-



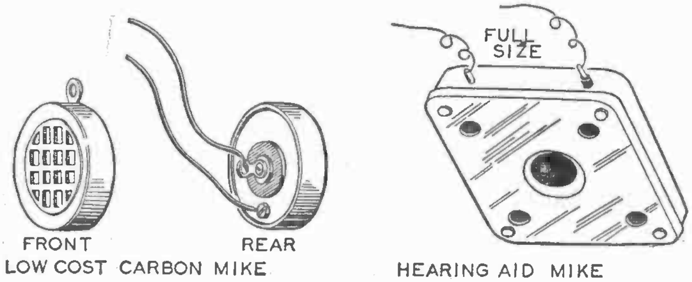
MICROPHONES

Several types of microphones are used in radio broadcasting. Here are three. (1) A single-button carbon microphone is shown in cross section at the upper left. The parts marked carbon disks are the electrodes. (2) A velocity or ribbon microphone consists of a thin corrugated Duralumin ribbon suspended between the poles of a permanent magnet. When the ribbon vibrates under the impact of sound waves, it is moving in a magnetic field and an alternating voltage is induced in the ribbon. The ribbon is connected to a small transformer and a high-gain pre-amplifier. The velocity microphone acquired its name from the fact that the ribbon vibrates in response to the velocity of the air particles moving in a sound wave rather than to the sound pressure. (3) The electrodynamic microphone reverses the principle of the speaker. A small coil of wire attached to a diaphragm is suspended in a magnetic field. When the diaphragm vibrates under the impact of sound waves an alternating current is generated in the moving coil. This current is fed into a small transformer, the secondary of which is connected to the input of an amplifier.

rent or voltage. If placed in a circuit with suitable direct current supply it will cause the current to fluctuate in step with the variations in its own resistance.

Crystal Microphones. No separate source of current or voltage is necessary for a crystal microphone. It generates its own voltage. A crystal microphone is practically a crystal earphone in reverse. The diaphragm of a crystal microphone is mechanically connected to a piezo-electric crystal. Sound waves which strike the diaphragm cause it to vibrate. The vibrations twist the crystal. Since it is a piezo-electric crystal, its disturbance generates a small alternating current voltage.

Electrodynamic Microphone. The electrodynamic or moving microphone reverses the principle of the loud-speaker. A small coil of fine wire attached to a diaphragm is suspended between the poles of a magnet. When the diaphragm vibrates under the impact of sound waves the



SMALL CARBON MICROPHONES USEFUL TO THE YOUNG AMATEUR EXPERIMENTER

Microphones such as these can often be purchased at small cost from mail order firms which advertise in radio magazines.

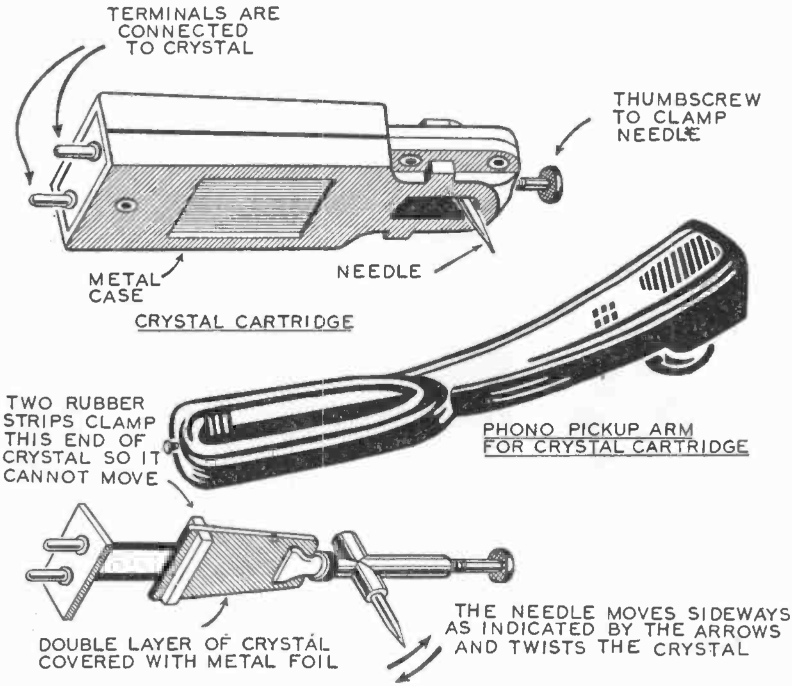
movements of the coil in the magnetic field generates an alternating voltage. An alternating current results if the microphone is connected in a closed circuit.

A PM loudspeaker can be used as an electrodynamic microphone. In fact PM loudspeakers function in intercom sets both as microphones and speakers.

Crystal Pickups. When certain crystalline materials are pressed or twisted, they generate electricity. The electromotive force produced in this manner is called PIEZO-electricity. The word *piezo* was derived from Greek and means *press* or *squeeze*. Crystals which will produce piezo-electricity are called piezo-electric crystals. Piezo-electric crystals have another remarkable and useful property. If placed between two metal plates, the crystals will change in width, in length or in thickness if a voltage is applied to the plates. Piezo-electric crystals of Rochelle salt and of quartz are in common use in electronics. The crystal pickups used to play phonograph records produce piezo-electricity. Movement of the needle as it follows the groove in a record twists two rectangular plates cut from a crystal of Rochelle salt. The two pieces of crystal are clamped together and covered with metal foil. The double layer is called a BIMORPH. Twisting the bimorph creates pulses of piezo-electricity which are amplified and fed to loudspeakers. From the speaker the sounds of the record come forth.

Variable Reluctance Pickups. All phonograph pickups do not utilize piezo-electricity. Some of the best reproduction from high-fidelity phonographs is furnished by variable reluctance pickups. These are magnetic devices.

Movement of the phonograph needle varies the amount of magnetism which passes through two small coils in the pickup. The variations in the magnetism generates a feeble alternating voltage which is greatly amplified before entering the loudspeaker. The voltage generated by a variable reluctance pickup is so small that it requires amplification by a pre-amplifier before it passes on to the ordinary phonograph amplifier.



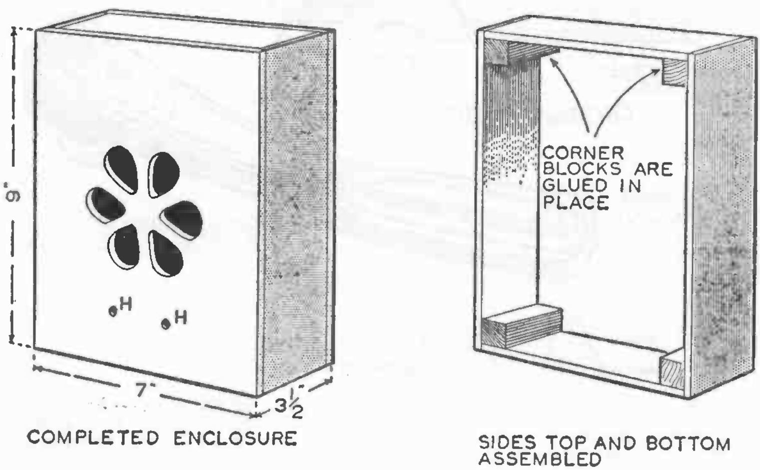
THE TRANSDUCER ON A RECORD PLAYER

Crystal pickups are in common use on record players. Movement of the needle or stylus as it follows the groove in a record twists two plates cut from a crystal of Rochelle salt. The twisting creates voltage pulses which are amplified and then led to a loudspeaker. The two plates of crystal are clamped together. The double layer is called a BIMORPH.

Baffles and Enclosures for Loudspeakers. Loud speakers should be mounted in a baffle or enclosure for two reasons:

1. To protect from dust and mechanical injury.
2. To improve the sound.

Sound waves are radiated from both the back and front of the cone-shaped paper diaphragm. When a speaker is not in a baffle or enclosure of some type, the sound waves radiated from the back of the cone combine with those from the front. The low-pitched sounds tend to combine and mutually cancel.



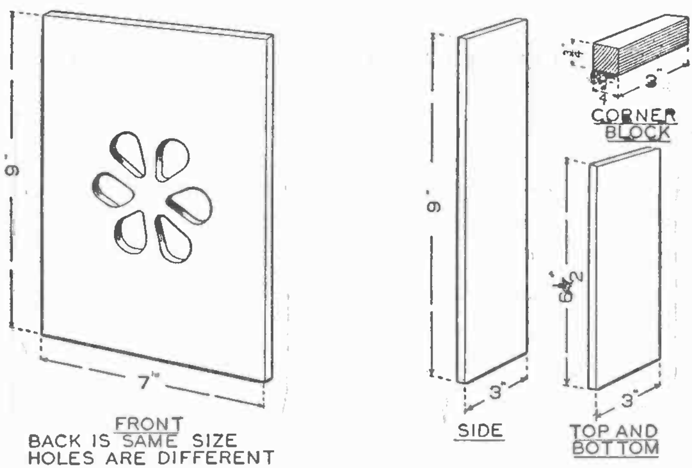
ENCLOSURE FOR SMALL SPEAKER

The enclosure illustrated above is suitable for a 3-, 4- or 5-inch speaker. The six petal-shaped openings in the front can be cut by hand with a fretsaw or with a power jigsaw. The speaker should be mounted on the back of the front panel. The location of the mounting holes depends upon the size of the speaker. The two holes marked HH in the illustration are for binding posts.

The simplest form of baffle is a large sheet of Celotex. A hole of the same diameter as the diameter of cone on the speaker is cut in the center of the sheet. The speaker is mounted on the back directly over the hole.

Two of the illustrations show a small cabinet suitable for a 3-, 4- or 5-inch speaker. This type of enclosure will not produce "hi-fi" tone quality but will protect the speaker and is easily constructed.

Base Reflex Cabinet. This is a common type of enclosure designed to secure the best tonal quality from a loudspeaker. Good results depend upon a cabinet of correct volume and an auxiliary port opening of correct area to suit the size of the speaker. One of the illustrations shows the correct dimensions for a 6-inch speaker. The cabinet

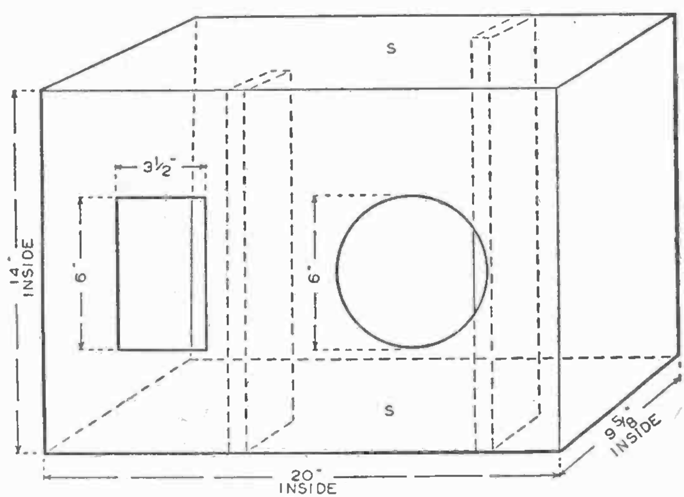


PARTS FOR THE SPEAKER CABINET

The parts for the cabinet, with the exception of the four corner blocks, are cut from ¼- to ⅜-inch plywood.

should be built of ½-inch plywood. The dimensions can be changed slightly to suit particular needs provided the area of the port in square inches and the enclosed volume of the cabinet measured in cubic inches are not changed. The inside surface of both sides and the inside surface of the back should be covered with Tufflex sound insulating material ⅝ inch thick. The Tufflex should be attached to the wood with rubber cement. The cement used for setting rubber floor tiles is satisfactory for this purpose. The speaker should be mounted on the back of the front panel directly over a circular opening of the same diameter as the speaker cone. A base reflex cabinet can be incorporated into a larger cabinet enclosing other portions of a "hi-fi" sound system.

BASE REFLEX CABINET FOR 6-INCH SPEAKER



Transistors—Versatile Midgets Which Can Do the Work of Vacuum Tubes

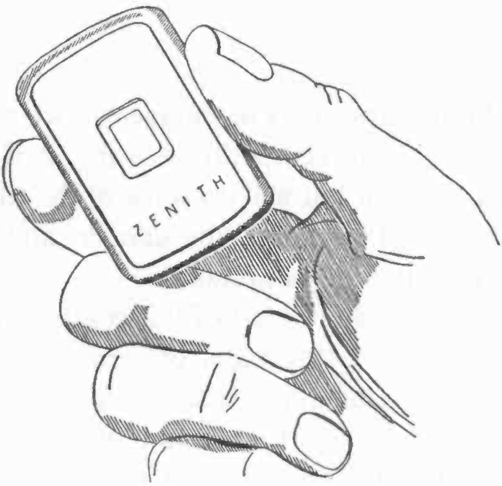
After many years of unique service the vacuum tube has a rival. This competitor is a tiny device, without vacuum or filament but will do some of the things which the conventional vacuum tube can do and, in addition, some things that tubes cannot do.

The essential part of this comparatively new electronic wonder is a tiny wafer of germanium. It is a first cousin of the germanium diode and is called a TRANSISTOR.

A considerable amount of effort has gone into the design and production of this new device and it has become the most revolutionary development in the field of electronics in many years. Transistors are semi-conductor devices capable of doing most of the things that vacuum tubes can do, and as previously stated, they perform some jobs which heretofore have been difficult if not impossible for vacuum tubes alone to handle. Transistors may be used as detectors, amplifiers, oscillators, mixers, modulators, attenuators and relays.

The Advantages of Transistors. Transistors are much smaller, lighter, longer-lived, more rugged and more efficient than vacuum tubes. They require no heater current or "warm up" time. They are ready for instant operation and consume only infinitesimal power. Two coins, one of copper and one of silver, moistened on the tongue will provide enough current to operate a transistor.

Transistors were invented by Dr. John Bardeen and



TRANSISTORS REDUCE THE SIZE OF ELECTRONIC EQUIPMENT

Transistors have made possible miniature electronic apparatus operated by tiny, low-voltage batteries. The Zenith "50-X" Hearing Aid, smaller than a package of cigarettes, is an example of such miniaturization. Four transistors supplied with current from a small low-cost battery do the work formerly performed by much larger vacuum tubes requiring expensive batteries.

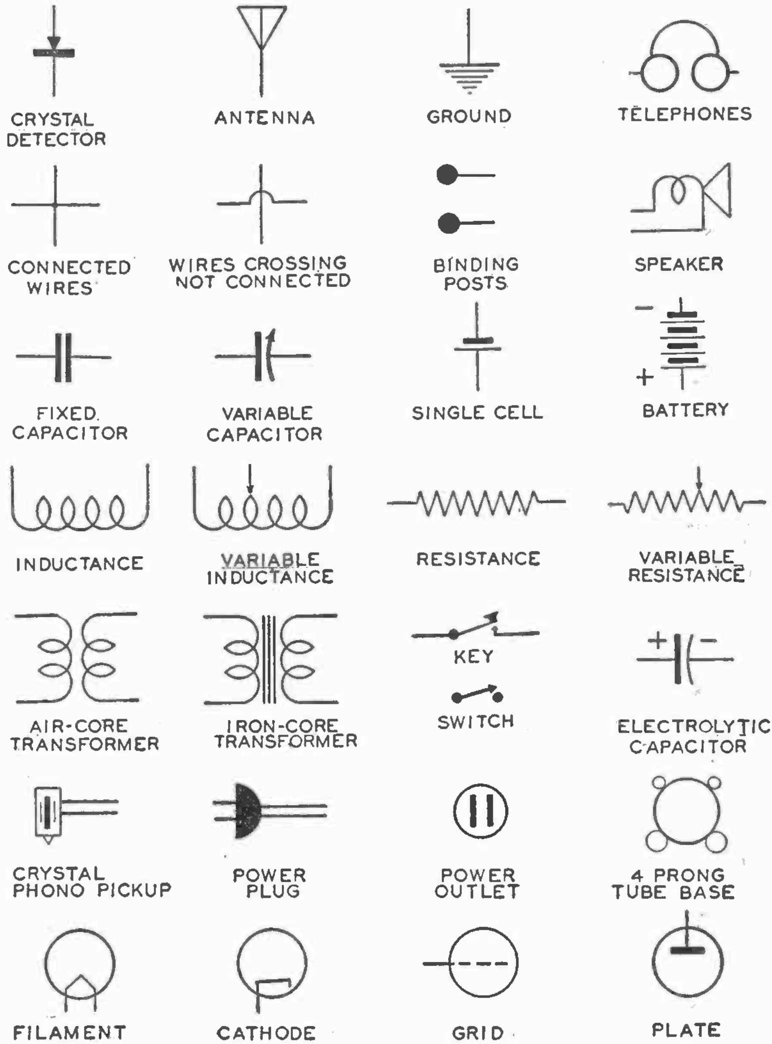
Dr. Walter Brattan, members of a research group in the Bell Telephone Laboratories directed by Dr. William Shockley.

The small size and low power requirement of transistors are changing the design of much electronic equipment by reducing its size. The first large use for transistors was in hearing aids where they replace the vacuum tubes used as amplifier tubes. Battery replacement is the major cost of operating a hearing aid equipped with amplifier tubes. Transistor-equipped hearing aids are not only much smaller in size but have slashed operating costs from $50 to $75 a year to $5 a year or less.

Transistors have made it possible to build small superheterodyne radio receivers the size of a cigarette package.

Transistor Types. Transistors will probably undergo changes as they are further developed. In their present form, they are triodes. They have three electrodes known as the EMITTER, the COLLECTOR and the BASE. Two types are manufactured.

One, called the POINT-CONTACT transistor, is of little use to the average amateur electronics experimenter. It consists of a very small piece of semiconductor material such as germanium with two properly spaced, pointed, small diameter wires (electrodes) making contact with the surface of the germanium. In appearance the point-contact transistor resembles a crystal diode with an additional electrode. Its mode of operation is entirely different. Point-contact transistors have wide use in switching circuits and in oscillator circuits at frequencies which are normally not possible with the type of transistor known as a JUNCTION transistor.

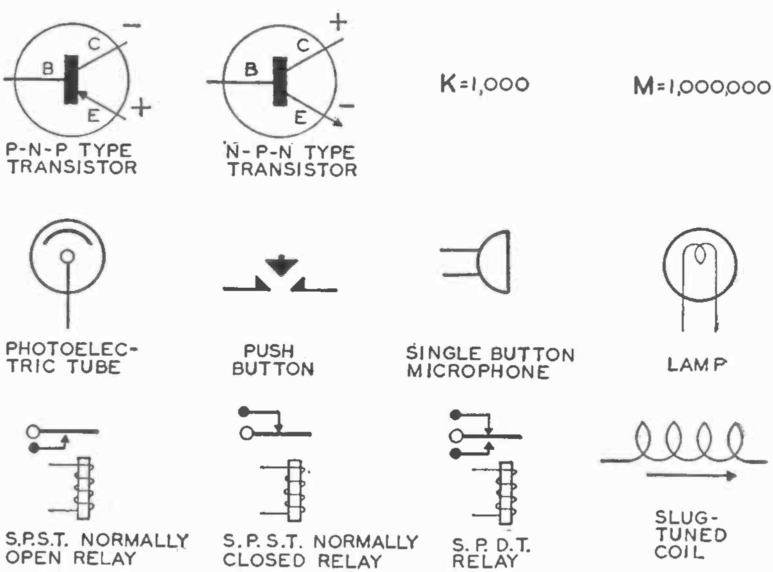


THE SYMBOLS USED IN DIAGRAMS OF RADIO CIRCUITS

Symbols are a sort of radio shorthand used to illustrate schematic circuit diagrams in radio books and magazines.

The junction transistor costs less than the point-contact type. It is of greater interest to the amateur experimenter in electronics and is the type used in building the transistor equipment described in this book.

There are several varieties of junction type transistors. The CK722 transistor manufactured by Raytheon Manufacturing Company of Waltham, Massachusetts, is the "p-n-p" type. It consists of a tiny wafer of germanium protected with about three layers of plastic so that it is hermetically sealed in its plastic jacket. The three wire leads which emerge from the bottom of the jacket are connected to the EMITTER, BASE and COLLECTOR. Current enters the transistor through the emitter lead and



THE SYMBOLS USED IN DIAGRAMS OF RADIO CIRCUITS, CONTINUED leaves through the collector lead. The emitter is a speck of indium on one side of the germanium wafer. The collector is also a tiny piece of indium but it is located on the opposite side of the wafer from the emitter. The wafer itself is the base. The wire lead on the side marked with the red dot is connected to the collector. The center wire lead is connected to the base. The remaining wire is connected to the emitter. In case you do not know what indium is, it may be interesting to know that indium is one of the metallic elements. It is white and somewhat soft like tin. It leaves a mark when drawn across paper. Indium was first discovered in 1863 by Ferdinand Reich, a professor of physics at the famous School of Mines at Freiberg, where germanium was also discovered. Reich's assistant, Hieronymus Theodor Richter, shared in the discovery.

Transistor Action. The action which occurs inside a transistor cannot be simply explained. Explanations of how and why transistors operate come to us from physicists, and their explanations involve much advanced mathematics and quantum mechanics. Quantum mechanics is a theory concerning the emission and absorption of energy by atoms and molecules. These explanations cannot be simplified so that they can be understood by the young experimenter who has not had an education in advanced physics. In fact the explanations are not well understood by many engineers. Theories concerning the transistor complicate, to some extent, the theory that we have all been taught that an electric current is a flow of electrons. It is not necessary to know anything about transistor action in order to build the transistor-equipped apparatus described in the following pages. For these many reasons, no attempt will be made here to explain transistor action except by making a slight comparison between it and the familiar vacuum tube.

Transistor Characteristics. The emitter, base and collector of a transistor compare somewhat to the vacuum tube's cathode, grid and plate. The fundamental differences between transistor and vacuum tube action are:

1. In the vacuum tube electrons are liberated into an evacuated space or VACUUM by a heated cathode. The movement of the electrons toward a positively charged plate is an electric current.

2. In a transistor, electrons or holes (spaces where there are inadequate electrons) are injected into the SOLID BODY of a semiconductor by means of a small battery. The movement of the electrons through the SOLID material is an electric current.

When these statements are summed up in fewer words, the fact most evident is that in a vacuum tube electric current FLOWS THROUGH A VACUUM, whereas in a transistor the current FLOWS THROUGH A SOLID.

Another fundamental difference between vacuum tubes and transistors is in their mechanism of control. Mechanism of control is an engineer's term. To explain the term "mechanism of control" we might call the PRESSURE ON THE TRIGGER the "mechanism of control" in a rifle. Signal VOLTAGE and a minute grid charging current controls the cathode to anode electron flow in a radio receiving or amplifier tube and is the mechanism of control.

Signal ENERGY or CURRENT controls the electron flow in a transistor and is the mechanism of control. The signal source employed to operate a tube need deliver VOLTAGE only, but the signal source employed to operate a transistor must deliver CURRENT.

When a circuit is to be designed to couple a tube or a transistor to microphones, telephone receivers, speakers, etc., the radio engineer bases his plans and calculations on:

1. A vacuum tube is a voltage-actuated high-impedance device.

2. A transistor is a current-operated low-impedance device.

The Care Required in Handling Transistors. Although transistors are fairly rugged they can be damaged if improperly handled. The following precautions should be observed.

1. Do not drop or subject a transistor to severe mechanical shock.

2. Do not operate a transistor at higher voltages or greater current values than those designated for it.

3. When connecting a transistor, observe and comply with the polarity designation. Passing a current through a transistor in the wrong direction may damage it.

4. Do not connect a transistor in a circuit until all other connections have been made.

5. Whenever possible, avoid cutting transistor leads short.

Transistors are easily damaged by too much heat and special precautions must be taken when transistor leads are soldered. Use rosin-core solder only, never acid-core. Use high quailty solder (60% tin and 40% lead). This quality is available in Ersin, Kester, Alpha and some other brands of solder. Scrape the connections before soldering so that they can be soldered quickly and without much heat. Use a small or miniature soldering iron. Grasp each transistor lead in turn as close to the free end as possible with a pair of long nose pliers. The pliers will conduct much of the heat away from the lead and prevent it from reaching the transistor.

There is no attempt at miniaturization in the design of the transistor-operated apparatus in this book. It is important to become familiar with the design, use and limitations of transistors before attempting to build MINIATURE receivers, amplifiers, etc.

Transistor Kits. If you wish to build miniaturized apparatus, you can buy complete kits of parts for building transistor-operated pocket radio receivers, amplifiers, etc. Miniature and sub-miniature controls, transformers, switches and coils are also available.

Transistor Batteries. Small 1½-volt flashlight cells called "penlite" cells give satisfactory service in many transistor circuits. They can be purchased at any "dime store" or hardware store. There are two sizes. Several manufacturers make them but the list numbers of all the different brands would be out of place here. The Burgess No. 7, called a "slim penlite" cell, or its equivalent of other brands is 1¾ inches long and $^{13}/_{32}$ inches in diameter. The Eveready No. 915, called a "penlite" cell, or its equivalent of other brands is 1$^{31}/_{32}$ inches long and $^{35}/_{64}$

inches in diameter. An Eveready cell of the same size, known as No. 1015, is made for hearing aids. The hearing aid cells cost approximately the same price as the penlite cells but will last about six times as long as the No. 915 in transistor service.

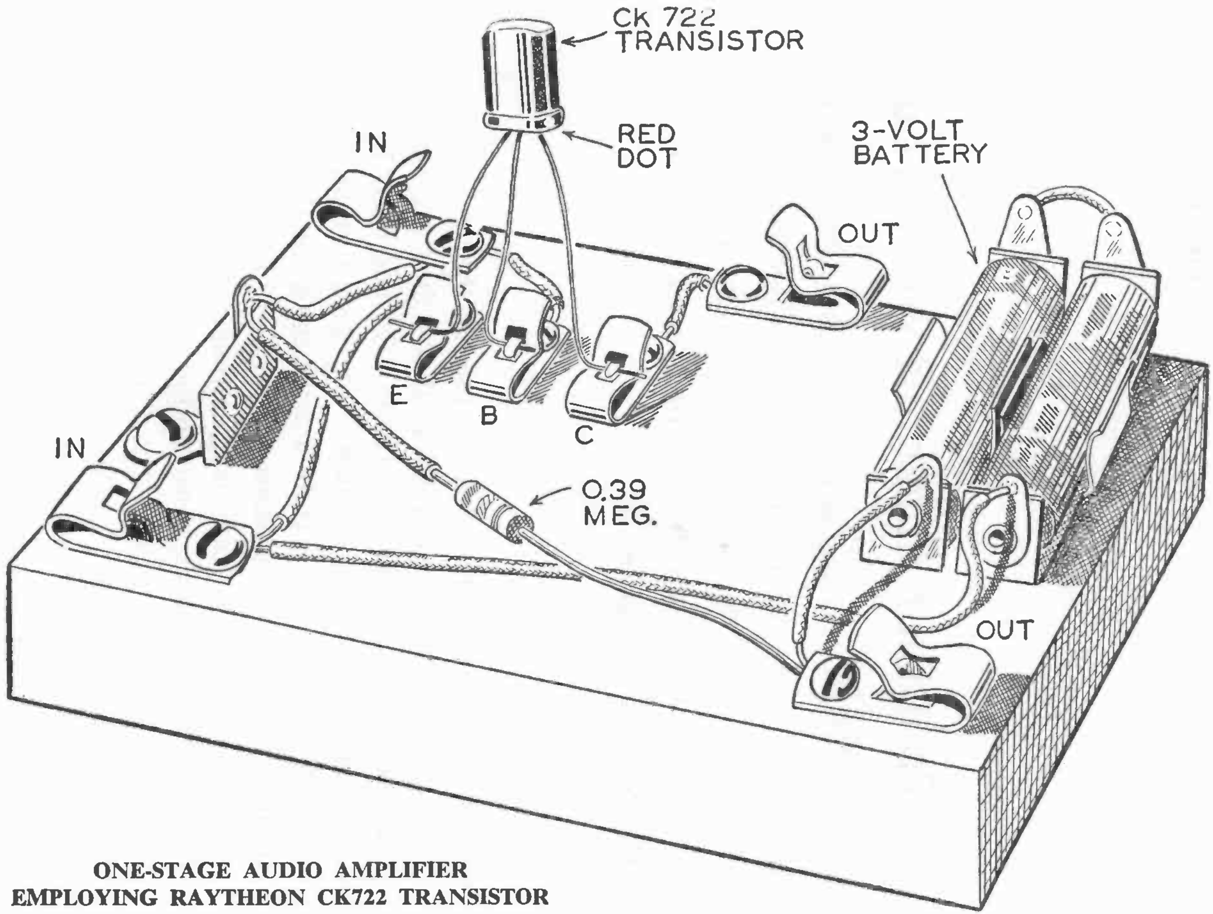
Special tubular-shaped transistor batteries are also obtainable. Each tube contains fifteen 1.4 volt alkaline dry cells. Power requirement from 1.4 to 21 volts can be met simply by slicing off the necessary number of cells.

Transistor Apparatus Which You Can Build . . .

A ONE-STAGE AUDIO AMPLIFIER • A COMBINATION CRYSTAL DIODE AND TRANSISTOR RADIO RECEIVER • A TRANSISTOR TIMER SWITCH • HOW TO BUILD A TRANSISTOR CODE PRACTICE OSCILLATOR • LEARNING TO TELEGRAPH.

Although transistors have been in use less than a decade, they have found so many applications they are being manufactured at the rate of 10,000,000 per year. In a few years transistor production is expected to total 30,000,000 per year. They truly are the basis for the electronics of the future. A transistor is free of many of the vacuum tube's limitations such as bulkiness, short life, fragility and high power consumption. A transistor saves space, weight, heat, power lasts 150 times as long as a vacuum tube and uses 1/1000 of the electric current.

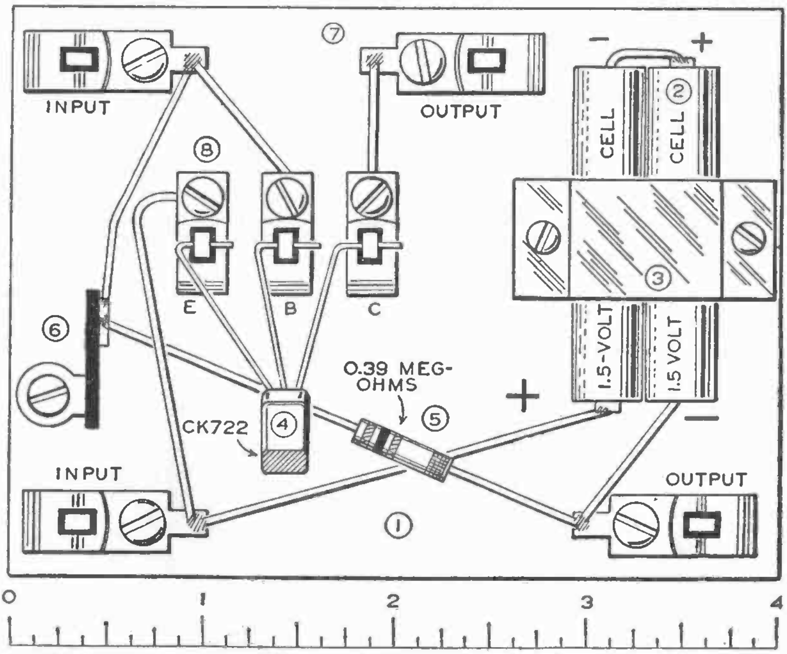
Building radio and electronic apparatus which uses a transistor in place of a radio tube is easy for the amateur experimenter. An important advantage from the stand-



ONE-STAGE AUDIO AMPLIFIER
EMPLOYING RAYTHEON CK722 TRANSISTOR

point of the young experimenter is: transistor circuits are not connected to the 120-volt power line. No one in your household can object to your hobby on those grounds. Transistor circuits are operated by batteries. The batteries cost only a few pennies and last a long time.

There is no attempt at miniaturization in the design of the instruments described in this chapter. To make or assemble miniature and sub-miniature apparatus requires more mechanical skill than to make or assemble apparatus of larger size. There are many first-class kits of parts on the market for building miniature amplifiers, radio

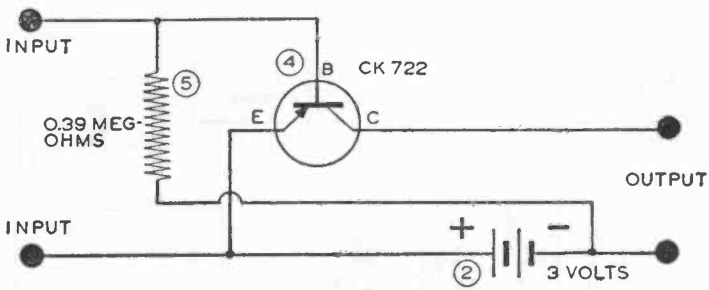


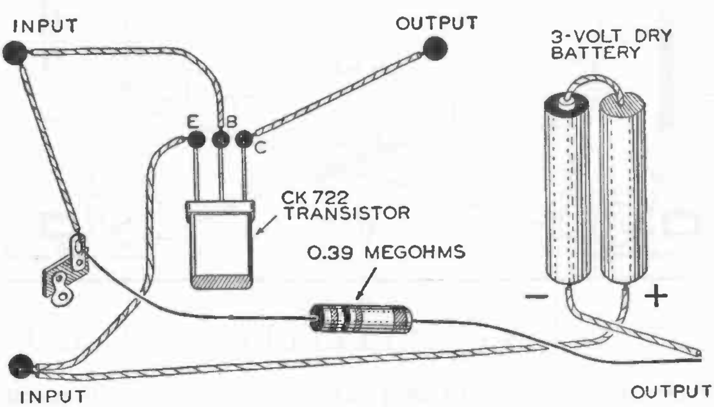
PLAN OF THE ONE-STAGE TRANSISTOR AUDIO AMPLIFIER receivers, oscillators, timers, etc. If you wish to build miniature equipment, it is advisable to buy the kits and follow the instructions which accompany them.

ONE-STAGE TRANSISTOR AUDIO AMPLIFIER

One of the simplest transistor circuits is the one-stage audio amplifier shown on the following page. In addition to simplicity this amplifier has the advantage of low cost.

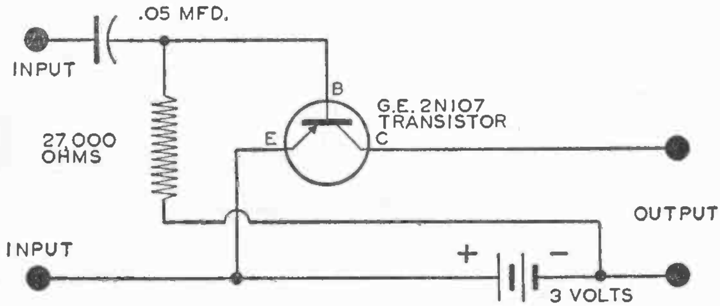
SCHEMATIC AND PICTORIAL DIAGRAMS
OF ONE-STAGE AUDIO AMPLIFIER
EMPLOYING RAYTHEON CK722 TRANSISTOR





The components can be purchased for $1.75 or less. When connected to either of the crystal detector receivers described in Chapter Three, this amplifier will greatly increase the strength of the signals.

The amplifier is so designed that the transistor is held in three Fahnestock clips. This eliminates soldering and possible damage to the transistor by the heat of the soldering iron. The transistor can be removed quickly from the clips for use in another piece of equipment if you wish. The first circuit diagram of the amplifier specifies a a Raytheon CK722 transistor. A General Electric type 2N107 transistor will serve equally well. A circuit diagram for the G.E. 2N107 is also illustrated. Notice that the values of the capacitors and resistors in the two circuits are different.



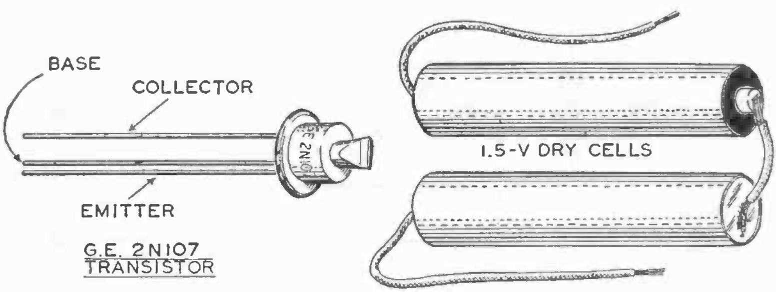
SCHEMATIC CIRCUIT DIAGRAM OF ONE-STAGE AUDIO AMPLIFIER EMPLOYING G. E. 2N107 TRANSISTOR

The diagram shows an .05 mfd. ceramic capacitor which does not appear in the previous circuit diagram.

Here is a list of the parts and materials needed to construct the amplifier:

1 Wood base 4 in. x 3 in. x ¾ in. (**1**)
1 Raytheon CK722 P-N-P transistor (**4**)
4 No. 2 Fahnestock Spring Contact Clips (**7**)
3 No. 10 Fahnestock Spring Contact Clips (**8**)
2 Burgess 1½-volt No. 7 dry cells (**2**)
1 Transistor battery holder for two Burgess No. 7 dry cells or 1 strip of thin metal sheet 2$\frac{7}{16}$ in. x 1 in. if battery holder is to be home-made (**3**)
1 ½-watt 390,000-ohm resistor (**5**)
7 ⅜-in. No. 6 round head wood screws
3 ⅜-in. No. 4 round head wood screws
1 Single contact tie-point (**6**)
Hook-up wire

Two size AA flashlight cells can be used instead of Burgess No. 7 cells. If a factory-made transistor battery



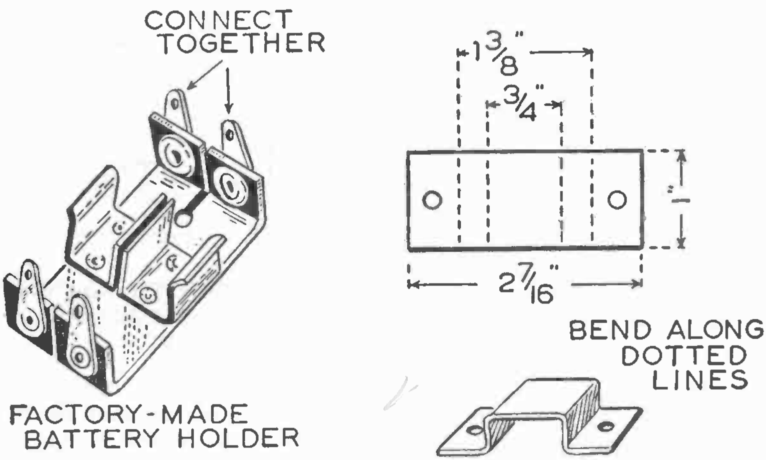
G. E. 2N107 TRANSISTOR

This is a PNP type transistor for experimental and amateur use. The right-hand sketch shows how two penlite cells are connected in series by soldering. If a G.E. 2N107 transistor cannot be obtained easily, a G.E. 2N191 or a G.E. 2N323 should give the same results.

holder is used, worn out cells can be removed without disturbing any soldered connections. If you wish to make a battery holder, clamp the cells to the wood base with a strip of thin sheet metal as shown in one of the illustrations. The Burgess cells are designed especially for transistors and will last longer than flashlight cells.

Assembling. Give all surfaces of the wood base a coat of white shellac. When the shellac is dry assemble the parts on the base as shown in the plan.

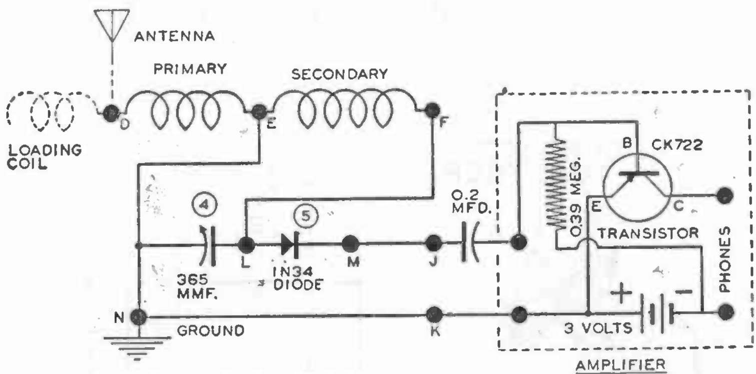
Although the plan drawing shows wires attached to the spring clips by soldering, it is easy to wire the amplifier without any soldered connections except those to the battery or battery holder. Remove the insulation from both



BATTERY HOLDERS FOR TWO 1½-v No. 7 CELLS

The right-hand sketch shows how to make a battery holder for clamping a two-cell battery to a wooden base. The holder is bent from a strip of sheet metal.

ends of each wire, and clamp the bare ends between the wood base and the spring clips. The single-contact tie-point can be omitted. Instead of soldering one terminal of the resistor and two wires to the tie-point, clamp them under a washer held firmly against the wood base by a round head screw which passes through the hole in the washer and into the base. When a factory-made battery holder is used, the cells should be placed in the holder so that they are in series and the terminal voltage of the battery is 3 volts. The positive end of the left-hand cell should be at the front of the holder and the positive end of the

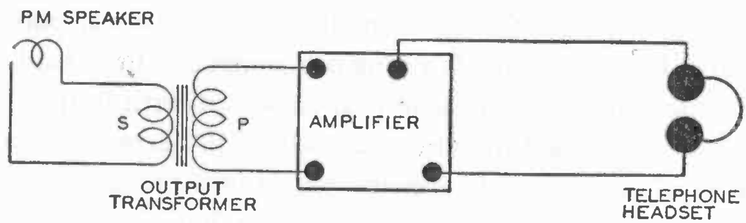


SCHEMATIC CIRCUIT DIAGRAM SHOWING HOW TO CONNECT THE AMPLIFIER TO THE "MORE SELECTIVE" CRYSTAL RECEIVER DESCRIBED IN CHAPTER III

Connect the PHONE terminal J on the receiver to the INPUT terminal on the amplifier which is connected to the EMITTER of the transistor and the POSITIVE terminal of the amplifier. Connect the other PHONE terminal J on the receiver to one terminal of an .02 mfd. ceramic capacitor. Connect the other terminal of the capacitor to the INPUT terminal on the amplifier which connects with the resistor and the base of the transistor. If a ceramic capacitor is not easily obtainable, a paper by-pass capacitor of the same capacitance can be used. The ceramic capacitor is preferable. Connect headphones to the PHONES or OUTPUT terminals of the amplifier.

right-hand cell should be at the back of the holder. Observe the indicated polarity carefully or possible damage to the transistor may occur.

Consult the plan and both circuit diagrams when wiring the amplifier. The center wire on a Raytheon CK722 transistor is the BASE terminal. The wire nearest the red dot on one side of the transistor is the COLLECTOR terminal. The remaining wire is the EMITTER terminal. The transistor terminals must be connected to the Fahnestock clips as shown in the diagrams. The letters **E, B** and **C** in the illustrations are abreviations for EMITTER, BASE and COLLECTOR *respectively*. Observe the transistor connections carefully. Possible damage to the resistor may result if it is not connected in the circuit properly.



AN EXPERIMENT WITH THE ONE-STAGE TRANSISTOR AMPLIFIER

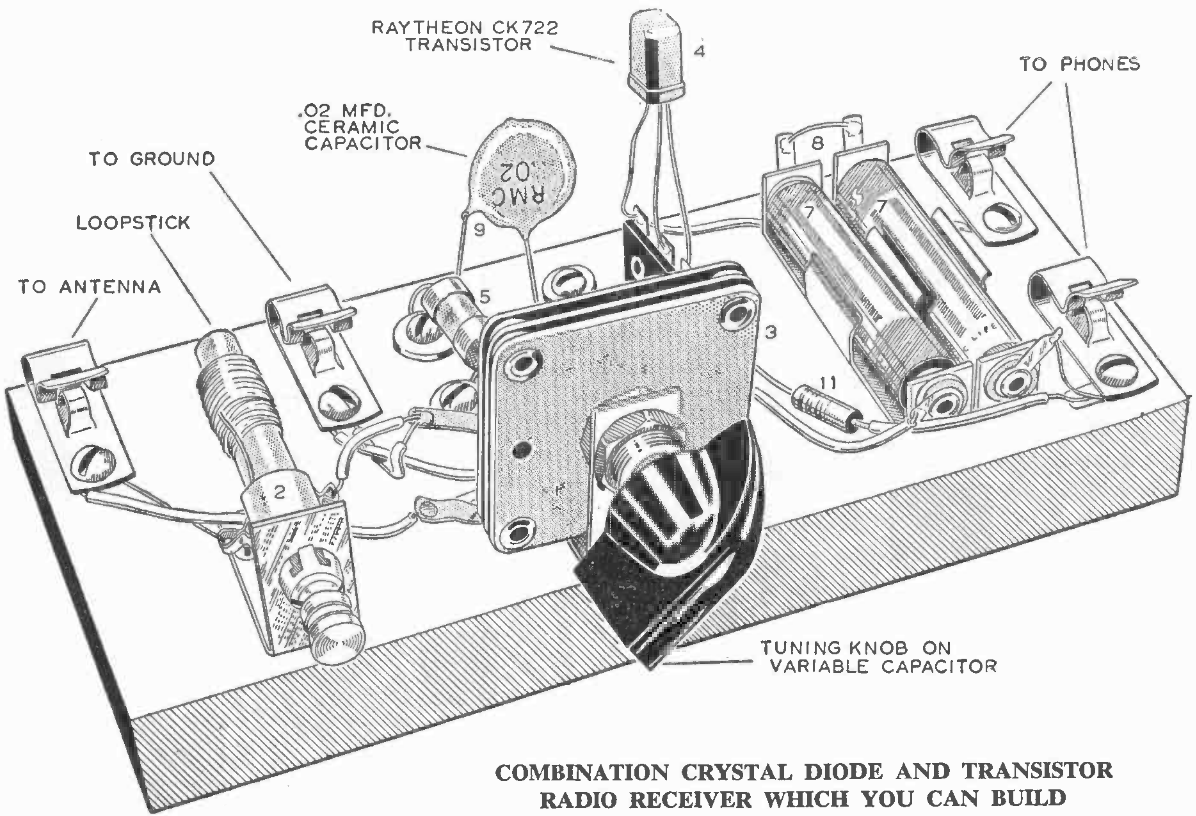
The gain or amplifying power of the amplifier may be demonstrated by hooking up the amplifier with a small PM speaker, a transformer and a pair of headphones. Connect the voice coil of the speaker to the secondary of a small output or matching transformer. Connect the primary of the transformer to the input terminals of the amplifier. Connect a 2,000-ohm headset to the output terminals of the amplifier. The speaker will act as a self-powered microphone. The wires connecting the headphones to the speaker should be long enough so that the speaker and amplifier are in one room and the phones can be carried to an adjoining room. Words spoken within a few feet of the speaker can be heard in the earphones in the adjoining room.

YOU CAN BUILD THIS COMBINATION CRYSTAL DIODE AND TRANSISTOR RADIO RECEIVER

This receiver is capable of providing good signals from broadcast stations within a radius of 50 miles using a 50-foot antenna and a first-class ground connection. In some locations, signals from stations 500 miles away can be picked up.

The antenna circuit includes a loopstick which can be used to select the station and a miniaturized 365 mmfd. variable capacitor to tune the station selected to a peak. A 1N34 diode is used as the detector.

There are several loopsticks on the market. They are intended as replacements for loop antennas in superheterodyne and other receivers provided with radio-frequency amplification. When used with a crystal detector and antenna a ground must be connected to the loopstick. A loopstick consists of a small coil wound on a plastic tube. Inside the tube is a plug of magnetic material called ferrite. The core can be moved back and forth in the coil by turning the threaded shaft which projects from one end of the tube. Moving the core tunes the coil, or, in other words, changes its impedance so that it will respond to different frequencies. A loopstick called a "tenna-loop" was used to build the receiver which is illustrated here. There are several other brands of equally good loopsticks, such as the "ferri-loopstick," "vari-loop" and Miller No. 6300 which can be used instead. Each loopstick comes equipped with a metal bracket. At one end of each loopstick is a metal ferrule. The loopstick is fastened to the bracket by pushing the ferrule into the large hole in the bracket. The bracket provided with a loopstick is usually

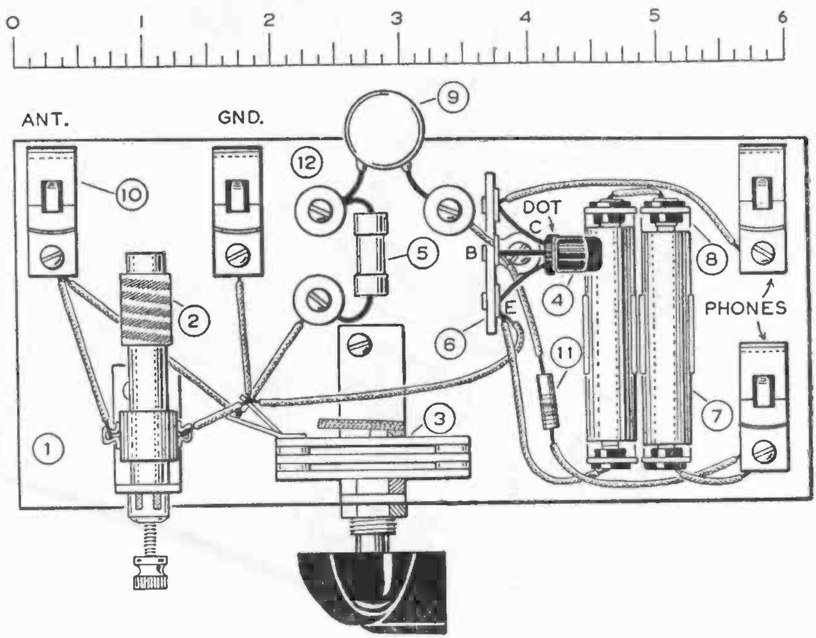


COMBINATION CRYSTAL DIODE AND TRANSISTOR
RADIO RECEIVER WHICH YOU CAN BUILD

a flat strip of metal which must be bent to suit the receiver under construction.

The components which comprise the receiver are mounted on a 6⅜ inch x 2¾ inch wood base. By crowding the components more closely together and providing a box-like wooden cover the receiver can be changed into an interesting pocket size radio.

The variable capacitor specified is a miniaturized version of a variable condenser which is only 3/16 inch thick, exclusive of the shaft. The capacitance ranges from 10 mmfd. minimum to 365 mmfd. maximum. The small size is achieved by using mica instead of air as the dielectric between the plates.



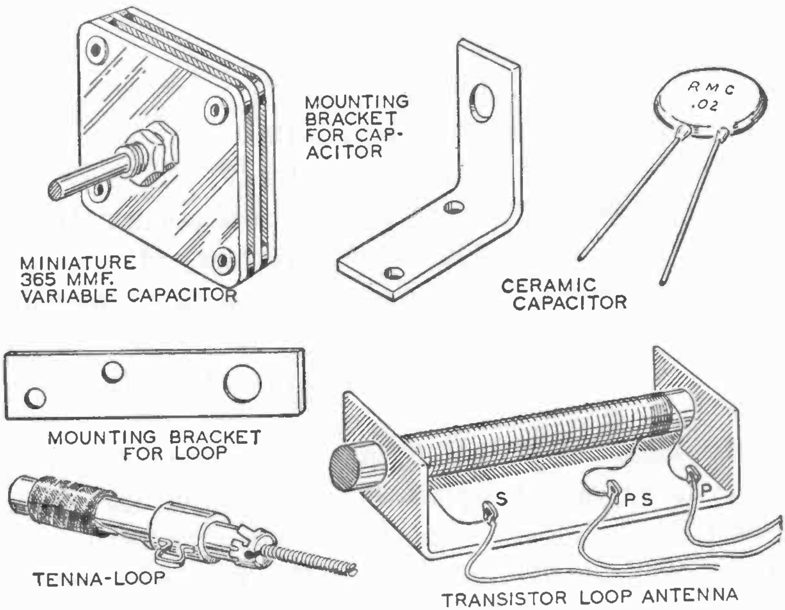
PLAN OF THE RECEIVER

PARTS NEEDED TO BUILD THE RECEIVER

1 Wood base 6⅜ in. x 2¾ in. x ¾ in. (**1**)
1 Loopstick antenna and bracket with small knob to fit threaded shaft on loopstick (**2**)
1 Miniaturized 365 mmfd. variable capacitor knob and bracket (**3**)
1 Raytheon CK722 transistor (**4**)
1 Sylvania IN34 diode crystal (**5**)
1 3-contact tie-point (**6**)
2 No. 7 Burgess dry cells (**7**)
1 Battery holder for cells (**8**)
1 .02 mfd. ceramic capacitor (**9**)
4 No. 2 Fahnestock spring contact clips (**10**)
1 ½-watt, 390,000-ohm resistor (**11**)
3 No. 4, ⅜ in., round head wood screws with washers to fit (**12**)
9 No. 6, ⅜ in. round head wood screws

Assembling and Wiring. Mount the parts on the wood base as shown in the plan. The loopstick comes with a short length of bare or enamelled wire attached to one of its terminals. Discard the wire. The terminal to which the wire is attached should be considered the ANT terminal and connected to the stator of the variable capacitor and the ANTENNA Fahnestock clip. The other terminal of the loopstick is the GND terminal and should be connected to the rotor of the variable capacitor and to the GROUND Fahnestock clip. Connections to the loopstick should be soldered. The terminals of the crystal diode and the ceramic capacitor are clamped under brass washers held firmly against the base by a No. 4 round head brass screw through each washer and into the base.

Note that the terminals of the transistor are soldered to a 3-contact tie-point. If you use this method of construction, grasp each transistor terminal in the jaws of a pair of long nose pliers while soldering. Use a very small



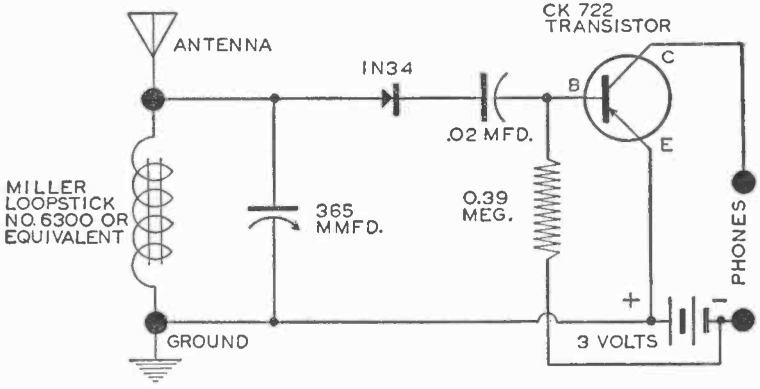
PARTS FOR TRANSISTOR CIRCUITS

The miniature variable capacitor uses thin sheets of plastic as the dielectric between plates. It is not as efficient as an air dielectric capacitor. Ceramic capacitors are much smaller than paper capacitors of equal capacitance. The transistor loop antenna at the lower right has a non-adjustable ferrite core. It is provided with two windings. **S** is one of the secondary terminals. **P** is a primary terminal. **PS** is a common primary and secondary terminal. The loopstick or tenna-loop at the lower left has an adjustable ferrite core. The winding is tuned by turning the projecting screw.

soldering iron. Transistors are easily damaged by heat and the purpose of the pliers is to draw the heat from the wire terminal and absorb it so that it cannot reach the transistor. If you do not wish to take the risk involved in soldering the transistor terminals you can clamp them under brass washers held to the base by round head screws.

Operation. Connect the ANT clip to a 50-foot antenna and connect the GND clip to a good ground. Connect a 2000-3000-ohm radio headset to the PHONE clips. Place the two dry cells in their holder. Observe the indicated polarity, or damage to the transistor may occur.

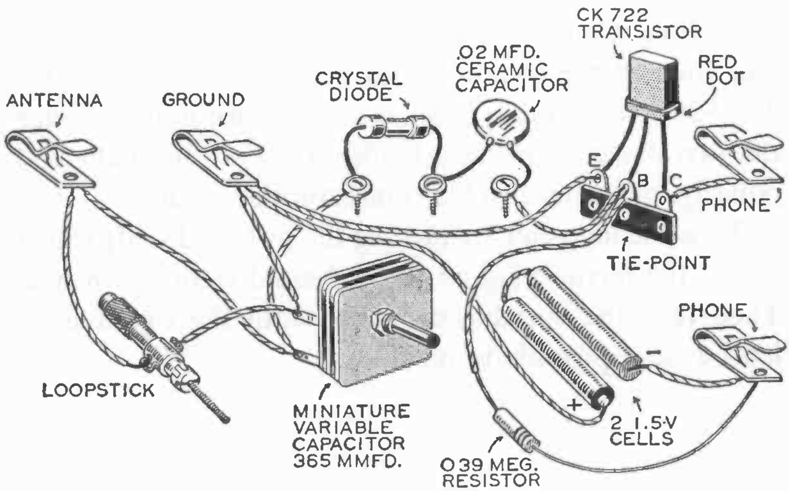
Tune the loopstick by turning the threaded shaft which moves the ferrite plug until the desired station is heard. Then tune the variable capacitor until the signal is as loud as it is possible to make it.



SCHEMATIC CIRCUIT DIAGRAM OF THE COMBINATION CRYSTAL DIODE AND TRANSISTOR RADIO RECEIVER

Trouble Shooting. If no signal is heard check the wiring and connections carefully, the polarity of the transistor and the polarity of the dry cells.

PICTORIAL CIRCUIT DIAGRAM OF THE COMBINATION CRYSTAL DIODE AND TRANSISTOR RADIO RECEIVER



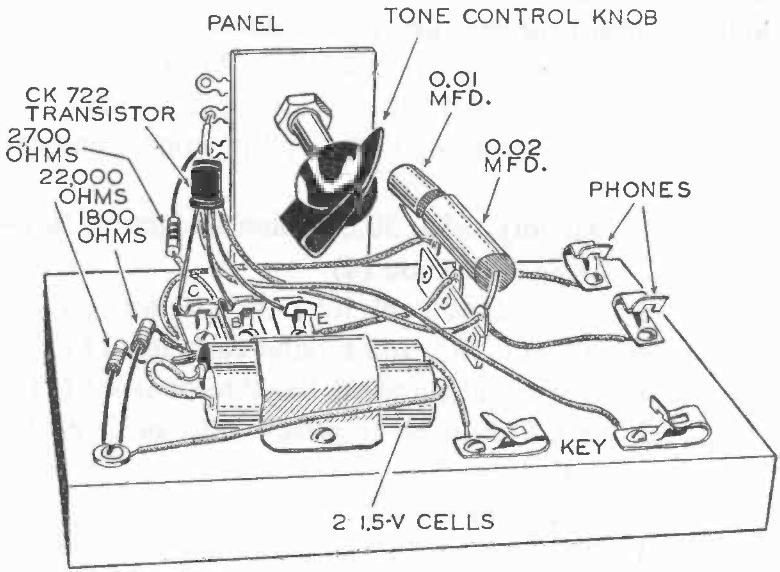
HOW TO BUILD A TRANSISTOR CODE PRACTICE OSCILLATOR

Radio telegraph messages are transmitted in the dot and dash signals of the Continental telegraph code. You will enjoy radio more if you can telegraph and read telegraph messages. You can listen to amateurs, ships and shore stations and perhaps obtain a license to operate a transmitter of your own.

Anyone who wishes to obtain an amateur license must pass an examination in reading the telegraph code. No fee is required for the license. It is necessary only to pass a simple examination in elementary radio theory, in the Federal Radio Regulations and in sending and receiving the Continental telegraph code.

When you can send and receive 65 letters, numerals and puctuation marks per minute accurately you can pass the government code test for an amateur license. During the examination, the code test is given first. If the applicant passes this, he may proceed with the examination covering the radio laws and simple technical problems.

The first step in learning to telegraph is to memorize



A TRANSISTOR CODE-PRACTICE OSCILLATOR

When the 50,000-ohm tone control is properly adjusted the circuit oscillates at an audio-frequency and sounds are produced by the headphones connected to the circuit. Adjusting the control varies the frequency and an exact imitation of the sound of radiotelegraph signals can be obtained.

the code. The second is to practice sending with a telegraph key. The simplest way to do this is to connect a telegraph key in series with a small high-pitched buzzer and a battery so that you can make DIT and DAH sounds on the buzzer by pressing the key. A code practice oscillator with a key and headphones is better than a key and buzzer. The DIT and DAH sounds are exactly like those heard in a radio receiver.

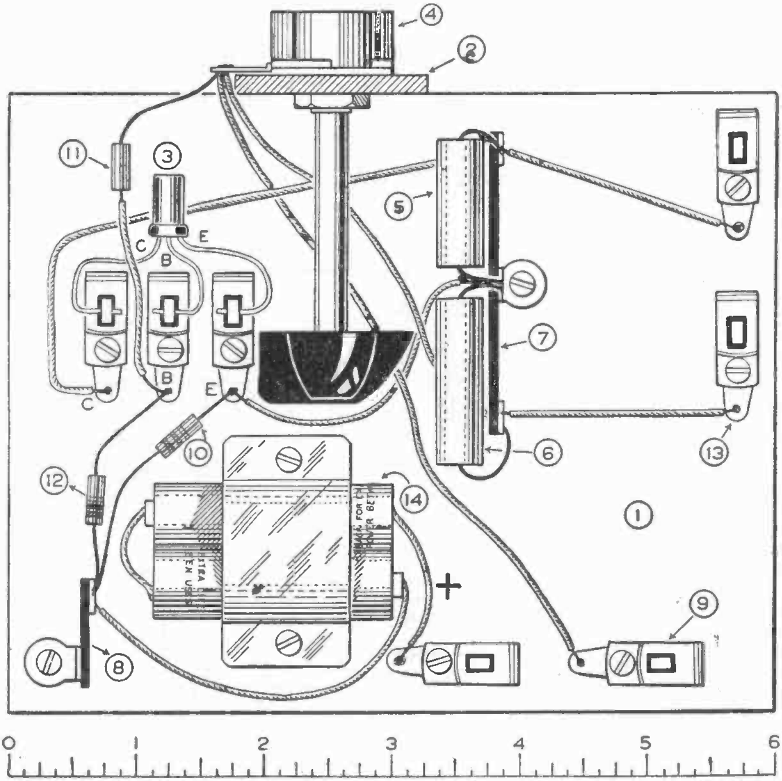
A compact, low-cost oscillator can be built with a transistor and a few other components.

The following components and materials are required to build the transistor code practice oscillator.

1 Wood base 6 in. x 4¾ in. x ¾ in. **(1)**
1 Wood panel 3 in. x 1½ in. x ⅛ in. **(2)**
1 Raytheon CK722 "p-n-p" junction transistor **(3)**
1 Mallory U-35, 50,000-ohm midgetrol, No. 4 taper with knob **(4)**
1 .01 mfd. 400 volt tubular capacitor **(5)**
1 .02 mfd. 400 volt tubular capacitor **(6)**
1 5-terminal standard Bakelite tie-point **(7)**
2 No. 7 Burgess transistor cells or 2 penlite cells **(8)**
7 No. 10 Fahnestock spring contact clips **(9)**
1 22,000-ohm, ½ watt, carbon, gold band resistor **(10)**
1 2,700-ohm, ½ watt, carbon, gold band resistor **(11)**
1 1,800, ½ watt, carbon, gold band resistor **(12)**

11 No. 4, ⅜-in. round head wood screws
1 Strip sheet metal 3 in. x 1 in. or a battery holder for 2 No. 7 cells

Assembling. Shellac or varnish the wood base and the small panel upon which the volume control is to be mounted. Fasten the Bakelite tie-points and the Fahnestock contact clips to the base in the locations indicated in the plan. Place a solder lug under the head of each

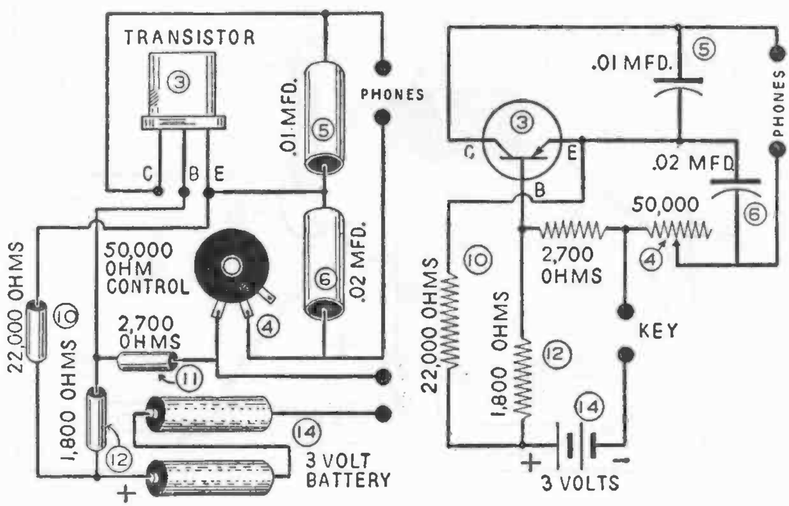


PLAN OF THE CODE PRACTICE OSCILLATOR

screw used to fasten a contact clip. The lugs make it easy to solder a connection to the clips.

Cut the strip of sheet metal 3 inches long and 1 inch wide from a tin can and use the strip to make a battery clamp as shown in one of the illustrations.

Wiring. Use pushback wiring for the connections and solder all wire terminals with rosin-core solder except the terminals of the transistor. Consult the schematic wiring diagram and also the wiring in the plan. Install the dry cells and observe the polarities indicated in the illustrations. Failure to do so may damage the transistor. The positive pole of one cell is connected to the negative pole of the second cell by a short piece of wire soldered to the cell terminals. This arrangement connects the cells in series so that they deliver 3 volts. Notice that the positive



PICTORIAL AND SCHEMATIC CIRCUITS OF THE CODE PRACTICE OSCILLATOR

pole of the 3-volt battery is connected to the EMITTER of the transistor through the 22,000-ohm resistor. The COLLECTOR terminal on the transistor is marked by a RED dot. The wire terminal in the center is the BASE terminal. The wire terminal on the side of the transistor opposite to that marked by the red dot is the EMITTER terminal. The transistor is connected in the circuit by fastening the ends of the terminal wires in the three Fahnestock clips marked **E**, **B** and **C** in the diagrams. One terminal wire on the 2,700-ohm resistor which is connected to Fahnestock clip (**B**) and a terminal of the volume control is close to Fahnestock clip **C** but must not be allowed to touch the clip and form a short circuit. If you pull a piece of insulation 1¼ inches long off a piece of pushback wire and slip it over the wire terminal of the resistor, it will form an insulating sleeve which will prevent a short circuit.

LEARNING TO TELEGRAPH

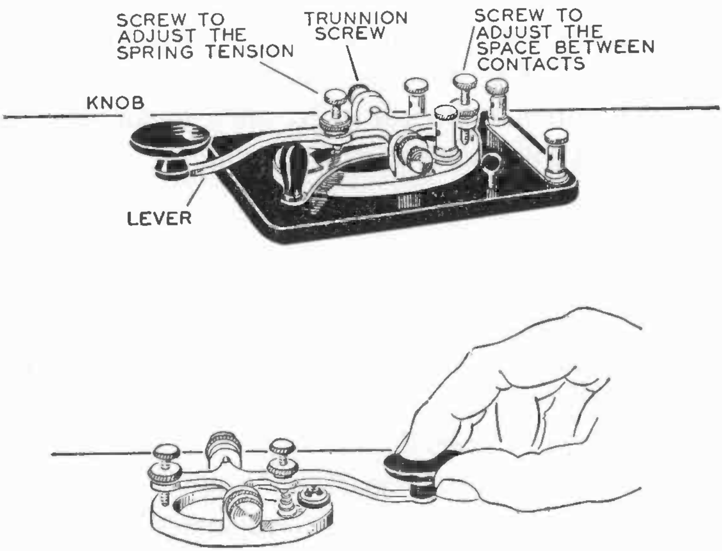
When memorizing the code do not think of the characters as dots and dashes but rather as sounds in which the sound DIT represents a dot and the sound DAH represents a dash. For example, the letter A is memorized as DIT DAH and not as "dot dash."

The DIT sound is made in the headphones connected to the code practice oscillator by pressing the key down and letting it come up again just as soon as possible. The DAH sound is made by pressing the key down and holding it down for an instant before releasing it so that the DAH sound is three times as long as the DIT sound.

Proper adjustment of the telegraph key is important.

The key contacts should be adjusted for the beginner so that the space between is about 0.01 inch. If the key lever has more up and down movement than is provided by a space of 0.01 inch between the contacts, the signals sent with it will be "choppy."

The key should be mounted on a table far enough back from the edge so that there is room for the elbow to rest on the table. Learn in the beginning to handle the key properly. Let the fingers rest lightly against the key knob. The thumb should be against the left side of the knob (unless you are a southpaw). The first finger should be



TELEGRAPH KEYS

Telegraph keys similar to those illustrated above are available from dealers in "ham" radio supplies. The drawing at the bottom shows a method of holding the key knob used by many professional telegraph operators. The forefinger rests on top of the key knob. The thumb and second finger grasp the edges of the knob and help the spring to raise the lever. The thumb and both fingers are used to press the knob down.

THE CONTINENTAL CODE

A ·—
B —···
C —·—·
D —··
E ·
F ··—·
G ——·
H ····
I ··
J ·———
K —·—
L ·—··
M ——
N —·
O ———
P ·——·
Q ——·—
R ·—·
S ···
T —
U ··—
V ···—
W ·——
X —··—
Y —·——
Z —··

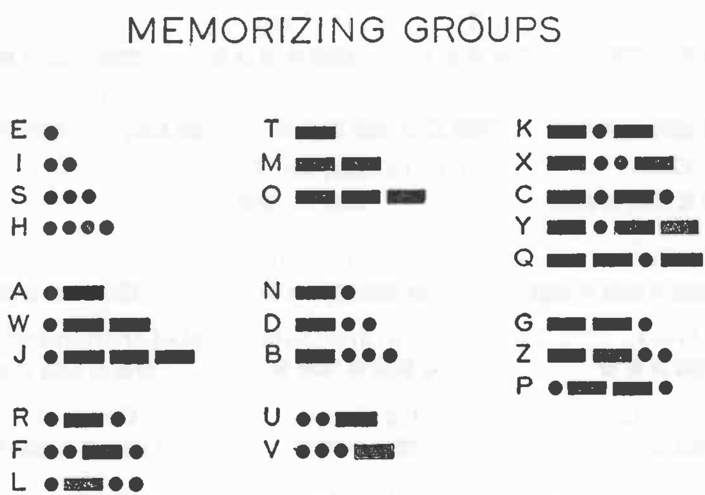
1 ·————
2 ··———
3 ···——
4 ····—
5 ·····
6 —····
7 ——···
8 ——··
9 ————·
0 —————

Call ·—·—
Invitation to Transmit —·—

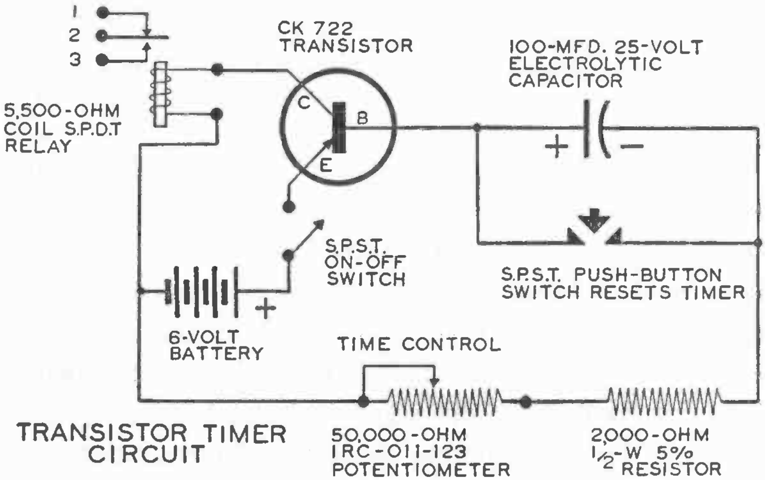
Period ·—·—·—
Interrogation ··——··
Break —···—
Wait ·—···
End of message ·—·—·
End of transmission ···—·—
Received ·—·
Go ahead —·—
Comma ——··——

THE CONTINENTAL TELEGRAPH ALPHABET
USED IN RADIOTELEGRAPHY

partly on top and against the edge of the knob. The second finger should be against the right edge of the knob. Allow the third and fourth fingers to curve naturally under the palm without tension or rigidity. Do not operate the key with the finger or wrist muscles. Use the forearm muscles. The fingers are merely the medium through which the stroke of the forearm is transmitted to the key and the wrist is merely a sort of hinge through which the motion of the forearm is transmitted to the key. Do not "tap" the key, as newspaper reporters and story writers say. A telegraph operator never "taps." An operator's thumb and fingers do not quit contact with the key knob until he is through sending. Do not think of speed at first during your practice. Take time to send slow, even clean-cut signals. Speed will come with sufficient practice.



There are two systems of memorizing the telegraph alphabet. One is to study the first four or five letters, then the next four or five, and so on. The other is to study the characters after they have been arranged in easily identifiable "memory groups" as above.



TRANSISTOR TIMER CIRCUIT

AN OPPORTUNITY TO DO YOUR OWN ENGINEERING

This is a schematic circuit for a timer switch which employs a transistor in its operation. The timer will open or close a switch after a definite period of time has elapsed. It can be used to turn off a photo-printing lamp after the lamp has burned a required number of seconds. A pictorial circuit, plan, list of components and detailed instructions have been omitted so that the young electronics experimenter can make his own layout from the information which can be gained by studying the schematic circuit.

With proper adjustment of the potentiometer and the spring on the relay armature, the relay can be made to operate at the end of any time period ranging from 2 to 40 seconds. A paper dial should be mounted under the knob and pointer on the potentiometer shaft and marked to indicate the time periods. Use a watch with a sweep second hand to test different settings of the potentiometer. Mark the dial to indicate seconds.

If the relay is connected to a lamp used for photo-printing, the lamp will remain lighted for periods of 2 to 40 seconds in accordance with the time indicated on the scale by the pointer. Use the relay terminals marked 1 and 2 in the circuit diagram as part of the lamp circuit. When the ON-OFF switch is closed and the push-button reset is pressed, the 100-mfd. electrolytic condenser is discharged and the relay armature is drawn toward the relay coil. This movement of the armature closes contacts 1 and 2 and lights the photo-printing lamp. As soon as the condenser is discharged by pressing the push button, the 6-volt battery begins to recharge it again. The time required to recharge the condenser depends upon the amount of resistance in the circuit, in other words, the adjustment of the potentiometer. When the condenser is recharged sufficiently the relay armature will move away from the coil, contacts 1 and 2 will open and the lamp will be extinguished. To light the lamp again it is merely necessary to press the push-button. When the timer is not in use the ON-OFF switch should be in the OFF position.

If you can get the assistance of an experienced operator to coach and criticize your sending, you will progress more rapidly. Perhaps the best substitute for the assistance of an experienced operator is for two beginners to learn the code together and send to each other with the code practice oscillator. When listening to signals, write down—"copy" it is called—the signals in the form of letters, numerals and punctuation marks, and not as dots and dashes.

There is not enough space in this book to give more than brief instruction for learning to send and receive radiotelegraph signals.

A copy of the 126-page manual called *The Radio Operator* used in training operators in the army will be found helpful and interesting to any one who wishes to learn to telegraph. Write to the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. and ask if the book is in print and its price. Ask for TM-454 *The Radio Operator.* The book is not always available. The price is usually nominal (25 cents).

The American Radio Relay League, Hartford, Connecticut, publishes an excellent instruction manual called *Learning the Radio Telegraph Code.* The price is 25 cents.

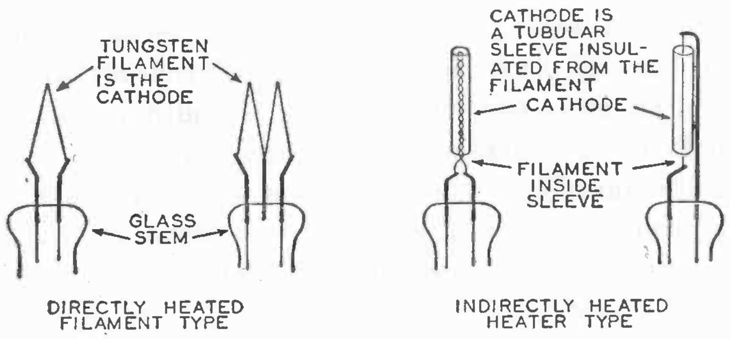
About Radio Tubes

The operation of all the apparatus described in the following chapters centers around some type of ELECTRON TUBE, popularly known as a radio tube. An electron tube consists of two or more metal electrodes sealed within a totally or partially evacuated metal or glass envelope. Since radio tubes are the "heart" of most electronic apparatus, it is useful to have some knowledge of how they work and of the circuits which employ them.

Classification of Tubes. There are more than one thousand different types of vacuum tubes regularly manufactured in the United States. This wide variety may be classified in a number of ways. A simple method is to group them according to their use—that is, whether they were designed to be DETECTORS, AMPLIFIERS, OSCILLATORS or RECTIFIERS. Another method is to divide them into groups having such family names as DIODE, TRIODE, TETRODE

The Diode. The first radio tubes were diodes. They were called Fleming valves. John A. Fleming, a British scientist, found the first practical application for the diode. He patented its use as a detector of wireless telegraph signals and it was thus employed for several years by the Marconi Company.

A diode contains two electrodes, a cathode in the form of a filament and an anode in the form of a metal cylinder or plate. The anode of a radio tube is commonly called the PLATE in radio language, The cathode is an EMITTER of electrons and the plate is a COLLECTOR of electrons. A diode is an electrical valve in which electrons can flow only from the cathode to the anode. This action is explained by the illustration on page 129 and its caption.



TWO KINDS OF RADIO-TUBE CATHODES

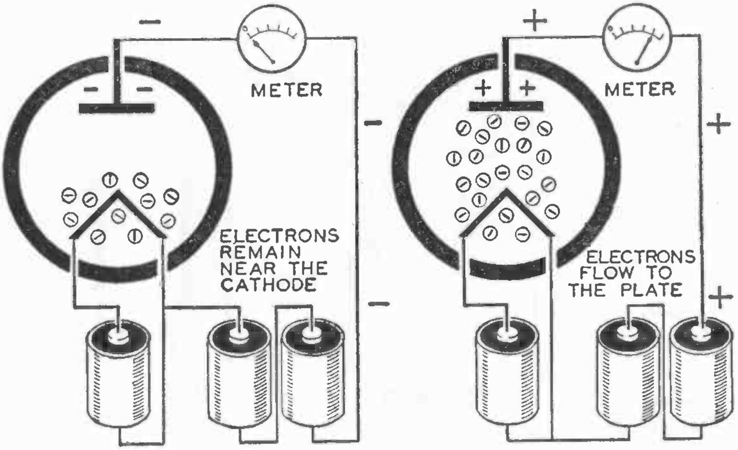
In the directly heated type (usually employed in battery-operated receivers) the cathode is a tungsten filament. The electrons are emitted directly from the hot tungsten, which is heated by an electric current passing through it.

In the indirectly heated type, the tungsten filament is enclosed in a chemically treated sleeve. The sleeve emits electrons when heated by the filament. The directly heated cathode requires direct current. An indirectly heated cathode may be operated on alternating current.

Since electrons can flow in only one direction through a diode, its basic use is as a rectifier. A rectifier changes alternating current into direct current.

The unidirectional flow of current through a diode is used in principle when a diode is employed as a DETECTOR. Diodes in which the filament is replaced by a combination of filament and cathode and which have been evacuated until only a few molecules of gas remain in the envelope, are used as detectors in some modern radios. Frequency modulation receivers use a diode detector.

Other diodes containing a small amount of mercury vapor to increase their current carrying capacity are used as rectifier tubes to change alternating current into direct

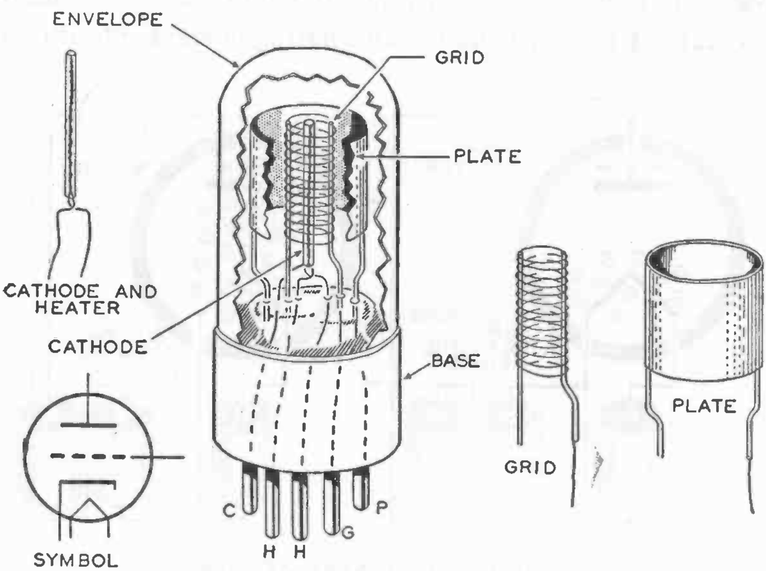


THE FUNDAMENTAL ACTION WHICH OCCURS IN A RADIO TUBE

If the plate is neutral or negative in respect to the cathode, the electrons emitted from the cathode remain close to the cathode. Some electrons reenter it. None reaches the plate and no current flows in plate circuit. (See meter in illustration.) If the plate is positive, electrons are drawn to it and pass across the vacuum space between the cathode and plate. Under this condition a current flows in the plate circuit. (See meter.)

current. Direct current is required in the plate circuits of all radio receivers and amplifiers, and in AC-operated receivers is secured by rectifying the AC.

The Triode. The greatest advance in the development of radio tubes was made in 1906 when Lee DeForest added a third electrode to the diode and it became a triode. The triode is similar in construction to the diode, except that a grid of fine wire or screen with openings through which electrons may pass is added between the cathode and plate. The addition of the grid gives to the tube its most

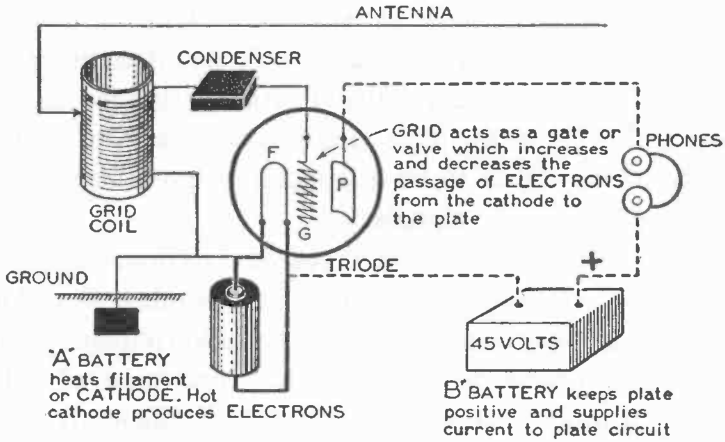


THE CONSTRUCTION OF A TYPICAL TRIODE

Part of the glass envelope and part of the plate are shown cut away in this illustration to reveal the arrangement of the electrodes. Electrical connections to the filament, cathode, grid and plate are made through wires which connect to the base pins. The cathode sleeve is insulated from the filament. Notice that the grid is much closer to the cathode than to the plate.

useful functions—the ability to amplify. The grid is called the CONTROL GRID. It makes it possible to control relatively large electron current across the space between the cathode and anode by very small variations in voltage applied to the grid. This can be accomplished without the expenditure of appreciable power in the control circuit. A triode may be used as a sensitive detector, a relay, an amplifier or an oscillator.

When a triode is placed in operation, the plate is con-



THE TRIODE AS A DETECTOR

The three circuits which are necessary in order for a triode to play its part as a detector in a radio receiver are illustrated. The tube represented is the filament cathode type. The grid circuit is indicated by light lines, the filament circuit is indicated by heavy lines and the plate circuit is indicated by broken lines. The high-frequency currents generated in a receiving antenna by incoming signals are alternating currents and as a result the charge upon the grid is alternately positive and negative and varies in degree in accordance with the signals. The number of electrons passing through the grid from the cathode to the plate and likewise the volume of current flowing in the plate circuit varies in accordance with the charge on the grid.

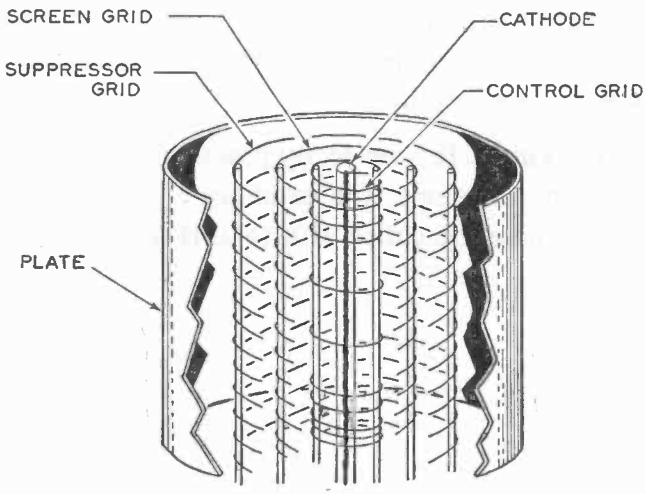
nected to a high positive voltage, usually designated by the abbreviation B+. The grid is connected so that it is negative in respect to the cathode. Since electrons are negative, they tend to be repelled by the negative grid and few of them get through the grid to the plate.

If the triode is used as a detector or an amplifier, the signals which reach the grid are alternately positive and negative. If the grid becomes less negative, more electrons will get through to the plate. If it becomes more negative, fewer electrons will get through to the plate. The number of electrons passing from the cathode to the plate will vary in accordance with the signals. So will the current flowing in the plate circuit. Very feeble signal impulses on the grid will produce relatively large variations in the current flowing in the plate circuit. In this action lies the ability of the triode to be a detector of great sensitivity and to amplify radio signals.

In the early days of radio, tubes were designed for general service. A single type of tube—the triode—served as detector, audio-frequency amplifier, radio-frequency amplifier and oscillator. Unfortunately one type of tube could not meet such varied requirements efficiently. The splendid performance of modern radio apparatus is largely due to the fact that hundreds of different tubes are available and that each one has been developed so as to be most efficient for a certain purpose.

Tetrodes and Pentodes. There is capacitance between the cathode, grid and plate of a triode just as there is between the plates of a small capacitor. For many years when triodes were the only tubes available, the capacitance between the plate and the grid prevented the development of satisfactory radio-frequency amplifiers. The problem was finally solved by adding a SCREEN GRID or fourth electrode between the grid and plate, thus changing the triode into a TETRODE. This reduced the capacitance between the control grid and the plate to a very low value.

With tetrode tubes as radio-frequency amplifiers it became possible to obtain much more amplification than with triodes. But before long it was discovered that a tetrode was not the final answer to the problem of radio-frequency amplification.



CONSTRUCTION OF A PENTODE

This is an example of the advance in tube knowledge and design since the first triode was created.

Part of the plate is shown cut away to reveal the three grids and cathode of a pentode designed to reduce distortion in radio-frequency amplifiers. Known both as a super-control amplifier tube and as a variable-mu tube, it also reduces "cross modulation." Cross modulation is the effect produced in a radio receiver by an interfering station "riding through" on the carrier wave of the station to which the receiver is tuned.

In all radio tubes the electrons emitted from the cathode and attracted to the plate may, if they strike the plate with sufficient velocity, dislodge other electrons from the plate. These dislodged electrons are called secondary electrons and their release is called secondary emission.

In a tetrode the screen grid offers an attraction to the secondary electrons and some of them are drawn to it with the effect that the plate current is lowered. It was soon found that the troublesome effect of secondary emission in lowering the plate current may be eliminated by adding a fifth electrode known as a SUPPRESSOR GRID. The suppressor grid, which added to a tetrode makes the latter a pentode, is located between the screen grid and the plate. Pentodes make excellent power amplifiers and radio-frequency amplifiers.

Multi-unit Tubes. It is perfectly practical to combine two tubes in one envelope, for example a detector and an amplifier. These are called MULTI-UNIT TUBES.

Introduction to Amplifiers

More vacuum tubes are employed as amplifiers than for any other purpose. To amplify means to enlarge or to increase. The electronic amplifier is one of the most important inventions of the twentieth century. It is an essential part of all radio, television and radar transmitters and receivers, of the telephone system,* of the modern phonograph and of almost unnumbered laboratory instruments.

Very small changes in voltage or current—so small that they would be useless without an amplifier—can be magnified by this device and made useful. The range of radio stations would be greatly limited if vacuum tubes could serve only as detectors. We would still wear headphones when listening to radio programs. Television, radar, long-distance telephony and talking motion pictures would be dreams and not realities.

Broadcasting and television transmitters put many thousands of watts of power into their signals but the

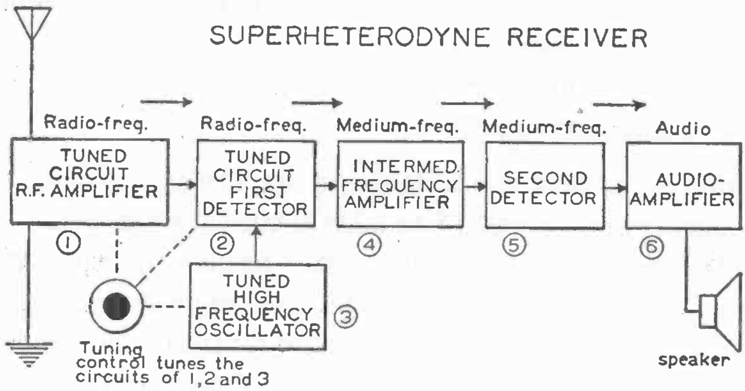
* The amplifier tubes used in telephone circuits are called REPEATERS.

energy picked up from them by your receiver is very small. It is usually only a few millionths of a watt and too weak to do more than produce faint sound in a sensitive telephone receiver. It is too feeble to operate a loud speaker or produce a television picture unless it is fed first into an amplifier. The common electronic amplifier employs vacuum tubes or transistors so arranged that a very small power in one part of the circuit will control a much larger power in an adjoining circuit. Many electronic devices require more than one tube or transistor to secure sufficient amplification. When the output of one tube or transistor is fed to another tube or transistor the arrangement is called a CASCADE AMPLIFIER. When one amplifier tube or transistor is used to do the job, it is called a single-stage amplifier. When two tubes or two transistors are used it is a two-stage amplifier. One, two and three-stage amplifiers are common. Some amplifiers consist of five or six stages.

A vacuum tube in itself is not an amplifier, nor is a transistor alone an amplifier. A single-stage amplifier utilizing a vacuum tube consists of the tube, a power source and three adjoining circuits. The three circuits may include resistors, transformers, capacitors, etc. (A single-stage transistor amplifier is illustrated on page 100.)

Amplifiers can be classified according to the frequency ranges over which they operate. There is no "universal" amplifier which will amplify all frequencies efficiently. The three general types are called:

1. Audio amplifiers
2. Video amplifiers
3. Radio-frequency amplifiers



WHAT IS A SUPERHETERODYNE RECEIVER?

One of the problems in designing a sensitive broadcast receiver is that it must include a radio-frequency amplifier which will operate over a wide range of frequencies. Such an amplifier cannot be as efficient as one designed for a single frequency. The higher radio-frequencies cannot be amplified as efficiently as the lower frequencies. Most home broadcast receivers overcome this difficulty by employing the circuit invented by Prof. E. H. Armstrong which he named the SUPERHETERODYNE.

The illustration above is a block diagram of a simple superheterodyne receiver. A schematic circuit diagram of a superheterodyne would be very confusing to one who is not familiar with radio circuits. Radio engineers often use block diagrams to represent intricate apparatus. A block diagram is somewhat like an architect's plan for a building. The architect's plan does not show all the individual beams, boards, pipes, bricks and other details. A radio engineer's block diagram does not show all the details of a circuit.

In the superheterodyne circuit, the frequency of an incoming signal is changed to a lower frequency which can be amplified efficiently. The radio frequency signal from the antenna is mixed in the first detector (2) with radio-frequency currents generated by a tuned high-frequency oscillator (3). The combining of the two radio-frequencies results in an entirely new signal called the I.F. signal. The tuning and mixing is done in such a manner that the I.F. signal always has a carrier-frequency of exactly 456 Kc.

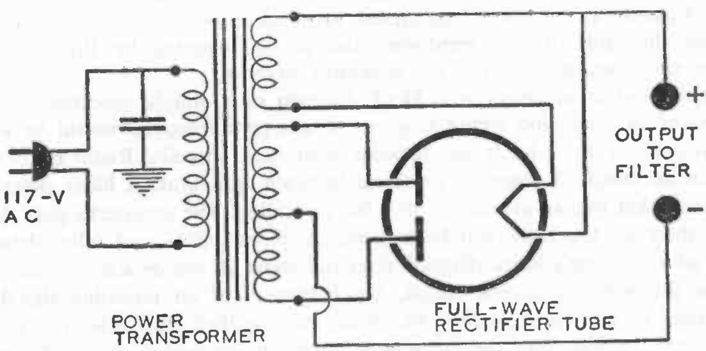
After the carrier-frequency of the desired incoming signal has been changed to 456 Kc by the mixer, first detector and oscillator, it is fed into the intermediate frequency (I.F.) amplifier (4). Since the I.F. amplifier works at only one frequency (456 Kc) it is many times more efficient than an amplifier which works at many different frequencies. The greatly amplified I.F. signal then passes through an ordinary detector (5) and audio amplifier (6). The modern superheterodyne receiver is simple to tune and so sensitive that it will pick up extremely faint signals.

Amplifiers can also be classified into two groups according to type of service as:

1. Voltage amplifiers
2. Power amplifiers.

Audio Amplifiers are designed to amplify signals with a frequency from about 15 to 20,000 cycles per second.

This is approximately the range of frequencies AUDIBLE to a good ear. Audio amplifiers are used to produce a large portion of the amplification in radio receivers and sonar. They are also used in telephony, phonographs, sound motion pictures and intercom equipment. The audio amplifiers in the common radio set do not usually have a



ELECTRON TUBES AS RECTIFIERS

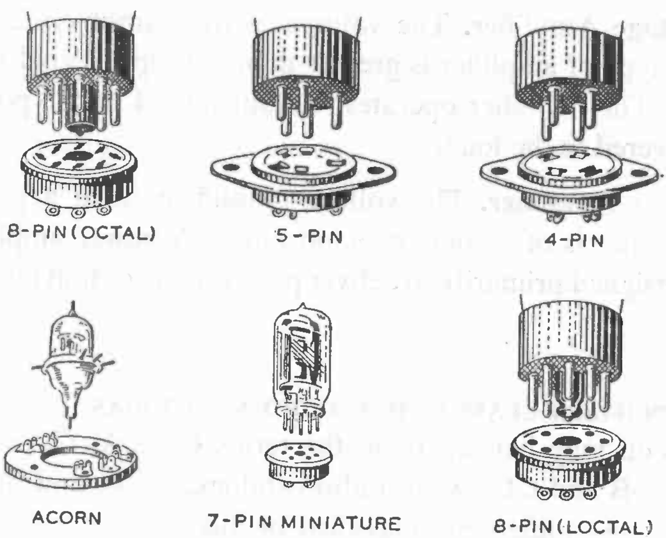
Electron tubes are used for rectifying or changing 117-volt alternating current into direct current. The direct current used as the plate supply in radio receivers, amplifiers, transmitters, etc., is generally secured in this manner. A half-wave rectifier rectifies only one-half of each alternating-current cycle and consequently produces a pulsating direct current. A full-wave tube, connected to a "center-tapped" transformer, rectifies both halves of each alternating cycle. This produces a pulsating direct current also but the current does not have such prominent ripples as the current from a half-wave rectifier and so is easier to smooth out with a filter. (The circuit of a full-wave rectifier is illustrated.)

frequency range of 15 to 20,000 cycles. They commonly cover a narrower frequency band (30 to 11,000 cycles per second).

Amplifiers which will amplify uniformly frequencies of 15 to 20,000 cycles per second are rated "high-fidelity."

Video Amplifiers are designed to amplify uniformly the audio range and, in addition, a wide band of frequencies inaudible to human ears. Video amplifiers amplify all frequencies from about 30 to 6,000,000 cycles per second.

Radio-frequency Amplifiers. Well designed audio-frequency amplifiers amplify all the frequencies in the audio range as equally as possible. Unlike the audio and video



THE BASES OF RECEIVING TUBES AND THEIR CORRESPONDING SOCKETS

The electrodes in a tube are connected to terminal pins which project from the base of the tube. There are six different types of bases commonly used for receiving tubes.

amplifiers, radio-frequency amplifiers need amplify only a very narrow band of radio frequencies. This narrow band may be any part of the wide range of frequencies from 30,000 to several billion cycles per second. Radio-frequency amplifiers use resonant, or tuned, circuits whereas audio-frequency amplifiers use untuned circuits.

AMPLIFIERS CLASSIFIED ACCORDING TO USE

When amplifiers are classified according to use, they can be divided into two groups known respectively as POWER amplifiers and VOLTAGE amplifiers. You will see these two types mentioned from time to time in radio literature.

Voltage Amplifier. The voltage of the output circuit of this type of amplifier is greater than the input signal voltage. The amplifier operates without regard to the power delivered to the load.

Power Amplifier. The voltage amplification in a power amplifier is of secondary importance. A power amplifier is designed primarily to deliver power in the output circuit.

AMPLIFIERS CLASSIFIED ACCORDING TO BIAS

You may happen upon the terms Class-A, Class-AB, Class-B and Class-C in radio catalogs, books and magazines. Amplifiers are classified in this manner according to the "bias voltage applied to their grids." An explanation of grid bias and its effects involves the use of mathematical curves and diagrams which are clear only to those who have studied sufficient mathematics. If you are interested in the meaning and effects of grid bias upon the action of an amplifier tube you may be able to find an explanation in a radio book at the nearest public library.

Class-A amplifiers are used in the output stages of radio receivers and low-power audio systems. They are also used as radio-frequency amplifiers in radio receivers. Class-A amplifiers produce little distortion (an especially desirable quality in an audio amplifier). They are also characterized by low power output and low efficiency.

Class-B amplifiers are used where it is desired to develop a relatively large output in the load circuit. The grid of a class-B amplifier is biased so that plate current flows only during half of the AC signal voltage that is applied to the grid. Class-B amplifiers are used in audio amplifiers. Distortion-free amplification is desired in an audio amplifier. To obtain this quality, two class-B tubes are arranged in a push-pull circuit. Some of the tubes used for this purpose consist of two triodes in the same glass or metal envelope. Then only one socket and what appears to be a single tube is necessary.

Class-AB Amplifiers. Sometimes it is desirable to compromise between the low efficiency and low distortion of class-A amplifiers and the comparatively high distortion and high efficiency of a class-B amplifier. This can be accomplished by biasing an amplifier so that its operation is halfway between that of a class-A amplifier and a class-B amplifier. Such an amplifier is called a class-AB amplifier.

Class-C amplifiers are by far the most efficient of the four classes for radio-frequency amplification.

THE MEANING OF COUPLING

Joining one circuit to another so that energy can be transferred from one circuit to the other is called COUPLING. There are several methods of coupling.

There are two common methods of coupling a circuit to either the INPUT or OUTPUT circuit of an amplifier. One method employs a transformer and the other method uses a resistor and a capacitor. They are called respectively:

1. Transformer coupling
2. Resistance-capacitance coupling

There are two types of transformers used for transformer coupling. They are:

1. Radio-frequency transformers
2. Audio-frequency transformers

Radio-frequency transformers are usually wound on a tube and may have either an air-core or a core made of a powdered iron compound called FERRITE. The ferrite is pressed into a short, straight rod and forms the type of core known as an OPEN-CORE.

Audio-frequency transformers have closed cores made of thin sheets of transformer steel. For further description of audio-frequency transformers refer to the paragraphs on transformers in the chapter on Components.

The Photocells and Phototubes Which Are Popularly Called Electric Eyes . . . HOW TO BUILD A PHOTOTUBE RELAY

There are several varieties of transducers which generate a voltage when light shines on them. They change the energy of light into electrical energy. These devices have several names. They are called "light-sensitive cells," "photocells," "photronic cells," and "electric eyes." Photocell and photoelectric cell are the terms we will use.

Uses for Photocells. Photoelectric cells are far more sensitive than the human eye to small changes in light intensity and color. They have important uses. Here are a few:

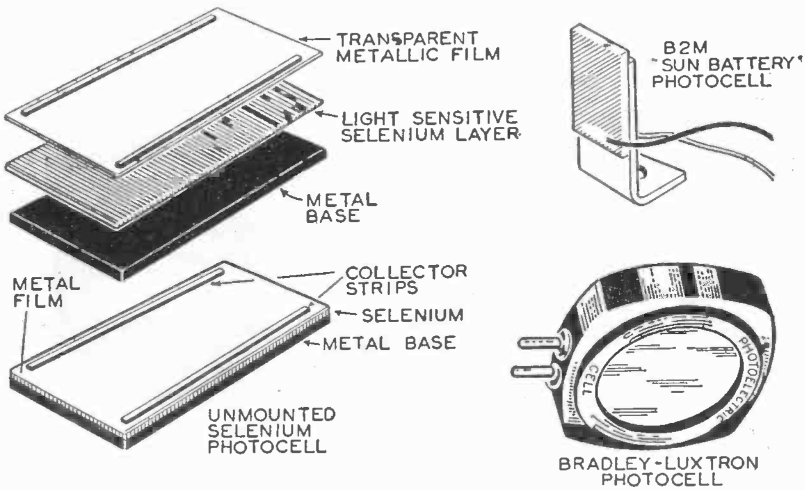
1. to measure illumination
2. as light meters to indicate proper exposure in photography
3. to measure the intensity of photographic negatives for automatic photo-printing machines
4. to count vehicles or people passing a given point

5. to open a door when a person approaches it
6. to signal the presence of an intruder
7. to count packages or manufactured articles passing on a conveyor belt
8. to determine the amount of ingredients in a solution
9. to keep color-printing presses in "register" or adjustment
10. to send photos, graphs, drawings, etc. by wire or radio
11. as an essential part of sound motion pictures
12. to level elevators at a floor
13. to turn street lights on when darkness comes and off when the sun comes up
14. to measure high temperatures
15. to signal the boiler room when smoke issues from the chimney of a power plant

Selenium. The first photocell was made with selenium. Selenium is an element that lies between an insulator and a conductor. Many years ago small rods of selenium were used occasionally as resistors in electrical circuits. For a long time it was not known that selenium has a unique quality. Then a discovery was made on a far away Pacific island. There was an ocean cable station on the island and the resistors used at the station were selenium. One of the cable operators noticed that when the sun came up in the morning he had to readjust his apparatus. He discovered that the adjustment was necessary because a change in resistance occured when the sun shone on the selenium resistors. Thus it was found that selenium has the unique quality of changing its resistance to electric current when exposed to light.

Selenium belongs to the same family of chemical elements as sulfur. It was discovered in 1817 by the great Swedish chemist, Jons Jakob Berzelius. Several chemical elements exist in more than one form. Selenium is one of these. It can be a brown shapeless mass or take the form of gray crystals. It is the gray crystalline selenium which has the property of being a conductor of electricity when exposed to light and almost an insulator in darkness.

First Photocell. A selenium photocell consists of two electrodes, separated by a thin layer of selenium. Alexander Graham Bell, the ingenious inventor of the telephone,

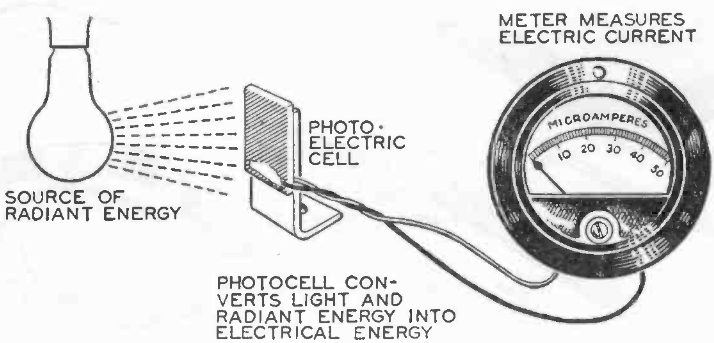


SELENIUM PHOTOELECTRIC CELL CONSTRUCTION

A selenium photoelectric cell is built in layers as shown at the left. The B2M "Sun Battery" is a low-priced photoelectric cell suitable for amateur experimenters.

was the first to make a USEFUL photocell. After much study of the remarkable behavior of selenium and much laborious research, Bell made a photocell in 1877. He used it to TELEPHONE OVER A BEAM OF LIGHT. The first successful selenium cells made by Bell for this purpose consisted of two copper or brass plates separated by a thin insulating layer of mica. A large number of holes were bored through both plates and mica. Conical brass studs were fixed in the holes in one plate and spaced so that they entered the holes in the other plate but did not touch the plate itself. The annular spaces surrounding the studs were filled with melted brown selenium and heated over a gas flame until the selenium again melted and turned into the slate-colored crystalline form.

Bell and an assistant named Taintner constructed a "photophone" with this cell and telephoned over a beam



LIGHT METERS

Light meters, used in photography for measuring the intensity of light, consist of a selenium photoelectric cell connected to a microammeter (measures millionths of an ampere). The meter is calibrated to indicate the correct exposure under existing light conditions.

of light. In their first experiments, the rays of the sun furnished the source of light. The light was reflected from a mirror attached to the small end of a megaphone. Words spoken into the megaphone caused the mirror to vibrate and vary the light beam reflected from the mirror. When one of the Bell's selenium cells was connected to a battery and a telephone receiver and placed where it would intercept the light beam, the variations in light were reconverted into sound waves which repeated the words spoken into the megaphone.

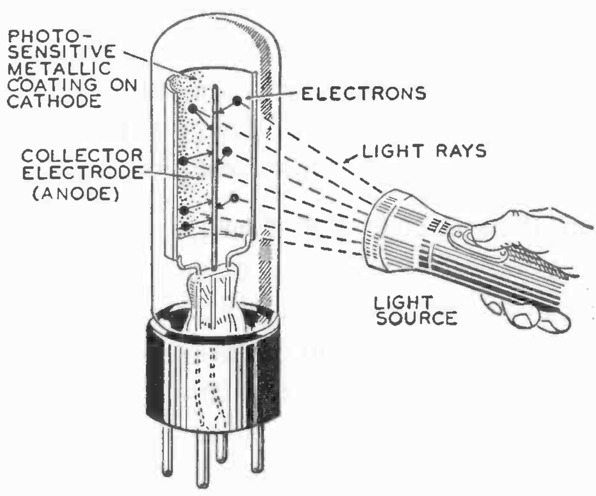
The Direct Conversion of Sunlight to Electricity. For many decades the selenium cell was apparently only a current-conducting device whose resistance changed when exposed to light. It was not known that a selenium cell could also be a photoelectric cell and in addition to changing its resistance it could also generate a voltage when exposed to light. It is the photoelectric voltage-generating quality of selenium that is now most widely used.

Selenium Photoelectric Cell Construction. The typical selenium photocell consists of a metal plate or disk (usually iron), one side of which is covered with a thin layer of selenium. A very thin film of gold or silver is spattered on the selenium. A current-conducting electrode or collector strips rest on the gold or silver film. The metal film is so extremely thin that it is transparent and permits light to pass and reach the selenium layer. When light shines on the cell a small current flows from the selenium to the metal base. Under proper conditions the flow of current varies almost directly as the amount of light which reaches the cell. Needless to say, the action of a selenium cell is electronic. Several theories explaining how light thus produces a flow of electrons have been proposed.

All photoelectric transducers are not constructed like a selenium cell. One different and widely used type is called a PHOTOTUBE.

Descripition of a Phototube. At first glance a phototube may have the general appearance of a radio tube intended for use in a radio receiver. It consists principally of two electrodes sealed in a glass envelope and has a black plastic base like the base of a radio tube.* The electrode in the

* This description does not fit some phototubes, namely, those of the cartridge and end types.

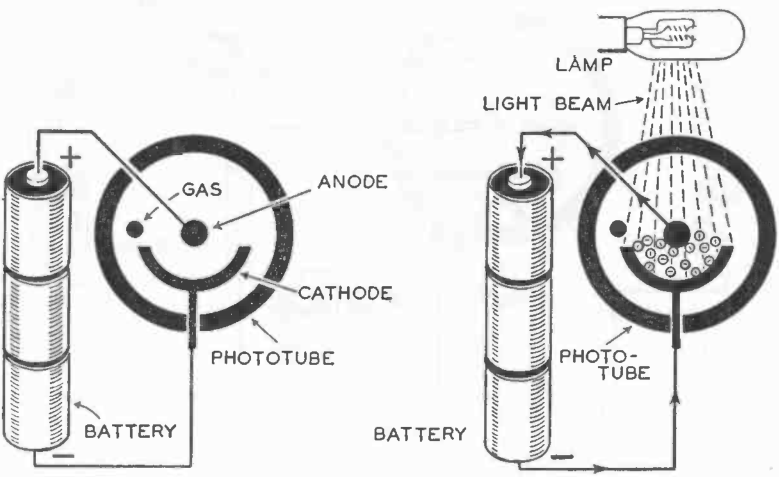


A PHOTOTUBE HAS A SMALL ANODE
AND A LARGE LIGHT-SENSITIVE CATHODE

When light strikes the photosensitive metallic coating on the cathode of the tube, electrons are thrown off from the metal. The electrons (represented by black dots in the sketch) move toward the anode and current flows in the tube circuit. This current can be amplified and made to operate a relay.

shape of a half cylinder, easily visible through the glass envelope, is the cathode. The anode is a short straight rod or wire. When the phototube is in operation the anode is connected to the positive terminal of a voltage source. The cathode emits electrons when its sensitized surface is exposed to light or other radiant energy.

The cathode is the only part of the phototube which is sensitive to light. It is the PRODUCER of electrons. The anode is a COLLECTOR of electrons. The cathode is a strip of thin, silver-plated, sheet copper bent into semicylindrical form. When the phototube is one which is sensitized with cesium, the silver on the concave surface of the cathode is covered with a thin layer of cesium oxide and

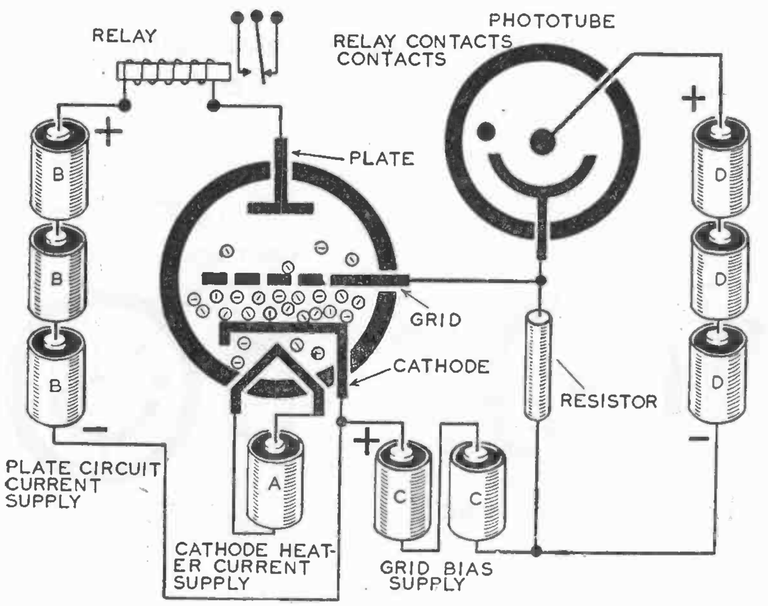


NO ELECTRONS ARE PRODUCED AT THE CATHODE UNLESS LIGHT STRIKES ITS SENSITIVE SURFACE

The large black dot is the conventional symbol for gas in a tube. The small circles enclosing a negative sign in the right-hand sketch represent electrons. When a photoelectric tube is placed in operation the anode is kept at a positive potential so that it will attract electrons.

the oxide is coated with a thin layer of metallic cesium. Cesium is a costly, rare, soft, silvery metal discovered nearly one hundred years ago by Professord Gustav R. Kirchoff and Professor Robert W. Bunsen.* Cesium oxidizes easily in air and decomposes water when immersed in the latter. It must be stored in a vacuum or in a chemically non-active gas.

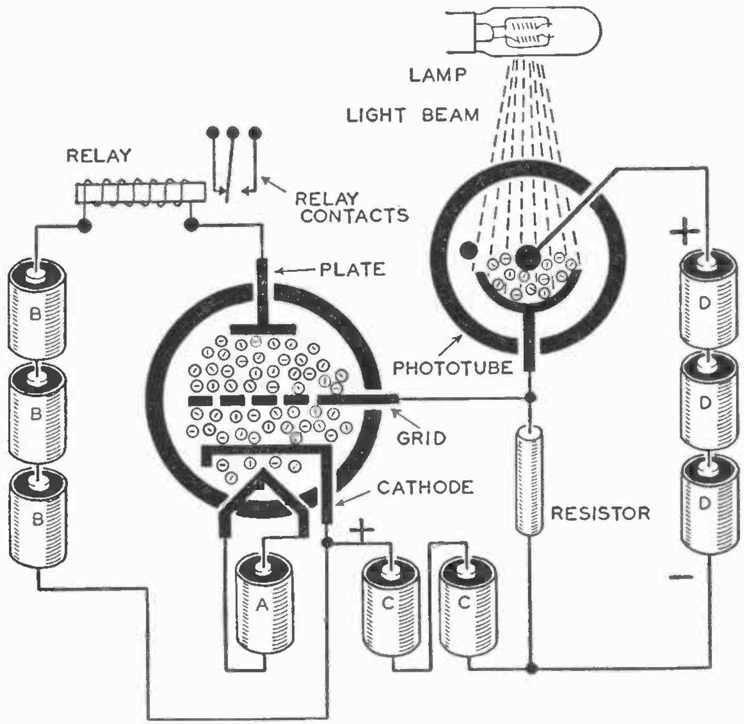
* Both of these scientists made many important discoveries. Look for their names in the encyclopedia and read about them in "Discovery of the Elements" by Mary Elvira Weeks or in other reference books at the library.



HOW A PHOTOTUBE RELAY OPERATES

When a phototube is put into operation the cathode is connected to a battery (DDD) or other source of positive potential. The circuit also includes an amplifier tube and a sensitive relay. The electric current produced in a phototube is too weak to operate any but the most sensitive relays. Therefore it is fed into an amplifier tube. The amplified current will operate a less sensitive but more rugged type of relay.

Little practical use has been found for cesium except in phototubes. However, cesium is not the only metal used for sensitizing the cathode in phototubes. Calcium, barium, strontium, etc., and their oxides, are also used for this purpose. Metals such as tantalum, thorium and



HOW A PHOTOTUBE RELAY OPERATES, continued

Compare this illustration carefully with the preceding one where no light strikes the phototube and consequently few electrons from the amplifier tube's cathode are able to get through the grid and reach the plate. In the illustration above, light is shown striking the cathode of the phototube. Electrons are released. The current flow in the phototube makes the grid of the amplifier tube more positive and electrons from the amplifier cathode reach the plate. Current flows in the plate circuit (**B, B, B** are the plate supply) and the relay armature is drawn toward the coil.

titanium are used on the cathodes of special purpose phototubes which respond to ultra violet light but are not sensitive to light visible to the human eye.

Different metals used as the sensitive surface of the cathode give phototubes different characteristics. Four types of surfaces known respectively as s1, s2, s3 and s4 are available in commercial phototubes. Two interesting examples are the standard phototubes known as RCA 929 and RCA 926. The 929 with an s4 surface has much greater sensitivity to blue rich light such as the light from a mercury vapor lamp than to the light of an incandescent bulb. (An incandescent lamp is blue deficient.) Phototubes are used frequently in industry to control the flames in large furnaces. The characteristics of 929 with s4 surface adapt it to flame control where it is desirable for the tube to respond to the flame and not to heated objects in the flame.

Tubes which have an s1 or s2 photo-surface have high sensitivity in the red and infra-red region of the spectrum. The RCA 930 is such a tube. It has the same physical appearance and dimensions as RCA 929 but gives high response to red and near infra-red radiation.

The s3 photo-surface used in the RCA 926 phototube responds, much as the human eye, to all the visible colors. Hence 926 s3 is often used in color measurement.

What happens? When a phototube is put into operation the anode is connected to the positive terminal of a battery or other source of positive potential. Then if light or other radiant energy strikes the photo-surface of the cathode, electrons are knocked out of the surface, and since electrons are negative they are drawn to the positive anode. They fly across the space between the cathode and the anode and continue to do so as long as radiant energy strikes the cathode and the anode remains positive. This movement of electrons is an electric current. The number of electrons emitted by the cathode depends upon the wave length of the radiant energy and the amount of light that falls on the cesium surface of the cathode. An intense light of the same wave length produces more electrons and a stronger electric current than a weak light. The electric current produced, even by an intense light is too weak (it is only a few millionths of an ampere) to operate any but the most sensitive relay—a type of relay too delicate to be practical for most applications of the "electric eye." Therefore the current produced in a phototube by light rays is fed into an amplifier. The amplified current will operate less sensitive but more rugged types of relay.

HOW TO BUILD AND USE A PHOTOTUBE RELAY

The components and parts required to build the Phototube Relay are listed below. The letters enclosed in parenthesis are the key to identity the parts in the illustrations.

1 Wood base 7 in. x 4¾ in. x ¾ in.
1 Piece of plywood 2⅝ in. x 1⅛ in. x ¼ in. or a metal bracket to support volume control
1 2500-ohm SPDT sensitive plate circuit relay (**E**)
1 2-watt, 10,000 or 20,000-ohm wire wound linear taper volume control (**B**)
1 SPST switch which can be attached to the volume control (**A**)
1 Knob for volume control (**C**)

- 1 CE23C gas Cetron phototube
- 1 117L7/M7-GT radio tube
- 1 Octal wafer socket for 117L7 tube **(K)**
- 1 Steatite 4-prong wafer socket for phototube **(L)**
- 1 16 mfd. 150 DCWV electrolytic capacitor **(J)**
- 1 10 megohm, ½-watt resistor
- 1 25,000-ohm, ½-watt resistor
- 2 single-terminal Bakelite tie-points **(H)**
- 1 2-terminal Bakelite tie-point **(H)**
- 1 6-ft. lamp cord and attachment plug **(G)**
- 1 Screw eye with ¼ in. eye
- 3 Binding posts or 3 Fahnestock connectors **(D)**
- 6 ½-in. No. 5 round head wood screws
- 4 1¼-in. No. 5 round head wood screws
- 4 ¾-in. spacers with hole to pass No. 5 wood screw
- shellac, hook-up wire, rosin-core solder

The Phototube. Several types of phototubes were tested for this book and it was found that the CE23C gas-filled Cetron and RCA 868 gave excellent results in a fairly simple circuit. The CE23C proved to be more sensitive than the RCA868. Both are 4-prong tubes which will fit into the same socket and either one may be substituted for the other without changing the circuit.

The Plate Relay. A relay is an electrically operated device for the opening and closing of a circuit, or, in other words, an electrically operated switch. A variety of relays are used in electronic circuits and several types will be found listed in the catalogs of firms dealing in radio, television and industrial electronic supplies. Each type is in-

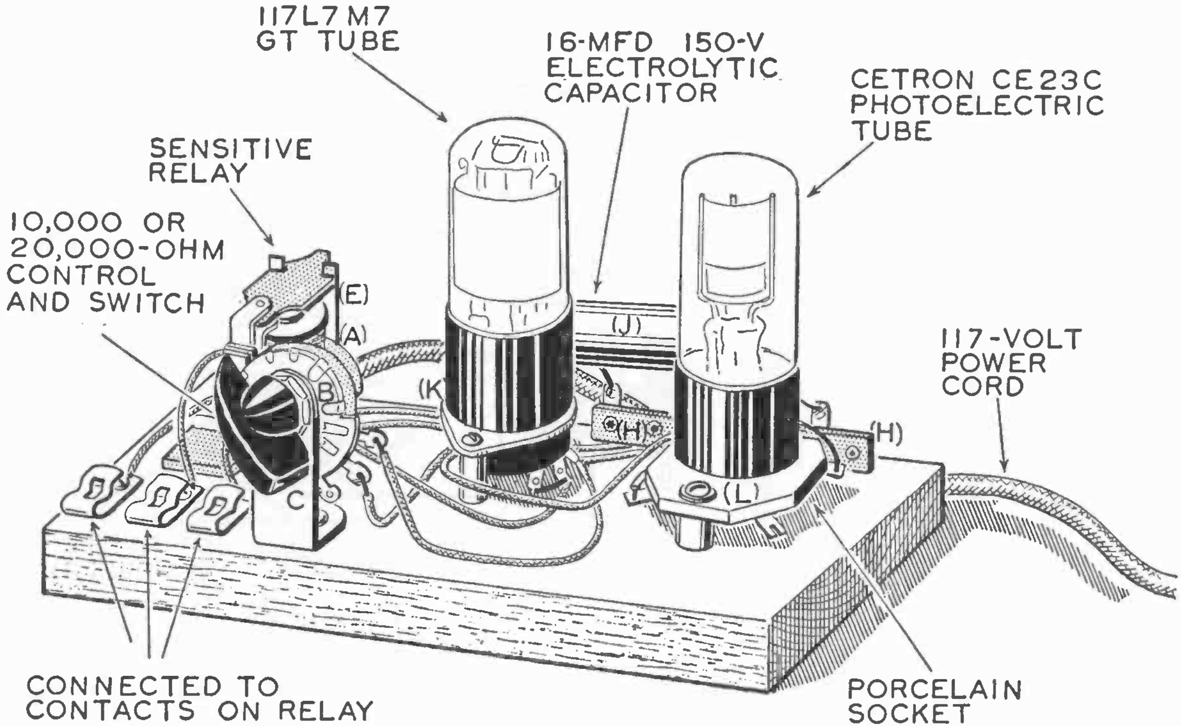


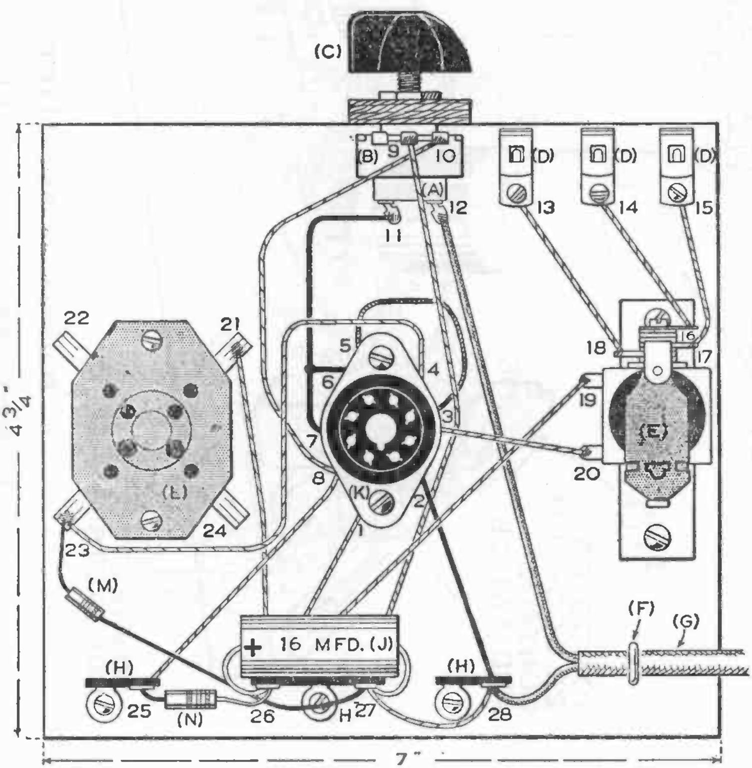
PHOTO-RELAY WITH CETRON CE23C TUBE

The letters enclosed in parentheses are the keys for identifying the parts with those in the plan.

tended for a special purpose. The relay selected to use with the phototube should be a medium-cost PLATE CIRCUIT relay with a 2,500 or 5,000-ohm coil. Such a relay can be operated by a current of only 8 or 9 milliamperes (0.008 to 0.009 amps.). Super-sensitive plate relays with a resistance of 5,000 to 10,000 ohms can be operated by a current as small as 1 milliampere (0.001 amp.). They

PLAN OF THE RELAY WITH CETRON CE23C TUBE

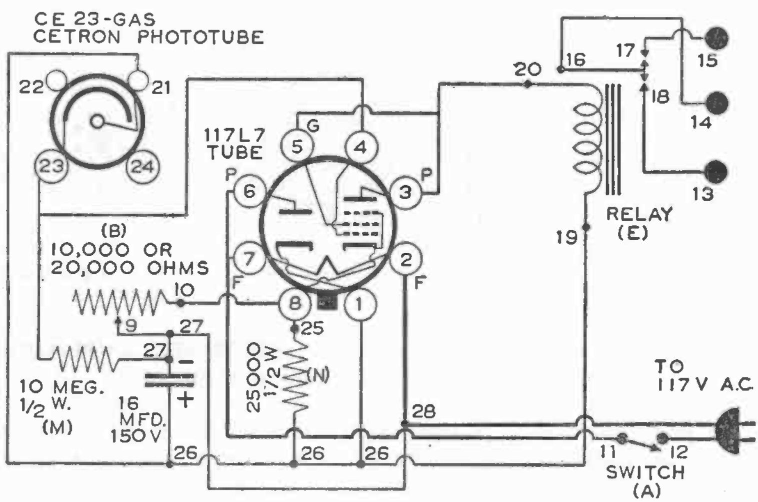
The letters in parentheses will aid in identifying the same parts in the circuit diagram and in the preceding illustration. The terminals can be identified with the terminals in the circuit diagram by the numerals.



cost more than the type of relay recommended in the list of components and their great sensitivity is not required for this project.

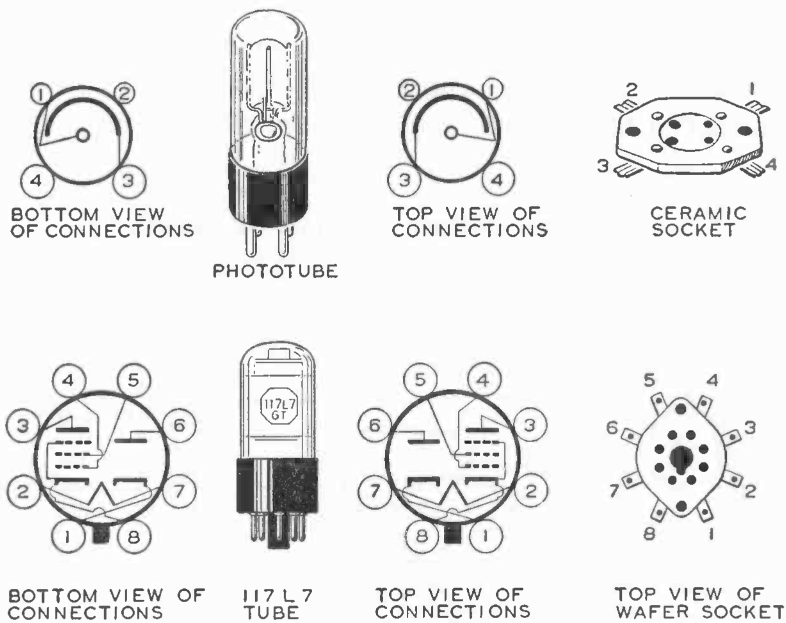
The Amplifier Tube. A 117L7/M7-GT tube is a combined half-wave rectifier and amplifier. A glance at the diagram will show it to be a diode and a pentode within the same glass envelope. The diode section together with a 16 mfd. electrolytic condenser rectify the 117-v alternating current, changing it into the direct current voltage required for the anode of the phototube and for the plate circuit of the amplifier. When electrons are emitted from the cathode of the phototube they are fed to the amplifier section of the tube. Their effect upon the grid produces a flow of current in the plate circuit which operates the relay. A

SCHEMATIC CIRCUIT DIAGRAM OF RELAY WITH CETRON CE23C PHOTOTUBE AND 117L7 AMPLIFIER AND RECTIFIER TUBE



117L7 tube operates directly from the 117-v AC power supply without any form of resistor in series.

Socket. It is not necessary to use a steatite socket for the phototube. Steatite is a low-loss porcelain-like insulating material used in the manufacture of sockets for transmitting tubes. A steatite socket is recommended because it is preferable to a Bakelite or other plastic socket but a Bakelite or plastic socket will be satisfactory for a "home-made electric eye."



CETRON CE23 PHOTOTUBE AND 117L7 COMBINED AMPLIFIER AND HALF-WAVE RECTIFIER TUBE

The phototube requires a four-pin socket. The amplifier-rectifier tube requires an octal socket. Consult the top view of connections when wiring socket.

Control. The 10,000- to 20,000-ohm, 2-watt, linear taper, wire-wound control specified in the list of components is a type of potentiometer carried in stock by television repairmen for replacement of defective television controls and should not be difficult to find.

Assembling. Smooth the wood base by sandpapering and shellacking all its surfaces. When the shellac has dried mount the sockets, relay, Bakelite tie-points and connectors in the locations shown on the plan. Each socket is raised above the base by two ¾-inch spacers so that the socket terminals do not touch the wood.

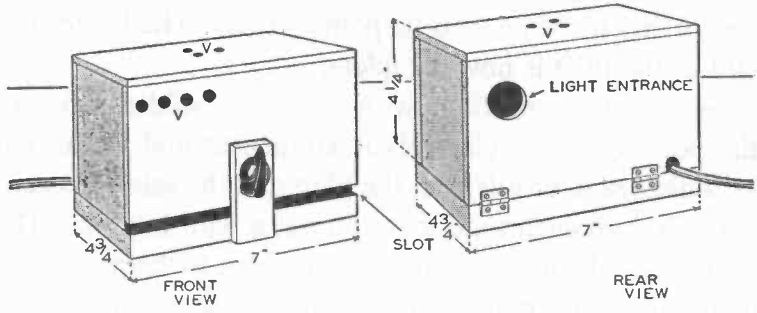
The control and switch is mounted on a metal bracket or on a 2⅝ in. x 1⅛ in. plywood strip attached to the front edge of the base at its center.

Begin wiring by tying the 117-v power cord (**G**) to the screw eye **F**. Connect one power wire to a Bakelite tie-point (**H**) 28 near the capacitor. Connect the other power wire to one terminal (**12**) of the switch (**A**). Next connect socket (**K**) terminal 7 to switch (**A**) terminal 11 and socket (**K**) terminal 2 to tie-point (**H**) 28. The heater circuit of the tube is now complete.

Solder all connections with rosin-core solder. Observe the polarity of the electrolytic condenser and connect it as indicated. Consult both the plan and the schematic circuit diagram each time that you put a wire in place. The wiring should not be difficult. In order to help you, all components are marked in the illustrations with an identifying letter in parenthesis. The numerals identify the terminals. After the assembly and wiring is completed, check your work with the diagrams.

Adjustment and Operation. Set the control knob at about the halfway point between its limits of movement. Place the 117L7 tube in its socket but leave the phototube out of its socket temporarily. Allow about one-half minute for warm-up, then place the phototube in its socket. Darken the room or cover the phototube with a small cardboard tube or box. Make a hole about one inch in diameter in the box or tube and position it so that the hole is opposite the center of the concave side of the phototube cathode. Move the control knob back and forth very slowly until you find a point where the relay armature is drawn toward the coil but moves away from the coil if the knob is moved slightly in the opposite direction. Let the control rest at the point where the armature moves away from the coil.

When the phototube relay is used for some practical purpose such as for an annunciator, it should be enclosed in a small cabinet. It can be adjusted to greater sensitivity when all non-essential light is excluded. One of the illustrations shows the details of a 7 inch x 4¾ inch x 4¼ inch



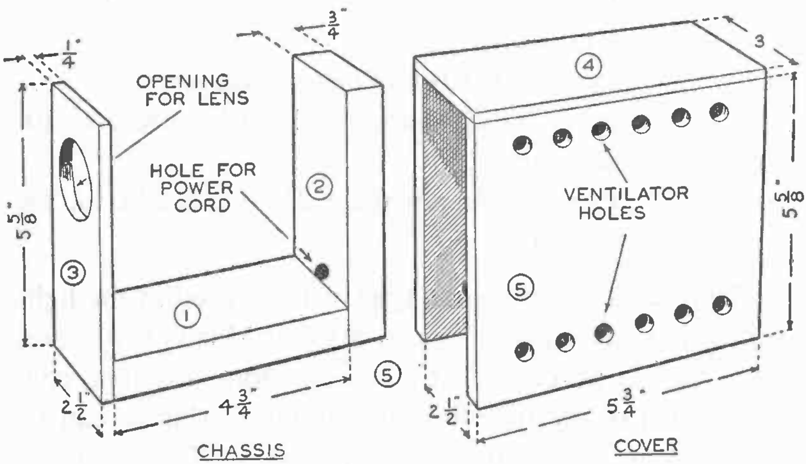
ENCLOSURE FOR PHOTOTUBE RELAY

The 5/16 in. diameter holes in the top and front of the enclosure (marked V) are for ventilation. The long slot along the lower edge of the front side of the enclosure is also for ventilation.

cabinet which can be fastened to the relay base with two small hinges. The light beam enters the cabinet through a 1 inch diameter round hole located exactly opposite the center of the concave side of the cathode. Three 5/16 in. holes are bored in the top of the cabinet directly over the 117 L7/M7-GT tube to let some of the warm air from the tube escape.

The Light Source. A match or a flashlight will test and demonstrate the action of the photo-relay. But if the relay is put into practical use, a source of steady light is required. Commercial light sources for photo-relays are fairly expensive. You can build your own at relatively low cost.

Two plans for light sources are illustrated and described. The one with cabinet is a more permanent arrangement than the other.

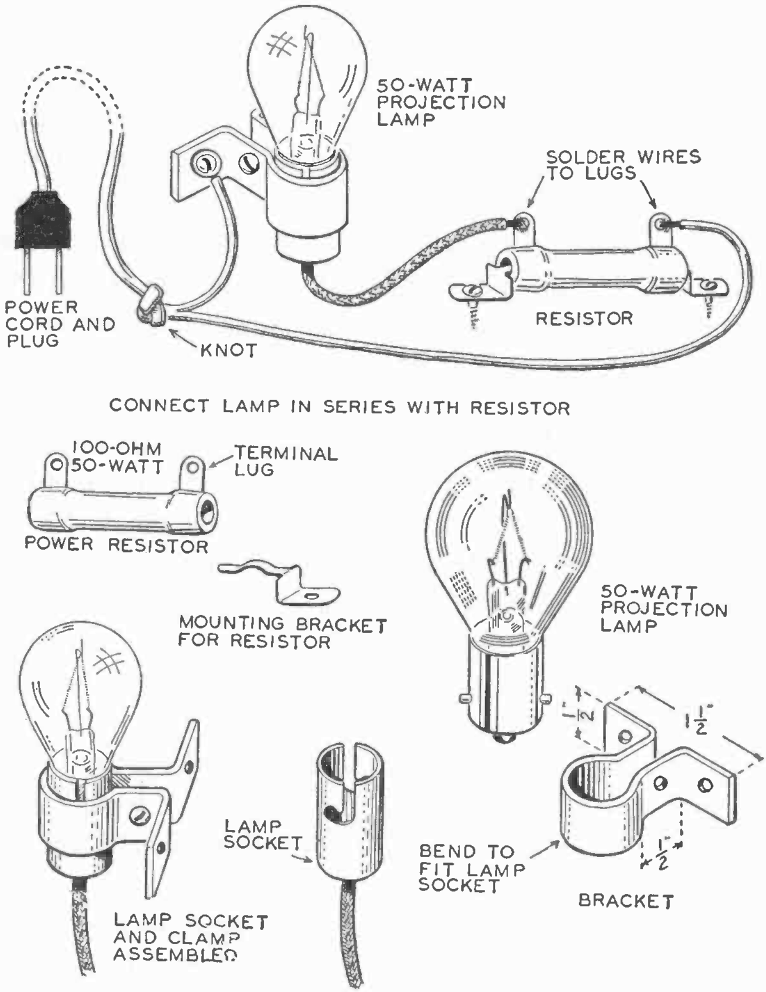


ENCLOSURE FOR LIGHT SOURCE

Materials and Parts Required for Building Light Source

1	Piece of pine 4¾ in. x 2½ in. x ¾ in. **(1)**
1	Piece of pine 5⅝ in. x 2½ in. x ¾ in. **(2)**
1	Piece of plywood 5⅝ in. x 2½ in. x ¼ in. **(3)**
1	Piece of plywood 5¾ in. x 3 in. x ¼ in. **(4)**
2	Pieces of plywood 5¾ in. x 5⅝ in. x ¼ in. **(5)**
1	Piece plywood 2⅜ in. x 2⅜ in. x ¼ in. with 1½ in. dia. hole in center **(6)**
1	115-125-volt, 50-watt, G. E. projection lamp with single contact bayonet candelabra base
1	100-ohm, 20-watt fixed wire wound power resistor with mounting brackets
1	Single-contact, candelabra-base lamp socket
1	Strip sheet metal 4¾ in. x ½ in. x approximately 1/32 in.
1	6 ft. length of lamp cord with attachment plug
1	Double convex lens, 1¾ in. diameter by 3 to 4 in. focal length
18	¾-in. No. 4 round head wood screws
1	½-in., 6-32, round head machine screw with hex nut
1	Piece bright tin plate 2¼ in. x 2¾ in. for reflector

A projection lamp is the type of lamp used as the light source in picture projectors. A 50-watt Mazda projection lamp can be purchased at a camera store. A single contact socket of the type used in automobile lamps can be obtained at an automobile supply store. Two or three dealers in surplus and chipped-edge lens advertise in the mechanical and handicraft magazines. They will supply a chipped-edge lens, approximately 1¾ inches in diameter and with 3 to 4-inch focal length at small cost. A 4-inch



PROJECTION LAMP, SOCKET, RESISTOR AND HOMEMADE BRACKET FOR LIGHT SOURCE

focal length is preferable. The bracket for holding the light socket to one end of the cabinet is home-made from the metal strip specified in the parts list. Aluminum is good material for this part. It can be bent into the required shape easily.

All wood parts should be given a coat of shellac or varnish to seal them against moisture. The three pieces marked (**1**), (**2**) and (**3**) in the parts list and illustrations are assembled first. The 1½-inch diameter hole in the end piece is centered 1½ inches down from the top edge. This hole should be cut with a fretsaw or jigsaw and the edge filed smooth. The 1½-inch diameter hole in part (**6**) is cut in the same manner. The lens is placed on the inside of the cabinet and clamped between (**3**) and (**6**) by four screws.

The clamp which holds the socket should be fastened to piece (**2**) with two screws and so located that when the lamp is in the socket, the center of the filament will be 3⅜ inches above the base. Make a small hole in each corner of the tin reflector and fasten it to piece (**2**) directly behind the lamp with four tacks.

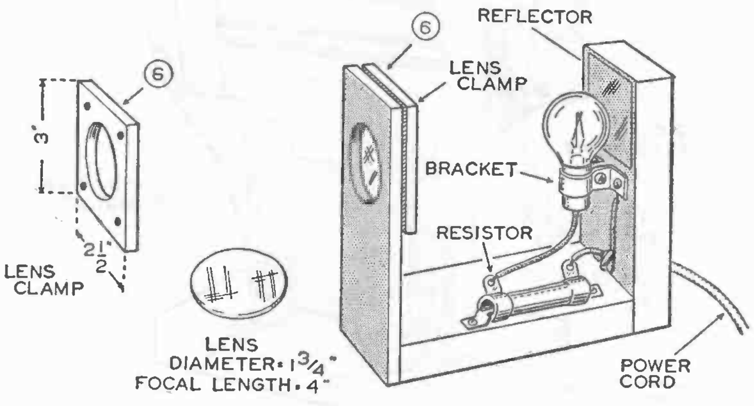
The free end of the lamp cord is passed through a ¼-inch hole in piece (**2**) and a knot is tied in the end so that it cannot slip back. The metal shell on the socket is one of its terminals. Connection can be made to it most easily by a wire under one of the screws which fastens the socket clamp.

Fasten the resistor to the base. Connect one of the power cord terminals to the socket bracket. Connect the other power cord terminal to one of the resistor terminals.

Connect the wire which comes out of the bottom of the socket to the other terminal of the resistor. This will connect the lamp and resistor in series.

The rows of ¼ inch holes near the top and bottom edges of the two side pieces (5) are necessary for ventilation. The 50-watt lamp and resistor generate considerable heat which must be dispersed. The top of the cabinet should be fastened to the two sides with glue and six or eight small brads.

One of the light sources illustrated in this book consists of a flashlight, transformer and power cord fastened to a wooden frame. The arrangement can be enclosed in a small cabinet if appearance is important. But if you wish to get a steady light source ready as quickly as possible, build it without a cabinet and save time.

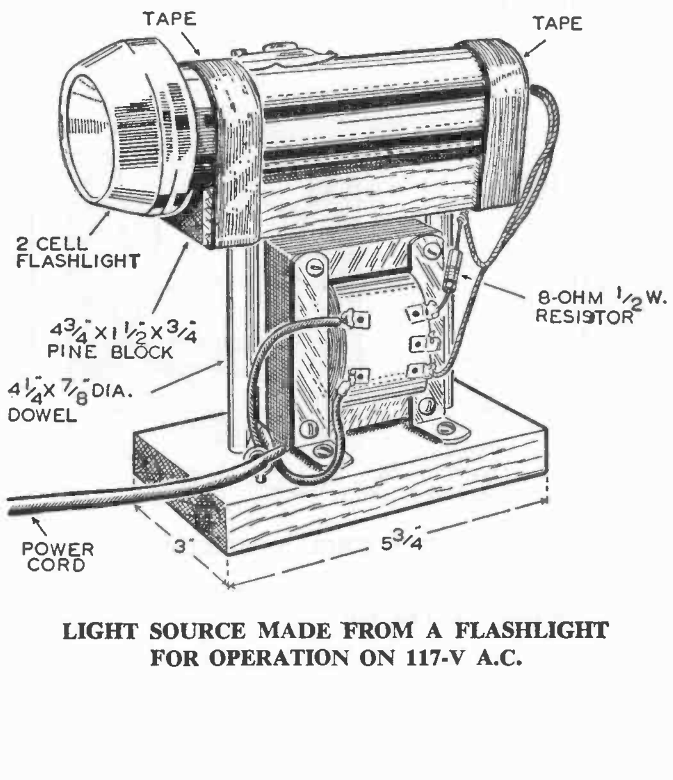


LIGHT SOURCE ASSEMBLY

This shows the light sources without its cover so that the assembly of the lens, socket and resistor can be seen.

The following parts and materials are required:

1 6 in. x 3 in. x ¾ in. wood base (**1**)
1 4¾ in. x 1½ in. x ¾ in. wood block (**2**)
2 Pieces ½ in. dowel rod 4½ in. long (**3**)
1 Piece of pine 1 in. x 1 in. x 4⅜ in. (**4**)
1 2-cell flashlight (**5**)
1 Small filament transformer with 6.3-volt secondary (**6**)
1 **6.2 volt miniature lamp with base to fit socket in flashlight (7)**
1 6 ft. power cord and plug (**8**)
1 Piece of thin brass or copper 2 in. x ¾ in. (**9**)
1 Small screweye (**10**)



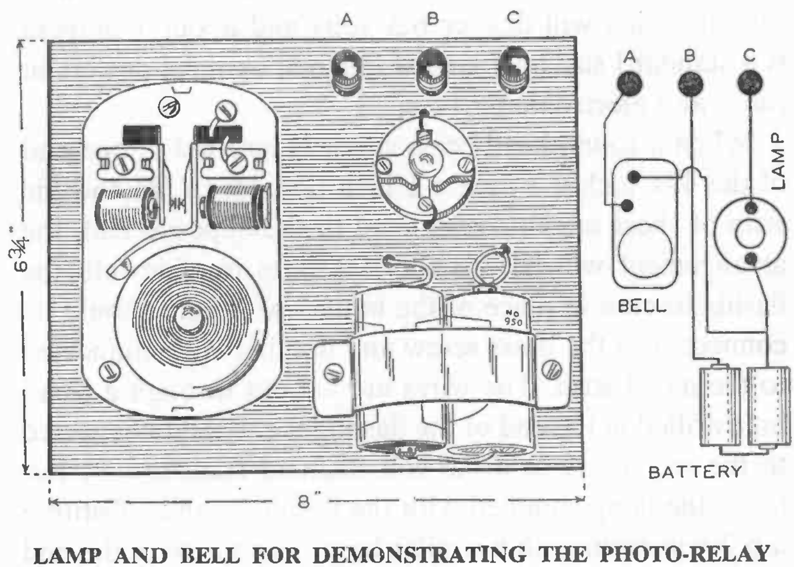
LIGHT SOURCE MADE FROM A FLASHLIGHT FOR OPERATION ON 117-V A.C.

1 2 ft. length of connecting wire
1 3 ft. length of friction tape
1 ¾-in. No. 6 round head brass wood screw

The flashlight should be a 2-cell spotlight or focussed type which throws a narrow concentrated beam. Flashlight batteries do not last long enough to use continuously so they are removed and the 117-v AC takes their place as a power source. The voltage is stepped down by a filament transformer. A filament transformer is used in many radio receivers and amplifiers to reduce 117-v AC to the proper value for the tube heaters. A small filament transformer which will deliver 6.3 volts and about 1 ampere is a standard size and carried in stock by most dealers in radio and electronic parts.

When a round head brass screw is inserted in one end of the 4⅜ inch x 1 inch x 1 inch pine block (**4**) and the strip of sheet metal (**9**) fastened to the opposite end, the arrangement will be just the right size to slide into the flashlight case in place of the batteries. A wire should be connected to the brass screw and another wire connected to the metal strip. The wires are led out through a small hole drilled in the end of the flashlight case and connected to the secondary of a 6.3-volt filament transformer. Remove the lamp supplied with the flashlight and substitute a 6.2-volt lamp with a similar base. The screw in the end of the block will make contact with the contact button on the bottom of the lamp base and the metal strip at the opposite end will make contact with the spiral spring in the end of the flashlight case. When the primary of the transformer is connected to the 117-v AC power supply, the switch on the flashlight case will still function and will turn the lamp on and off.

The flashlight is fastened to the framework of the light source by two bands of friction tape and can be removed at any time and restored to normal use by unwinding the tape and installing batteries and suitable lamp. The transformer is mounted on the wood base below the flashlight. The power cord connected to the primary of the transformer is tied to a small screweye in the base so that there will not be a strain on the connections if the cord is pulled.



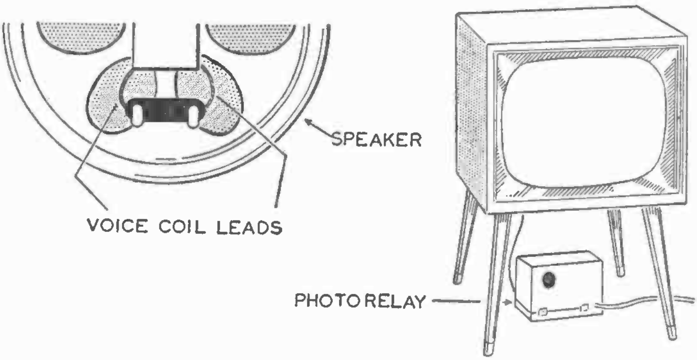
LAMP AND BELL FOR DEMONSTRATING THE PHOTO-RELAY

A bell, flashlight lamp and two size D flashlight cells mounted on an 8 in. x 6¾ in. wood base. The dry cells are connected in series and secured to the base by a clamp made from a sheet metal strip 5¼ in. x 1 in. The 2.5-V flashlight lamp screws into a miniature flat base porcelain receptacle. If binding post terminals **B** and **C** are connected to the relay, the lamp will light when the relay operates. If binding post terminals **A** and **B** are connected to the relay, the bell will ring when the relay operates.

The Phototube Relay which has just been described can be used as an annunciator. An annunciator is an electrically controlled signal or indicator which "makes an announcement." The small lights which flash on a telephone switchboard are annunciators. When one of the lamps is lighted, it is an announcement that someone is calling.

No one needs to touch a phototube annunciator to set it into operation. A light source and a phototube relay are

ELECTRONIC "BLABBER STOPPER"



You do not have to leave the comfort of your favorite chair to turn down the volume when you are tired of hearing too much blabber about toothpaste, razor blades, beer, shaving cream, etc. Connect a photoelectric relay so that it will open one of the voice-coil leads on the receiver speaker. Short-circuiting the voice coil may work equally well. To short the voice-coil connect terminal (13) on the photo-relay to one of the voice-coil terminals and terminal (14) to the other voice-coil terminal. To open the voice coil circuit cut one of the voice-coil leads near its terminal and connect the ends of the lead to terminals (14) and (15) on the photo-relay. The voice-coil leads and terminals are located on the back of the speaker as illustrated above.

Adjust the photo-relay so that it will close when you direct the beam of a flashlight at it or turn on a table lamp alongside your chair. When the light is extinguished the program will resume.

placed near a doorway and arranged to announce when anyone passes through the doorway. Anyone who enters or leaves will interrupt the light beam and operate the relay. The relay can be connected to a bell, buzzer, chimes or lamp.

CHAPTER THIRTEEN

Prospecting for Uranium

RADIOACTIVITY • GEIGERSCOPES • GEIGER COUNTERS
SCINTILLOMETERS • HOW TO MAKE A GEIGER COUNTER

Thousands of amateur prospectors have discovered valuable uranium deposits. Many have thereby become rich. Part time and vacation prospecting has sometimes brought large rewards. The U. S. Government is offering $10,000 plus up to $35,000 more in cash bonuses for the discovery of new rich uranium deposits. In the two years just prior to the time when this was written, the U. S. Government paid about four million dollars in bonuses for uranium discoveries. This sum does not include payment for the ore or for land leases. Strikes have been reported throughout the United States from Oregon to Maine and California to Florida.

Prospecting for uranium does not require a great deal of technical "know-how." Uranium reveals itself by its radioactivity. It is not a particularly rare element. It is more abundant than gold and silver. It is found in virtually every kind of rock and natural water but concentrated deposits of uranium are rare.

The search for uranium is not solely to obtain raw material for the manufacture of atomic weapons. There are other uses for this metal. It is a source of energy—a replacement for coal and oil. There are more than 1,000 industrial uses of uranium products. Of perhaps greatest importance are the medical applications of the radioactive uranium products called ISOTOPES. Their healing power may already have saved more lives than were destroyed by the atom bombs at Hiroshima and Nagasaki.

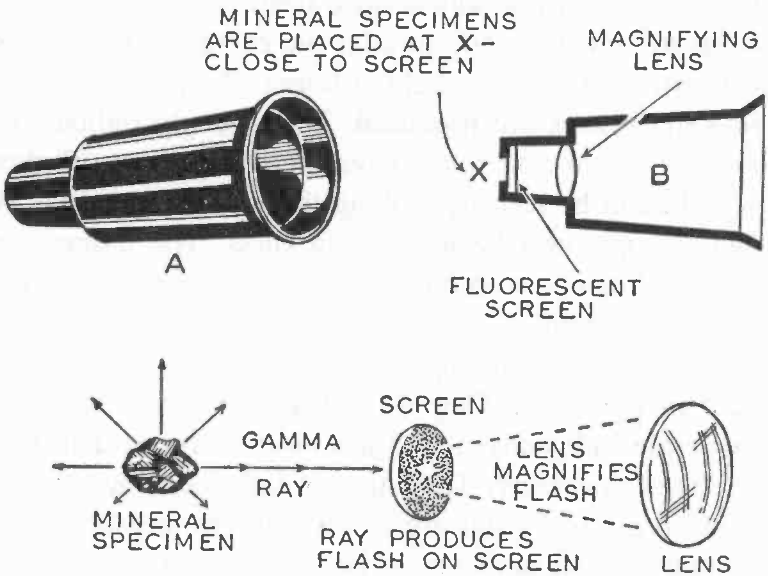
Radioactivity. Some elements continuously undergo a process of atomic disintegration in which energy is liberated. This process is called RADIOACTIVITY and while it is taking place one or more radiations known as particles and rays are spontaneously emitted. The three principal radiations have been named after the first three letters of the Greek alphabet: alpha-particles, beta-particles and gamma-rays. Radium, uranium and thorium and their products are radioactive substances. Their radioactivity cannot be seen, heard or felt directly but there are ways in which it can be revealed. There are several laboratory instruments for detecting radioactivity. Only three are practical to use for prospecting in the field. These are:

1. The Geigerscope
2. The Geiger-Muller Counter
3. The Scintillometer

The Geigerscope (also called a Scintilloscope) is an optical device. The Geiger counter and the scintillometer are electronic instruments. A description of the Geigerscope and the manner in which it operates makes it easier to understand an explanation of the scintillometer.

What is the Geigerscope? At first glance, a Geigerscope resembles the magnifying glass which a watchmaker uses, called a loupe. The body of the Geigerscope is made of black plastic and is funnel-shaped. At the small end is a magnifying lens and a PHOSPHOR screen.

The word *phosphor* comes from a Greek word meaning *light-carrier*. The name of the element phophorus is from



THE GEIGERSCOPE

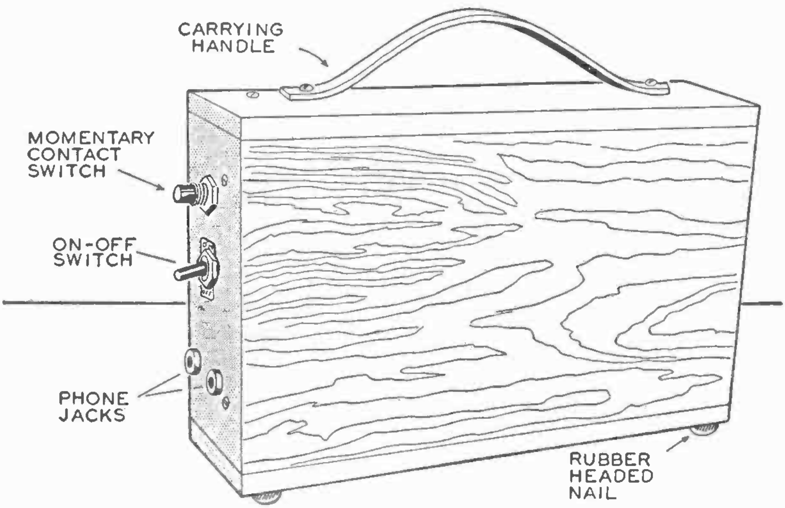
The screen of a Geigerscope is coated with zinc sulfide. When alpha rays from a radioactive material strike the screen, flashes of light known as scintillations are produced. The scintillations can be seen by looking through the eyepiece. (**B** is a section of the Geigerscope shown at **A.**)

the same word. Phophorus emits light when exposed to natural weathering. Many photoluminescent phosphors are employed in television tubes, radar tubes, in paints and inks, in fluorescent lighting and in instruments for detecting various radiations. Photoluminescent phosphors produce light at low temperatures. They absorb energy and then re-emit this energy in the form of visible light. The hands and numerals on a "radium" watch dial which glow in the dark are coated with a photoluminescent phosphor.

The screen of a Geigerscope also is coated with a photoluminescent phosphor, namely zinc sulfide powder. When the rays, known as alpha rays, from a radioactive material strike zinc sulfide powder the energy of the rays is converted into visible light. Flashes of light known as SCINTILLATIONS are produced. If a strongly radioactive mineral is held close to the screen of a Geigerscope, flashes of light can be seen by looking through the eyepiece. A Geigerscope must be used in darkness. The flashes are faint and can be seen only after the observer's eyes have become thoroughly adjusted to darkness. Geigerscopes are useful for examining specimens of ore which can be held in the hand. They do not always detect weak or moderate radioactivity and are most useful in detecting strong radioactivity. They are not influenced by the size of an ore sample and are of no value in measuring the amount of radioactive material in an ore sample.

The Geiger Counter. The Geiger-Muller counter, popularly called Geiger counter, was first devised in 1928 as a laboratory instrument for measurements of radioactivity. When the wide search for uranium ores began during World War II, the laboratory counter was developed into a rugged portable device which could be used by prospectors.

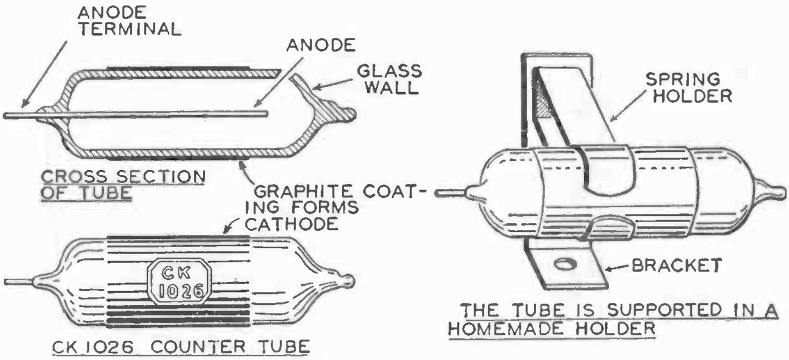
A portable Geiger counter resembles a small battery-operated radio in general appearance. It consists essentially of a Geiger-Muller tube (often spoken of as a G-M tube), a source of high voltage (700-1200 volts), an electronic amplifier and one or more transducers. The transducer provided with inexpensive counters is a telephone receiver or a set of earphones. The more expensive counters are provided with a meter and a neon tube in addition to the earphones. The equipment varies with model and price.



"GAMMA SNIFFER" OR HOMEMADE GEIGER COUNTER FOR DETECTING URANIUM ORES

The Geiger Counter Tube. The "heart" of a Geiger counter is the G-M tube. This may be a few inches long or several feet in length and be made of either glass or metal. In some counters the G-M tube is enclosed within the counter case. In others it is apart from the case but connected thereto by a cable. But all G-M counter tubes, regardless of size or form, operate in the same manner. They all consist of a metal or glass envelope and two electrodes, a cathode and an anode. The envelope is filled with one or more gases. Helium, argon, chlorine and Krypton are some of the gases used in G-M tubes.

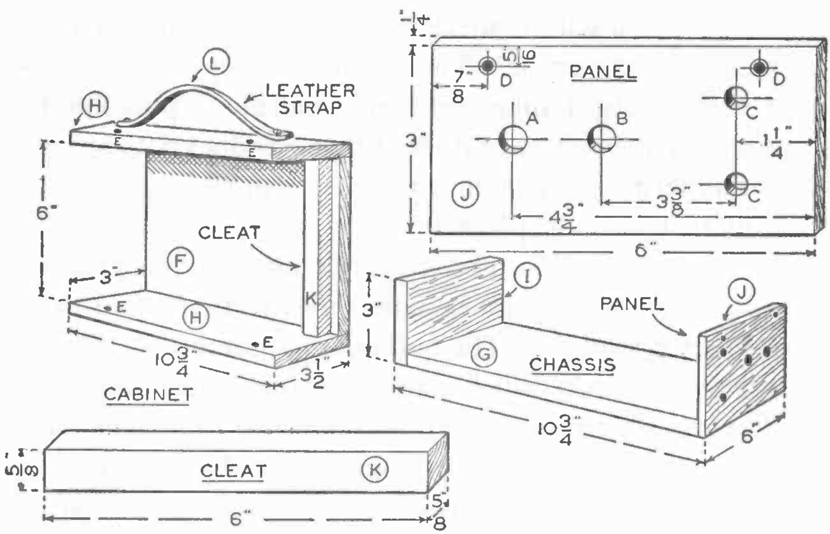
When a G-M tube is in operation a high voltage positive charge (500 to 1000 volts depending upon the tube) is applied to the anode. When thus charged, the tube is sensitive to radioactivity. Ores containing such radioactive elements as uranium and radium are radioactive and emit particles and rays. If a Geiger counter is brought



RAYTHEON TYPE CK1026 GEIGER-MULLER COUNTER TUBE

This is the sensitive, low-priced G-M tube used in the "Gamma Sniffer." The illustration shows also the homemade holder used to support the tube.

close to a radioactive ore a few rays (gamma rays) pass through the wall of the G-M tube and collide with molecules of the gas enclosed in the tube. The collisions knock electrons out of the molecules. The negative electrons are attracted to the positively charged anode and produce a negative electrical pulse each time that an electron collects on the anode. The anode is connected to the grid of an amplifier tube and each time an electron reaches the anode it is indicated by the transducer connected to the amplifier. If the transducer is an earphone it clicks each time an electron reaches the anode. If the transducer is a meter or a neon light it gives a visual signal. The number of clicks in the earphones or flashes in the neon tube which occur in a minute is called the "count" and is a measure of the radioactivity to which the tube is exposed.



DETAILS OF THE WOOD CABINET FOR THE GEIGER COUNTER

When the transducer is a properly calibrated meter the position of the pointer indicates the count.

The Scintillometer. This instrument, (also called a scintillation detector and a scintillation counter) like the Geiger counter was used originally only in laboratories. Portable models for uranium and thorium prospecting are now manufactured. A scintillometer is more than 200 times as sensitive to gamma rays as the most sensitive Geiger counter. It can be used for uranium prospecting from an airplane or a moving vehicle and for the detection of radioactive minerals located from a few feet to hundreds of feet from the instrument.

A scintillometer can be described as an "electrified Geigerscope." As in a Geigerscope the rays from a radioactive material strike a phosphor and produce light. The phosphor in a scintillometer is usually a thallium-activated sodium iodide crystal. The crystal is coupled to an ingenious electron tube commonly called a "photomultiplier." (The Institute of Radio Engineers does not approve of this term and recommends that MULTIPLIER PHOTOTUBE be used in its place.)

A multiplier phototube is a very sensitive type of phototube which is many times more sensitive than any of the ordinary phototubes. The multipler phototube has a light-sensitive cathode which emits electrons each time it is illuminated even by a faint flash invisible to human eyes. The multiplying action of the tube is produced by one or more electrodes called DYNODES. Through the action of the dynodes a single electron from the cathode can start an avalanche of electrons flowing and produce a considerable amount of plate current. Amplification of the order of 100,000 times is possible with this mechanism. A meter properly calibrated and connected to the scintillometer will indicate the percentage of uranium in samples of uranium ore.

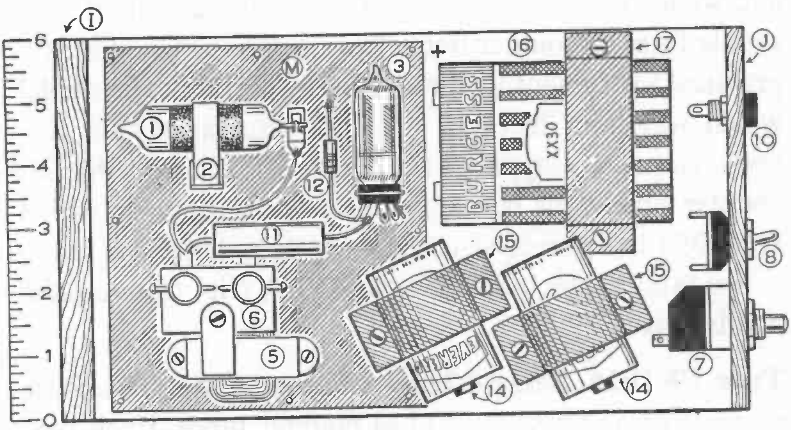
HOW TO BUILD THE "GAMMA SNIFFER," OR GEIGER COUNTER

The components of an efficient scintillometer cost more than two hundred dollars at retail and consequently are not within the means of the average amateur experimenter. On the other hand, the components of a simple Geiger counter cost less than fifteen dollars. The Geiger counter, nicknamed "The Gamma Sniffer," and described on the following pages, can be built for slightly less than fifteen dollars by anyone who can make a simple cabinet and solder the circuit wiring. The "Gamma Sniffer" is a simple form of counter but is extremely sensitive and is a practical instrument for uranium prospecting. The model which was built in order to make illustrations for this book employs a type CK1026 Raytheon Geiger-Muller counter tube. This is a low-priced tube (listed by Allied at $3.35) but proved sensitive enough to detect the radioactive fallout which reached New York City from atomic bomb tests in Utah.

Type CK1026 Geiger-Muller Counter Tube. There are several types and sizes of G-M counter tubes. Each type has its own characteristics. The Raytheon Type CK1026 is a low-cost glass envelope tube for use in detecting gamma radiation. It is commonly used in inexpensive prospector's units and demonstration units. The envelope is a sealed glass tube about 2 inches long and ¾ of an inch in diameter. The cathode is a band of colloidal graphite about one inch wide applied to the outside surface of the tube. Connection is made to the graphite band by a spring clamp. The anode is a straight wire which runs through the center of the tube and terminates at one end in a contact pin. A small Fahnestock spring contact clip is the best means of making connection to the pin which forms the anode terminal.

If not broken or mistreated, a CK1026 has a relatively unlimited life. It is not sensitive to light and therefore does not have to be enclosed in a light-tight box or shield.

The Chassis and Cabinet. Commercial Geiger counters



PLAN OF THE GAMMA SNIFFER

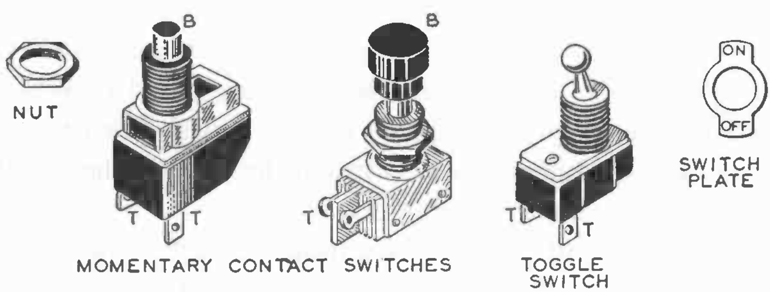
This illustration shows the arrangement of the parts on the chassis. The scale at the left can be used to locate their exact position. The letters and numerals correspond to those in the list of parts and can be used for identification.

are enclosed in a steel or aluminum case. A metal cabinet can be factory-produced in quantities at less cost than a well-finished wood cabinet. Another reason why metal cabinets are used is that a metal enclosure of sufficient thickness will shield the G-M tube from alpha particles and to a great extent from beta particles. The counter is thus made sensitive mainly to gamma rays.

Some readers of this book may not have the skill or tools required to make a metal cabinet but a wood cabinet is not difficult to make. Wood will permit the G-M tube to respond to all three forms of radioactivity. There is no objection to this.

Some commercial Geiger counters are very compact and the manufacturer features their small size. In designing the Geiger counter for this book, no attempt was made to reduce it to the smallest possible size. It is easier to assemble and wire than it would be if smaller.

The components of the counter are assembled on a wood chassis. When the cabinet is attached to the chassis all components are completely enclosed except those mounted on the panel. Plywood is used to make the



SWITCHES OF THE TYPES USED IN BUILDING THE SNIFFER

chassis and cabinet. Six pieces of plywood and one piece of pine cut to the following dimensions are required:

MATERIALS REQUIRED FOR BUILDING THE WOODEN CABINET AND CHASSIS

1	Piece of plywood 10¾ in. x 6 in. x ½ in (**F**)
1	Piece of plywood 10 in. x 6 in. x ½ in. (**G**)
2	Pieces of plywood 10¾ in. x 3½ in. x ½ in. (**H**)
1	Piece of plywood 6 in. x 3 in. x ½ in. (**I**)
1	Piece of plywood 6 in. x 3 in. x ¼ in. (**J**)
1	Piece of pine 6 in. x ⅝ in. x ⅝ in. (**K**)
4	Rubber head tacks
1	Piece leather strap 9 in. x ½ in. (**L**)
4	1-inch No. 6 flat head wood screws
2	⅜-inch No. 5 round head wood screws
1	Piece sheet metal 5 in. x 5¾ in. (**M**)
	⅞-in. brads and glue

The pieces marked **I, G** and **J** are assembled to make the chassis. The other four pieces form the cabinet. The 6 inch x 3 inch x ¼ inch piece (**J**), used as a panel, should be drilled as shown in the illustration before it is fastened to the chassis. The holes **A** and **B** are for the switches. The phone tip jacks are inserted in holes **C** and **C**. When the cabinet is put into place on the chassis, two wood screws in the holes **D** and **D** fasten the edge of the panel to the cleat (**K**) on the cabinet.

Use glue and ⅞-inch wire brads to fasten the wood parts together. When the glue has set, sandpaper all surfaces smooth and finish with two coats of shellac. Some sort of carrying handle should be attached to the top of the cabinet (**H**). A piece of leather strap (**L**) makes a good handle. The holes **E, E, E, E** are for the screws which hold the cabinet to the chassis.

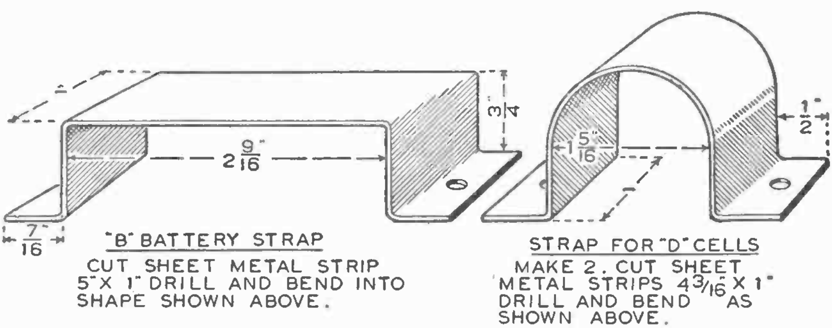
Cut a 5 inch x 5¾ inch rectangle from a piece of thin tinned or galvanized sheet iron. Use the point of an 8 d nail to punch a small hole through the plate at each corner and midway along each edge. Use ⅜-inch wire nails to fasten the plate to the chassis at the end opposite from the panel. (*See plan*). When the chassis has been assembled and the shellac or varnish finish is dry attach a rubber head tack at each corner on the underside.

COMPONENTS OF THE GEIGER-MULLER COUNTER CIRCUIT

All of these components, with the exception of the spark gap and tube holder are standard parts listed in many radio supply catalogs.

1 Type CK1026 Raytheon Geiger-Muller Counter Tube **(1)**

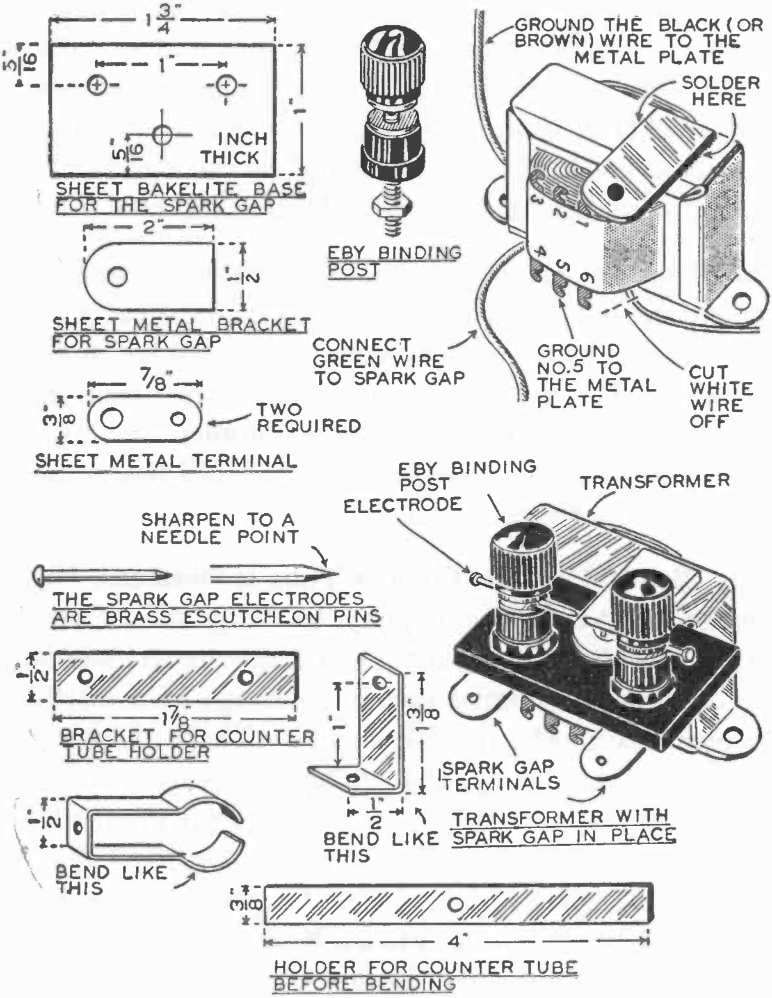
1 Homemade clamp for counter tube **(2)**



HOMEMADE CLAMPS FOR SECURING THE BATTERIES TO THE CHASSIS

1 Type 3S4 power pentode miniature radio tube (**3**)
1 Miniature bottom-mounting Bakelite tube socket for 3S4 tube (**4**)
1 Output transformer of the type used with 50L6 tubes in small radio receivers (**5**)
1 Homemade spark gap (**6**)
1 Momentary contact switch (**7**)
1 SPST toggle switch (**8**)
1 ON-OFF switch plate (**9**)
2 Phone tip jacks (**10**)
1 .05 mfd. 600 VDC by-pass capacitor (**11**)
1 10-megohm, ½ watt resistor (**12**)
1 Small Fahnestock Spring contact clip (**13**)
2 Size D 1.5 volt flashlight cells (**14**)
2 Homemade clamps for cells (**15**)
1 Type XX30 45-volt Burgess B battery with Snapon terminals (**16**)
The equivalent Eveready battery is No. 455 and the equivalent RCA battery is No. VS055
1 Homemade clamp for battery (**17**)
10 ⅜-inch No. 4 round head brass wood screws
1 2000-ohm radio headset

The Spark Gap. There is no small spark gap on the market and you must make this part of the counter. It consists of two pointed electrodes made from brass escutcheon pins 1 inch long. Escutcheon pins are round-headed nails obtainable at a hardware store. The pins are pointed at one end but the point is too blunt. It should be filed until it is as sharp as a needle. Each electrode is supported in an Eby binding post. Both binding posts are mounted on a hard rubber, Micarta, polystyrene or Bakelite base. Any thin plastic which will insulate high voltage



DETAILS OF THE SPARK GAP, BRACKET AND HOLDER FOR G-M TUBE

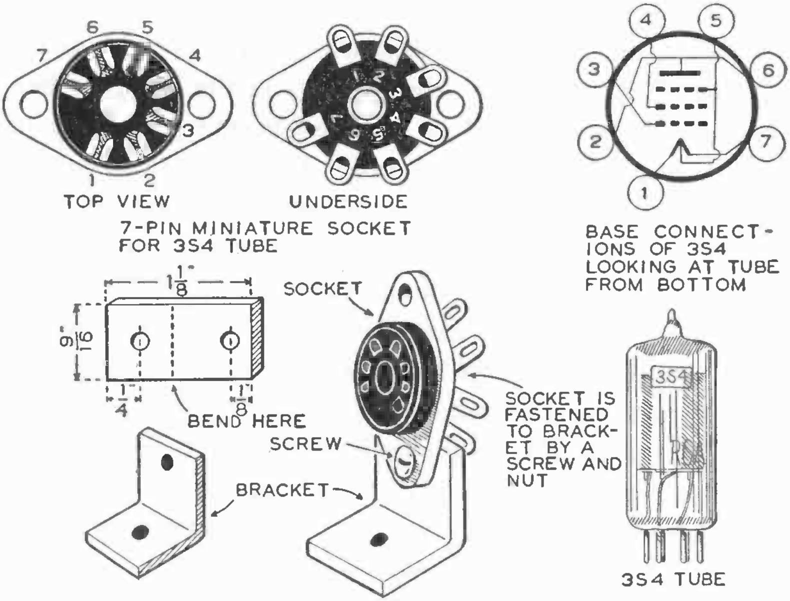
can be used. Bakelite and other plastics can be cut with a fine-tooth hacksaw. A piece 1 inch x 1¾ is required. It does not need to be more than ⅙ inch thick. Drill three holes in the plastic with a No. 28 drill. Locate the holes as shown in the illustration. Cut two terminals and a bracket out of sheet metal of the shape and size illustrated. One terminal is placed under each binding post. The bracket is clamped to the spark gap base with a short 6-32 machine screw and nut. The other end of the bracket is soldered to the top of the transformer.

The Tube Holder. This is another part which must be homemade. It consists of a 4 inch x ⅜ inch strip of spring sheet brass or bronze approximately .025 in. thick. A hole is drilled in the center of the strip and it is then bent into the shape of a pair of tongs (*see illustration*). The holder is clamped to a small homemade "L"-shaped bracket cut and bent out of sheet metal.

How High-Voltage for Counter Tube is Obtained. High voltage direct current is required to charge the anode of a Geiger-Muller counter tube. It will not operate without the charge. The normal operating-voltage of a CK1026 counter tube is 850 to 950 volts D.C. There are several methods of producing high voltage direct current for counter tubes. All of them cost more than the method employed in "Gamma Sniffer." For example, the 300-volt dry batteries manufactured for Geiger counters cost about $8.00 each. At this price a battery with a terminal voltage of 900 volts costs $24.00.

The "Gamma Sniffer" employs a small transformer, a spark gap, two size "D" Flashlight cells and a momentary contact switch. This same method is used in low-priced factory-built Geiger counters. Here is how it operates:

The small transformer is an OUTPUT transformer ordinarily used to couple the plate circuit of an audio amplifier tube to the voice coil of a loud speaker. The primary winding on an output transformer of this type contains a large number of turns of wire and the secondary contains comparatively few turns. When it is used to couple an amplifier tube to a loudspeaker it is a STEP-DOWN transformer. The voltage across the primary terminals is higher than the voltage across the secondary terminals. However, if the primary winding is used as a secondary winding and the secondary is used as a primary

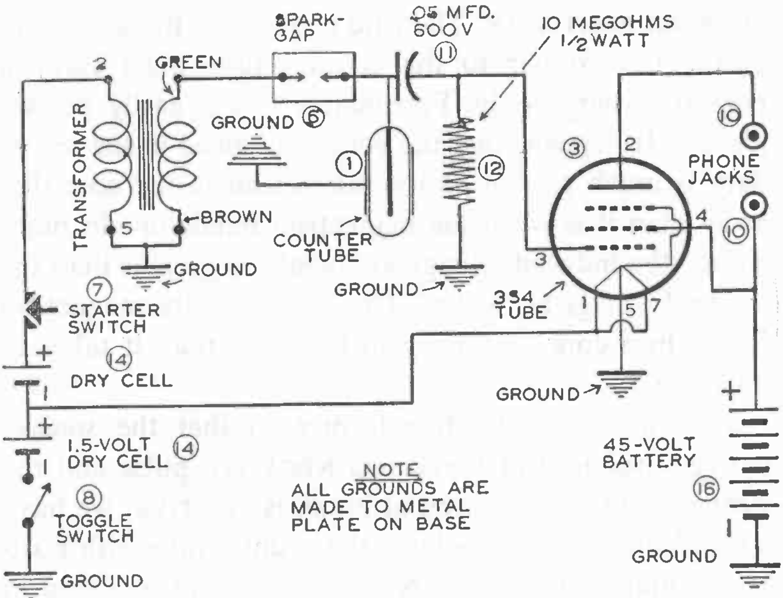


THE 3S4 AMPLIFIER TUBE, ITS SOCKET AND BRACKET FOR MOUNTING THE SOCKET ON CHASSIS

the transformer becomes a STEP-UP transformer and INCREASES voltage. It will raise the voltage of two flashlight cells (3 volts) to several hundred volts. An output transformer was not designed to produce high voltage for a Geiger counter tube but it serves this purpose quite well and is used because there are no small step-up transformers readily obtainable.

The transformer operates in the same manner as the ignition coil or spark coil in an automobile. When a direct current flows steadily through the primary winding there is no voltage induced in the secondary. It is only while a current BEGINS to flow and CEASES to flow through the primary that a voltage is induced in the secondary. The primary winding of an automobile ignition coil is connected in a circuit which includes a BREAKER. The breaker is an engine-operated switch which STARTS and STOPS current flowing through the primary at the instant when enough voltage should be induced in the secondary to produce a spark at a spark plug. The primary circuit of the transformer used in the "Gamma Sniffer" also includes a breaker to stop and start the current. In this instance the breaker is a hand-operated momentary contact switch. When the switch is pressed current from the two flashlight cells flows through the transformer to which it is connected. The instant the switch is pressed the current begins to flow in the winding but it takes time (a small fraction of a second) for the current flow to reach its full strength. It is only during the time that the current is increasing or decreasing in strength in the primary that a voltage is induced in the secondary. When the current reaches its full strength the voltage in the secondary disappears until the switch is released and the current in the primary winding is cut off. The current is not cut off instantly. It dies away gradually (in a very small fraction of a second) and while it is ceasing to flow a voltage is again induced in the secondary.

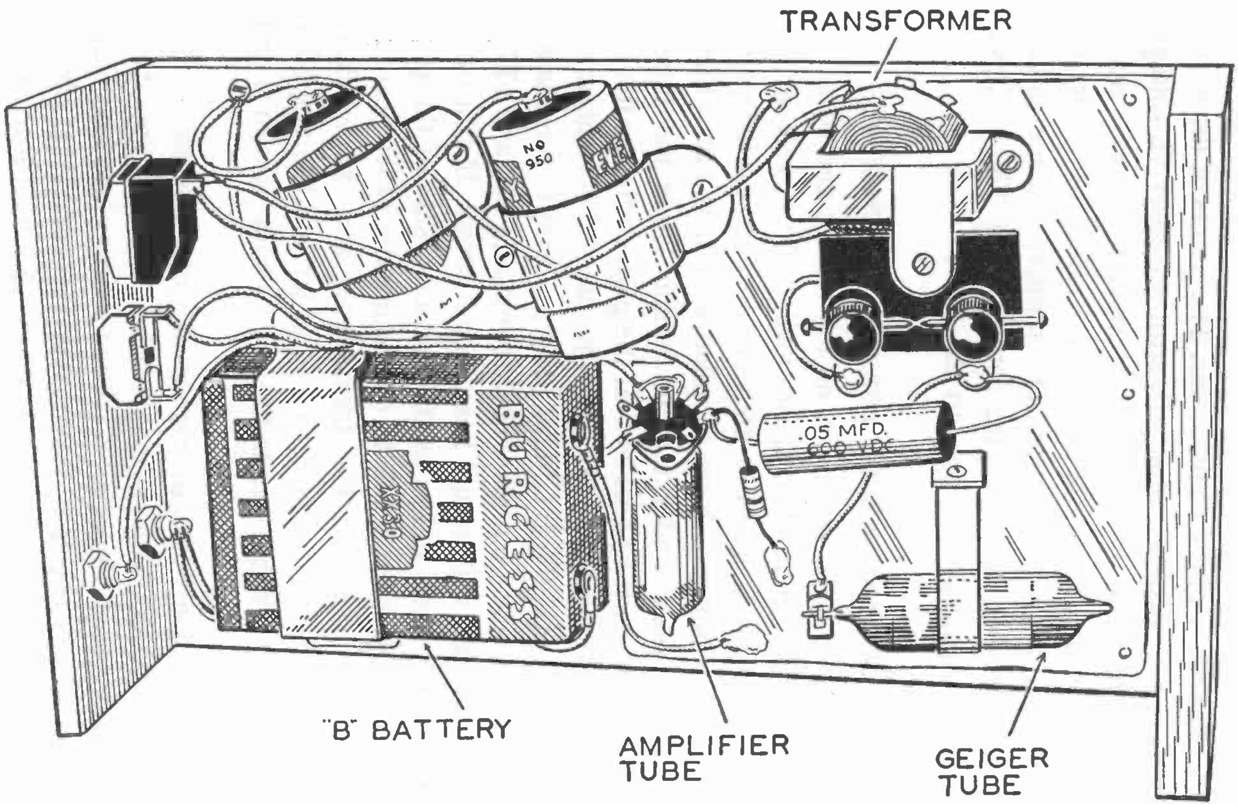
Electromagnetism is the agent which causes the current flow to increase gradually when the circuit is closed and to cease gradually when the circuit is opened. It is also electromagnetism which induces a voltage in the secondary. When current flows through the primary winding it builds up a magnetic field in the iron core of the transformer. In other words, current flowing through the primary winding magnetizes the iron core of the trans-



SCHEMATIC CIRCUIT DIAGRAM OF THE "GAMMA SNIFFER" former. The secondary winding is also wound around the iron core. When current begins to flow through the primary, a short space of time (fraction of a second) is required for the magnetism to reach its full strength. When current ceases to flow through the primary a fraction of a second is required for the magnetism to die away and disappear. It is during the short periods when the magnetism is either building up or dying away, in other words fluctuating, that a voltage is induced in the secondary.

When the magnetism is building up it produces a voltage in the secondary which is of opposite polarity to that produced when the magnetism is dying away. This imposes a small problem when the transformer is used to charge the anode of a counter tube. The anode MUST BE CHARGED POSITIVELY. The wire connecting the secondary of the transformer to the counter tube must carry a POSITIVE charge only. Fortunately this is easily accomplished. It happens that the voltage induced in the secondary is much greater as the magnetism in the core dies away than it is when the magnetism builds up. In other words, the induced voltage at "break" is greater than the induced voltage at "make." This is because the magnetism in the iron core dies away in less time than it takes to build up.

By connecting the transformer so that the weaker voltage produced at break is a NEGATIVE pulse and the stronger voltage produced at break is POSITIVE, we have a simple method of supplying the counter tube with POSITIVE voltage pulses only. A small spark gap is placed in the wire which connects the anode of the counter tube to

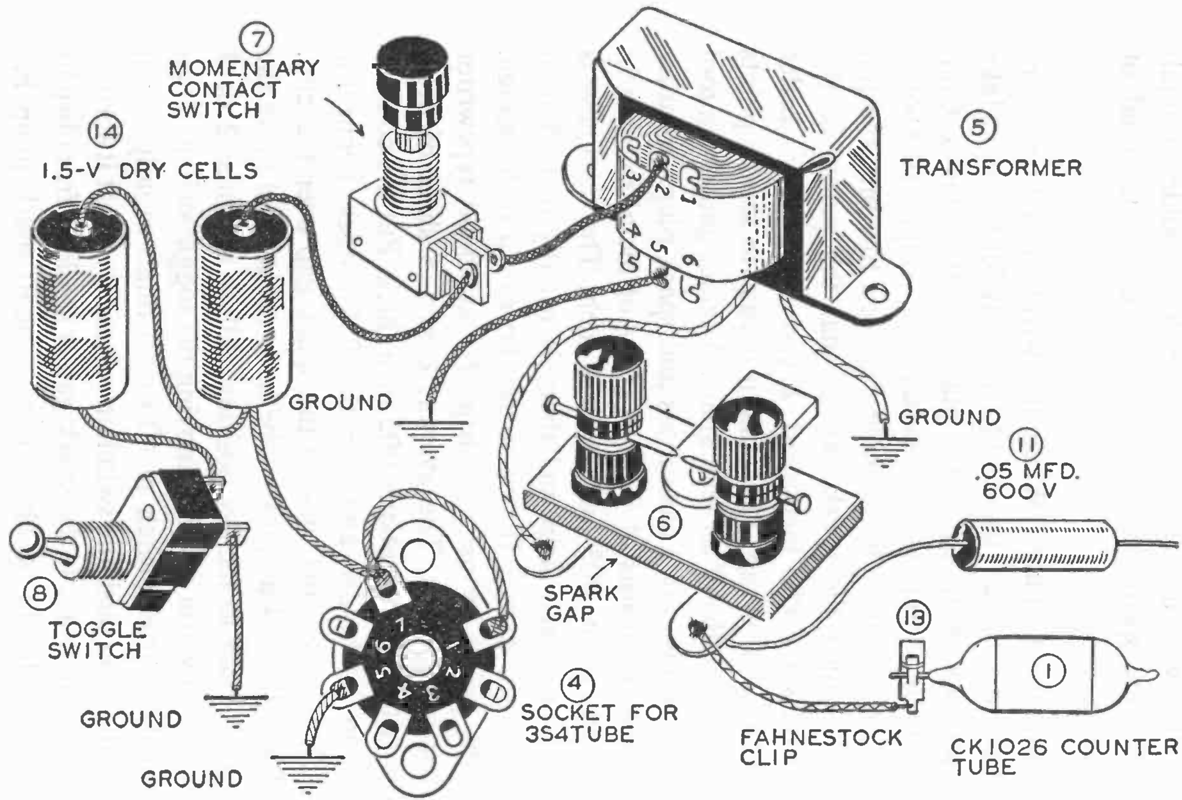


THE ASSEMBLED AND WIRED CHASSIS OF THE GEIGER COUNTER the secondary of the transformer. The points of the spark gap are set a distance which the stronger POSITIVE voltage pulse can jump but which the weaker negative pulse cannot jump. Thus, the spark gap serves as a sort of electrical selector or valve. The positive voltage pulses pass through it and reach the counter tube. The negative voltage pulses do not pass to the tube.

ASSEMBLING AND WIRING THE "GAMMA-SNIFFER"

Assemble the components on the chassis and panel as shown in the plan. The starter switch **(7)**, toggle switch **(8)**, and pin jacks **(10)** are held in place on the panel by the hex nuts which are supplied with these parts. Place a switch plate under the nut which holds the toggle switch **(8)** to the panel so that the plate indicates the ON and OFF position of the switch. The two 1.5-volt flashlight cells **(14)** and the B battery **(16)** are held to the chassis by straps made from strips of sheet metal, **(15)** and **(17)**, and fastened with round head wood screws. If you trace the 6-inch scale shown at the left hand side of the plan you can use the tracing to determine the exact position of the components. The transformer and the brackets which support the counter tube holder and the amplifier tube socket are fastened to the chassis with ⅜-inch round head wood screws.

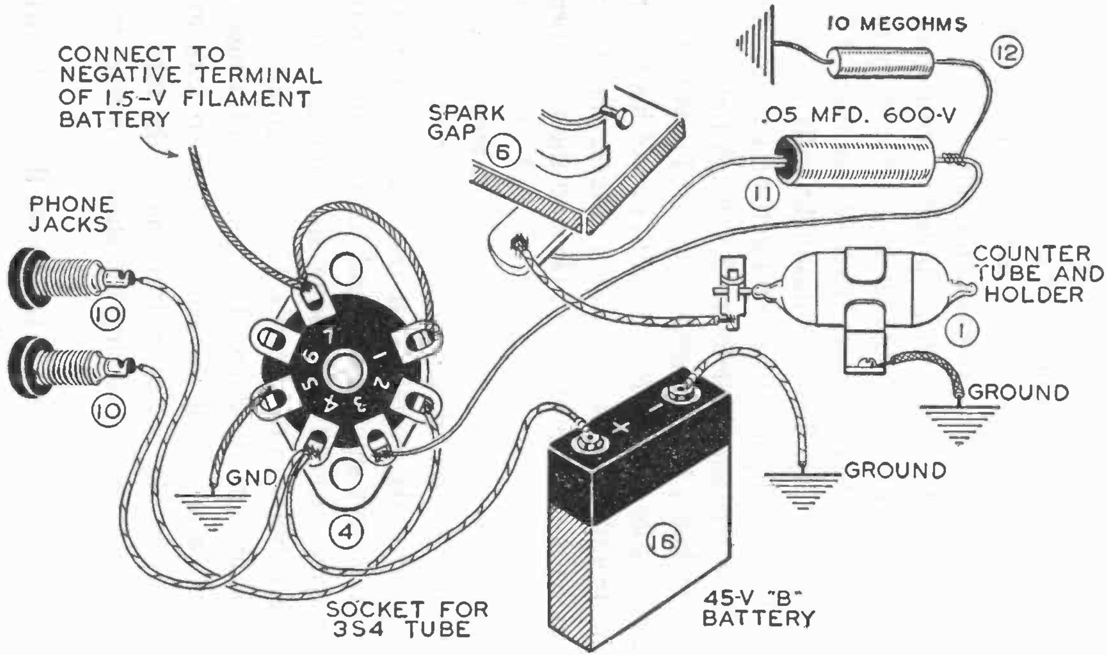
Use hook-up wire to connect the components. Solder all connections with rosin-core solder. Refer to the circuit diagrams each time that a wire is put in place and carefully double check to insure that the completed circuit is exactly like the diagrams. The wire which leads from one side of the spark gap to the counter tube should be



PICTORIAL DIAGRAM OF PART OF THE GEIGER COUNTER CIRCUIT a flexible wire and about 3 inches long. Solder a small Fahnestock spring connector to the anode terminal of the counter tube.

Testing the Counter. When the wiring has been completed and checked, the counter is ready for testing. Make the test before the cabinet is placed on the chassis. Connect a 2000-ohm radio headset or a single 1000-ohm telephone receiver by pushing the cord tips into the pin jacks. Adjust the spark gap so that the points of the electrodes are .005 inch apart. If you can borrow a feeler gauge from a garage mechanic it is easy to set the points five-thousandths of an inch apart. A feeler gauge is a tool used to adjust valve clearances and spark plugs on automobiles. It consists of 8 or 10 strips of metal ranging in thickness from .003 inch to .040 inch. The thickness is marked on each strip and there is usually a .005 inch strip on the gauge. If you cannot borrow a feeler gauge, set the points by using a strip of good bond typewriter paper as a gauge. The average common sheet of bond typewriter paper is about .005 inch thick. Put the counter tube in its holder and slip the Fahnestock connector which connects the tube to the spark gap over the clip.

Place the 3s4 amplifier tube in its socket and move the toggle switch to the ON position. Allow the tube 2 or 3 minutes to warm up after moving the toggle switch. Then push the starter switch in 40 or 50 times rapidly. Each time that you push the switch in release it so that it springs back all the way. If the spark gap is shielded from bright light you should be able to see a small spark jump between the points each time that the button on the switch is released. Bring a sample of radioactive mineral or the radium dial of a watch close to the counter tube and listen



PICTORIAL DIAGRAM OF PART OF THE GEIGER COUNTER CIRCUIT in the headphones. You should hear a loud rapid clicking in the earphones. Each one of the clicks is produced by a gamma ray from the radioactive mineral or radium dial which passes through the wall of the tube and knocks an electron out of a molecule of gas in the tube.

If you test the counter in accordance with these instructions and do not hear the clicks produced by radioactivity, you will have to start "trouble-shooting." Check the wiring carefully. Test the flashlight cells and the B battery. The flashlight cells should deliver 1.5 volts each and the B battery should deliver 45 volts. A radio service man will probably be sufficiently interested in your Geiger counter to make the test for you with one of his meters.

If the trouble cannot be located reverse the primary connections on the transformer. Ground the transformer terminal which was previously connected to the starter switch and connect to the starter switch the terminal which was previously grounded. The reason for making this change is to make certain that the counter tube is receiving a POSITIVE small charge and not a negative charge.

When you succeed in making the counter operate, fasten the cabinet to the chassis. Keep the counter away from moisture at all times. Dampness will cause the charge on the anode of the counter tube to leak away rapidly. It is usually necessary to recharge the tube every five or ten minutes by pressing the starter switch several times.

When the counter is not in use, move the toggle switch to OFF so that the battery current will not be wasted. In order for the counter to operate it is necessary for the 1.5-volt cells to be fresh.

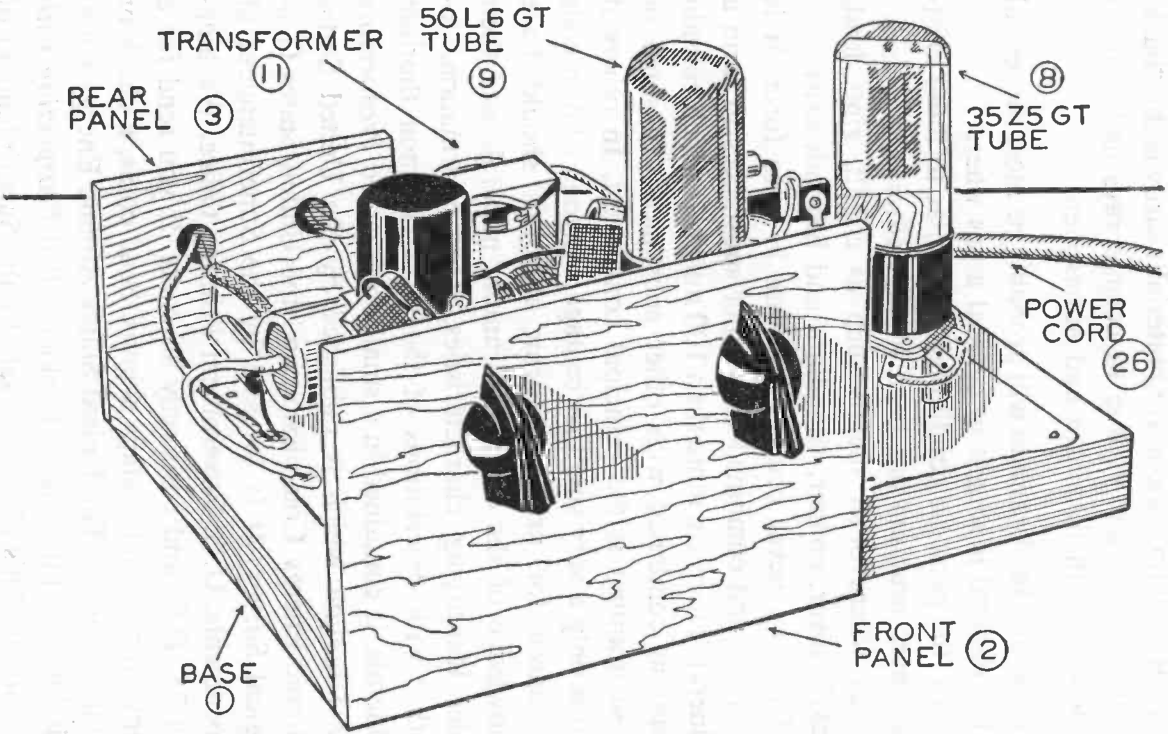
The clicks which occur a few seconds apart when there is apparently no radioactive material nearby is the "background" count and is due to cosmic rays and general radioactivity in the earth and atmosphere.

Prospecting for Uranium will probably be most successful if the mineral is sought in general areas where

(1) the geologic conditions are similar to those existing where uranium has been found before;

(2) where other metals such as cobalt, zinc, lead, nickel, silver, copper, vanadium and bismuth exist.

Uranium never occurs in nature in pure form. It is always found combined with other substances to form a mineral. There are more than 100 minerals which contain uranium combined with other substances. In some of these uranium is the principal constituent. In others it forms only a very small percentage. Anyone who intends to search for uranium-bearing minerals should have knowledge of the common uranium minerals and their chief identifying characteristics. This information, together with descriptions of the most common thorium minerals, is contained in a small book called *Prospecting for Uranium* which is published by the United States Atomic Energy Commission and the United States Geological Survey. It is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C. and costs only 45 cents. If you send for a copy do not send postage stamps. Send coins, a check or a money order. The United States Atomic Energy Commission also publishes a booklet called *Prospecting with a Counter*. This also is for sale by the Superintendent of Documents. The price is 30 cents. Both books are worth having if you are interested in radioactivity, uranium or counters.



FRONT VIEW OF TWO-STAGE AUDIO-AMPLIFIER

How to Build a Two-stage Audio Amplifier

This simple, low cost amplifier is not "hi-fi." Nevertheless it will provide good musical reproduction when connected to a record player with a crystal pickup. An amplifier which could be rated "hi-fi" costs more and is not so easy to build.

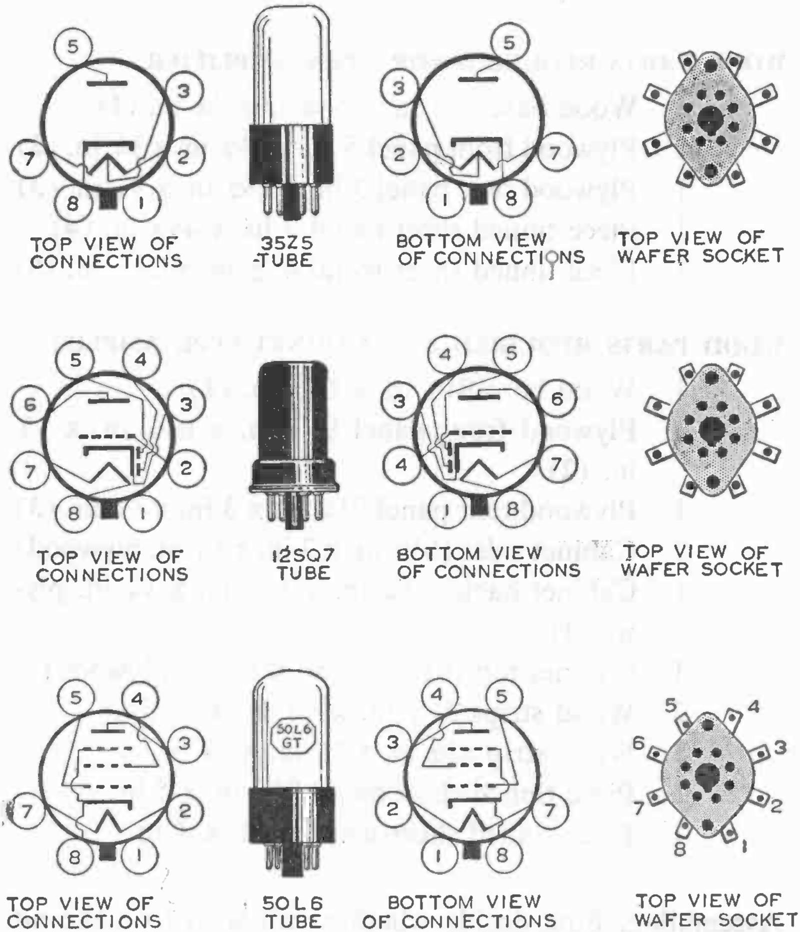
Resistance coupling is used between the amplifier stages and the pickup. An "on-off" switch and tone and volume controls are provided. The amplifier tubes are a 12SQ7 and a 50L6. Plate current is supplied by a 35Z5 half-wave rectifier. All three tubes fit standard octal sockets. 12SQ7 is a metal-envelope, multi-unit tube which contains two diodes and a triode. The triode portion only is used in this amplifier. The triode in a 12SQ7 has characteristics which adapt it for use in resistance coupled amplifiers. The 50L6 is a beam power pentode. In other words, it is a five-element screen grid tube designed for use in the output stage of low-powered amplifiers. 50L6 is frequently used in the output stage of broadcast receivers.

The amplifier is assembled on a wood base or chassis and can be of the open type or enclosed in a cabinet. The wood parts for the open and for the cabinet type are listed separately.

The components and materials required to build the two-stage audio amplifier are:

3	Octal wafer sockets **(6)**
6	Metal spacers ¾ in. long for supporting sockets **(7)**
1	35Z5 radio tube **(8)**
1	50L6 radio tube **(9)**
1	12SQ7 radio tube **(10)**
1	50L6 output transformer with tapped secondary **(11)**
1	1-megohm volume control with SPST switch and knob **(12)**
1	½-megohm volume control and knob **(13)**
1	Dual section 50-30 mfd., 150-volt electrolytic capacitor with common negative terminal **(14)**
1	.02 mfd., 600-volt tubular capacitor **(15)**
1	.004 mfd., 600-volt tubular capacitor **(16)**
2	.01 mfd., mica capacitors **(17)**
1	150-ohm, 10-watt wire wound resistor **(18)**
1	22,000-ohm, 1-watt carbon resistor **(19)**
2	0.47-megohm, ½-watt carbon resistors **(20)**
1	5-megohm, ½-watt carbon resistor **(22)**

2 3-terminal Bakelite tie-points (**23**)
2 Phono pin plugs and jacks (**24**)
1 117-volt plug-in receptacle (**25**). This part is optional.
1 6-ft. length of lamp cord with attachment plug (**26**)



THE TUBES FOR THE AMPLIFIER

Sandpaper, shellac, varnish, push-back wire, shielded phono wire, rosin-core solder, miscellaneous screws and wire brads.

All of the components in the above list are standard electronic parts which can be purchased from radio dealers who carry supplies for service men and amateurs.

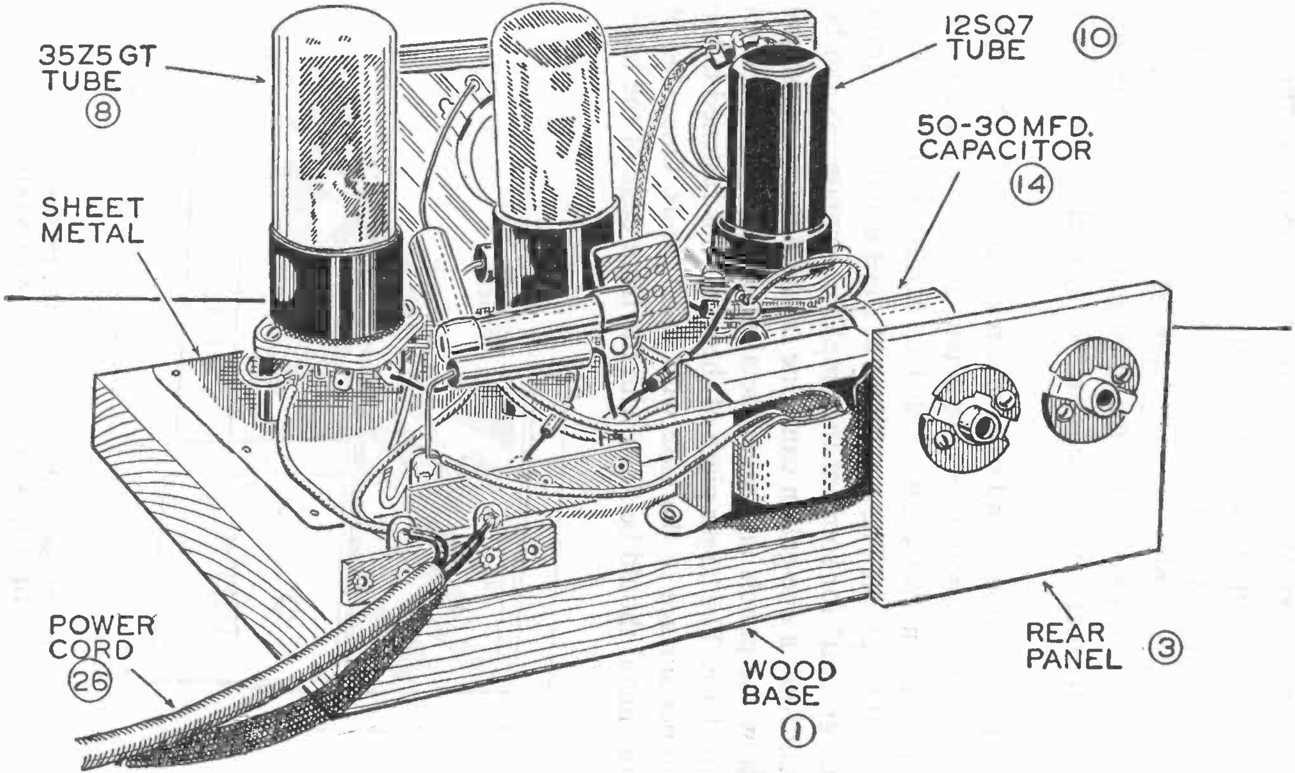
WOOD PARTS REQUIRED FOR OPEN AMPLIFIER

1 Wood base 8⅛ in. x 5¾ in x ¾ in. **(1)**
1 Plywood front panel 5 in. x 3½ in. x ¼ in. **(2)**
1 Plywood rear panel 3 in. x 2½ in. x ¼ in. **(3)**
1 Piece tinned sheet metal 7 in. x 4½ in. **(4)**
1 Piece tinned sheet metal 4½ in. x 2½ in. **(5)**

WOOD PARTS REQUIRED FOR CABINET-TYPE AMPLIFIER

1 Wood base 9¼ in. x 6½ in. **(1)**
1 Plywood front panel 9¼ in. x 6½ in. x ¼ in. **(2)**
1 Plywood rear panel 9¼ in. x 3 in. x ¼ in. **(3)**
2 Cabinet sides (6½ in. x 7 in. x ¼ in. plywood)
1 Cabinet back (9¼ in. x 3½ in. x ¼ in. plywood)
1 Cabinet top (9¼ x 7 in. x ¼ in. plywood)
2 Wood strips 5½ in. x ¾ in. x ⅜ in.
1 Wood strip 8½ in. x ¾ in. x ⅜ in.
1 Piece tinned sheet metal 8½ in. x 5 in.
1 Piece tinned sheet metal 5 in. x 4 in.

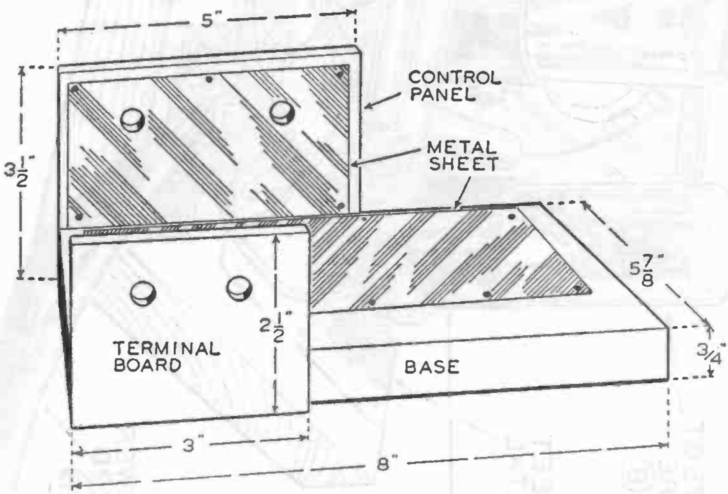
Assembling. First decide whether you wish to make an amplifier which is enclosed in its own cabinet or an am-



REAR VIEW OF THE AMPLIFIER

plifier without a cabinet. Then make the wood parts necessary. If you intend to build a record player and enclose the amplifier in the player cabinet it will not need a cabinet of its own. On the other hand, an amplifier for general experimental use is preferably enclosed in its own cabinet.

The wood base and front and rear panels of either type of amplifier should be completely dry and all their surfaces given two coats of shellac varnish to make them moisture-proof. The two pieces of sheet metal which form a "ground" for some of the amplifier components can be cut from a one-gallon can. One of the illustrations shows how the panels and sheet metal pieces are assembled on the base. The larger piece of sheet metal is fastened to the upper surface of the base with small brads. One edge of the metal should be flush with the front edge of the base.



THE CHASSIS UPON WHICH THE COMPONENTS OF THE AMPLIFIER ARE MOUNTED

The smaller metal piece is fastened to the back of the front panel (the panel which supports the tone and volume controls). The two pieces of sheet metal should be electrically connected to each other by soldering at several spots where the edges adjoin.

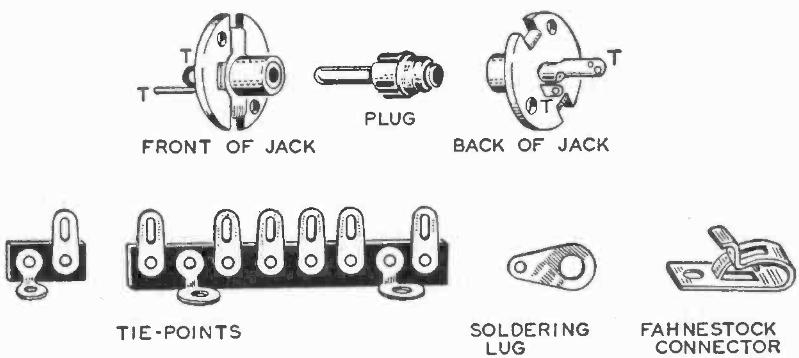
The location of the components on the base and panels can be determined from the plans. The sockets (**6**) are mounted with spacers so that the socket terminals are raised above the metal plate (**4**) and cannot come into contact with it. If the sockets are located exactly in the positions shown in the plans, the wiring will be easier to follow. The two Bakelite tie-points (**23**) are anchorages for the terminals of the power cord and several of the resistors and capacitors. The electrolytic capacitor (**14**) is fastened to the base by a round head wood screw which passes through the metal mounting strap which is supplied with the capacitor. The SPST switch (**12**) is mounted on the volume control (**12**) before the latter is put in place on the panel.

Wiring. When all the components which are fastened to the base and panel are in place, the amplifier is ready for wiring. Use push-back wire for making the connections, except the wire which connects the phono jack to the volume control. This should be a piece of shielded phono wire. Make all connecting wires as direct and as short as possible. Solder all connections with rosin-core solder. When the solder has cooled, test each connection by pulling on it.

Consult both the schematic circuit diagram and the plans. The wiring shown in the plans has been divided between two illustrations to make it clearer. One illustration, in which the wires are heavy black lines, shows the power wiring—in other words, the power supply to the heaters and the 35Z5 rectifier. The second plan shows the audio wiring.

Each resistor and each capacitor must be identified before it can be connected in the circuit. The capacity or resistance of some of these components may be printed on them. Others must be identified from the colors of their dots or bands. Make certain to connect the 50 mfd. section and the 30 mfd. section on the electrolytic capacitor exactly as shown in the illustrations.

The 50L6 output transformer **(11)** has six metal terminals connected to the secondary winding. They are numbered from 1 to 6. The No. 1 terminal should be connected to one of the terminals on the OUTPUT phono jack **(24)**.

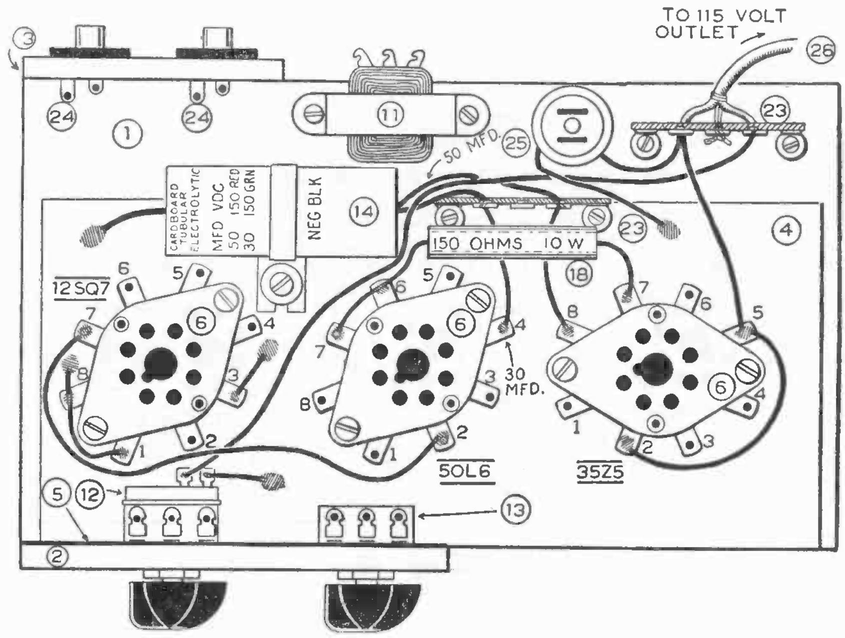


PHONOGRAPH JACK AND PLUG, TIE-POINTS, ETC., USED IN BUILDING THE AMPLIFIER

One of the tie-points illustrated above has six terminals. Only three are necessary on the tie-points used for the amplifier.

The other OUTPUT phono jack terminal should be connected to one of the other secondary terminals on the output transformer. The proper terminal is selected by testing when the amplifier is connected to a speaker and in operation. The terminal which gives the best tone is a "match" for the speaker and is the one which should be used.

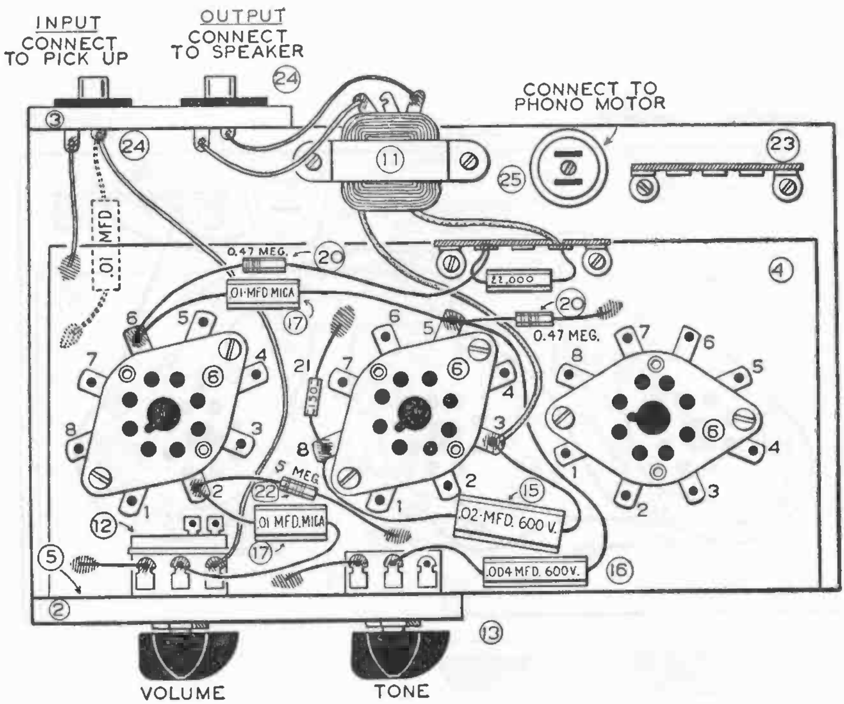
There are three terminal wires connected to the primary winding of the 50L6 output transformer. Only two are used in this amplifier. Usually one wire is dark brown, one is green and one is white. The white wire is a center



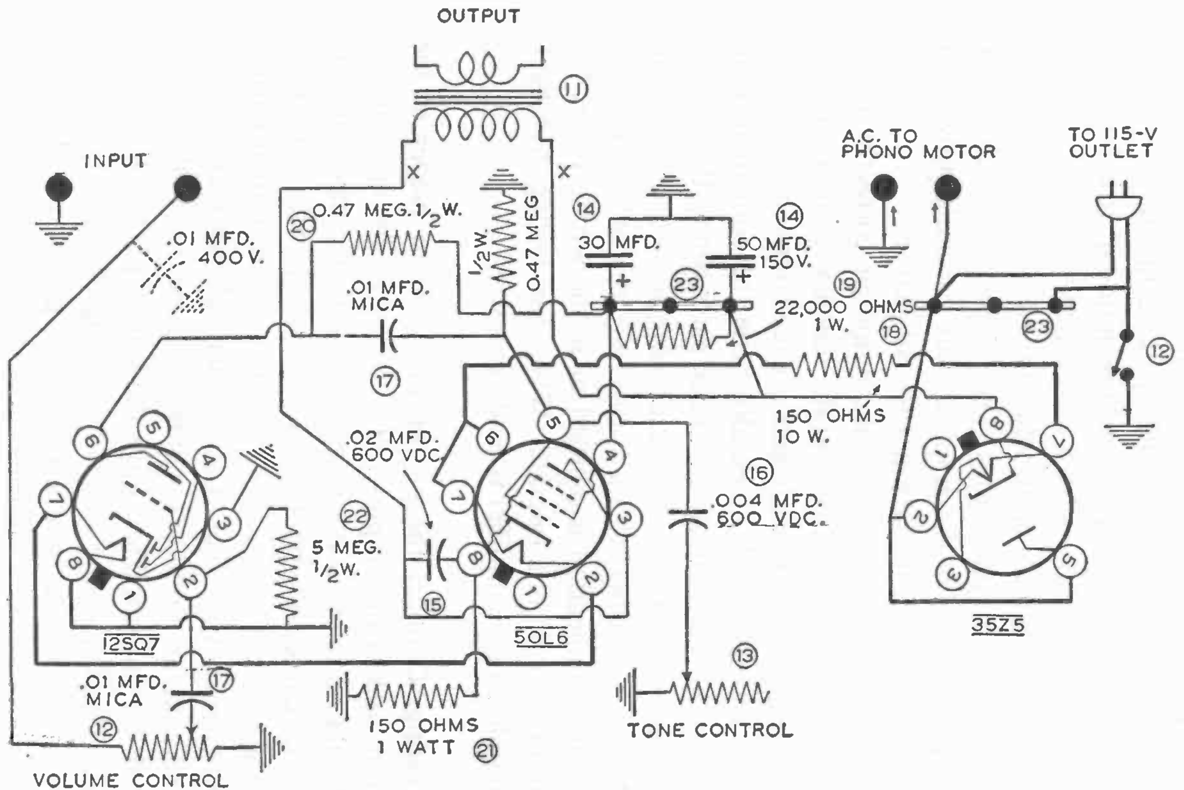
PLAN OF THE AMPLIFIER SHOWING THE POWER WIRING TO THE TUBE HEATERS AND PLATES

tap, that is, connected to the center of the primary winding. Use only the brown and green terminal wires. Connect one to the No. 3 terminal on the 50L6 tube socket. Connect the other to one of the terminals on the nearest Bakelite tie-point.

The outside terminal on the INPUT phono jack (24) is "grounded" by a short wire which connects it to the metal ground plate on the base. Remember to use a piece of shielded phono cable to connect the inner terminal of the INPUT phono jack to one of the outer terminals on the volume control. Use the wire conductor inside the cable



PLAN OF THE AMPLIFIER SHOWING THE WIRING OF THE AUDIO CIRCUIT



SCHEMATIC CIRCUIT DIAGRAM OF TWO-STAGE AUDIO AMPLIFIER

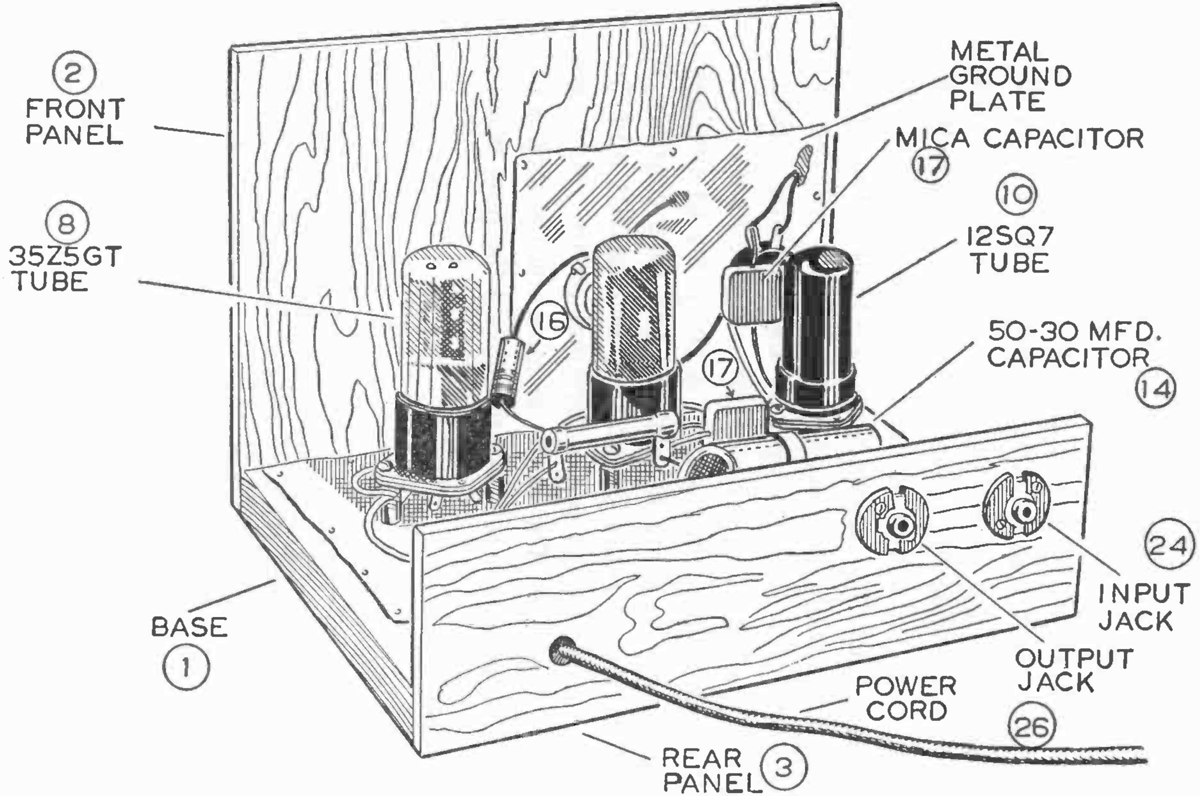
If the amplifier is to be connected to a speaker equipped with a matching transformer, omit transformer **(11)** and connect the two wires marked **X** directly to the output jack.

to make the connection. The shielding should be grounded by connecting it to the outer jack terminal.

The 117-v plug-in receptacle is optional. It is handy if you use the amplifier with a record player. It is connected to the two terminals on the Bakelite tie-point at which the power line cord terminates. The plug-in receptacle is not a necessary part of the amplifier but it usually provides a convenient place to plug-in a record player.

It is not difficult to wire the amplifier correctly if you follow the plan drawings and the schematic diagram carefully. Have a pencil ready and as each connection is made, make a small check mark alongside the equivalent connection in the illustration. Check each connection in this manner to insure that none are overlooked. After completing the wiring, check it carefully the second time. If a single connection is omitted or in the wrong place, the amplifier will not operate. When the wiring has been completed the amplifier is ready to test.

Testing. Connect the pickup on a record player to the input jack of the amplifier. The wire used for this purpose should be shielded phono pickup cable. Connect one end of the cable to a phono pin plug which will fit into the phono jack. Connect the output to a 4 to 6-inch permanent magnet speaker. Use shielded phono pickup cable and a phono pin plug to connect the speaker to the output jack on the amplifier. Push the power plug into a 117-v outlet and close the switch by turning the volume control. When the tubes have warmed up, put a record on the player and start it spinning. Put the pickup on the record. If all the connections have been made correctly you will



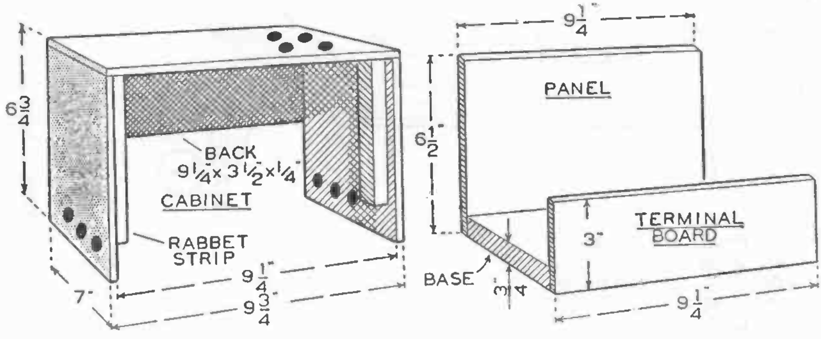
THE AMPLIFIER ON A CHASSIS WHICH CAN BE COMPLETELY ENCLOSED

Note that no matching transformer is shown. The transformer (**11**) is omitted when the speaker used is equipped with a transformer.

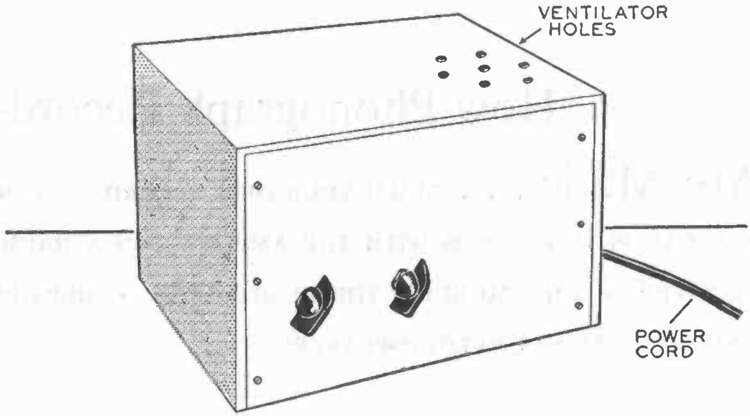
be rewarded with music from the speaker. Use the volume control and tone control to regulate the sound.

If the music of the record does not come forth from the speaker, check the connection to the speaker. If there is no fault there pull out the pin plug connected to the pickup. Connect a telephone receiver to the terminals of the pin plug while the record is playing. You should be able to hear the sound of the record in the receiver. If you cannot hear the record there is a fault in the pickup or the connection to it. A magnetic pickup will not produce enough volume to operate the amplifier satisfactorily. A pickup of the crystal type must be used.

If the amplifier operates but is noisy, try to eliminate the noise by adjusting the volume and tone controls. If this does not get rid of the noise connect a 0.01 mfd. by-pass capacitor to the center terminal on the input jack and to the ground. The center terminal on the jack is the one that makes contact with the pin on the plug when it



CABINET AND CHASSIS FOR AN ENCLOSED MODEL OF THE AMPLIFIER is shoved in place. This capacitor and its connection are shown by dotted lines in two of the drawings. Remember that noise can also be caused by a worn record, a worn stylus or a damaged pickup.



THE AMPLIFIER ENCLOSED IN A CABINET

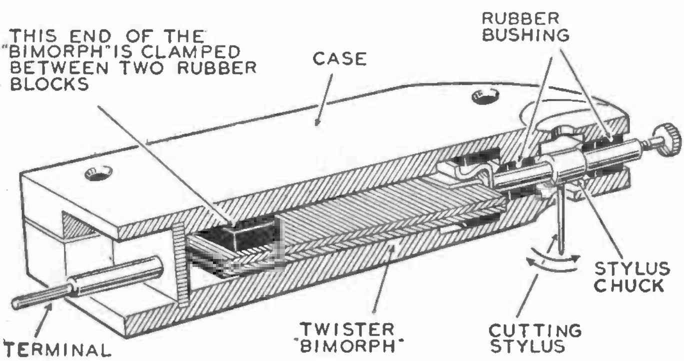
The volume and tone control knobs are on the front panel so that they can be adjusted without opening the cabinet.

How Phonograph Records Are Made . . . BUILD YOUR OWN RECORD PLAYER. YOU CAN PLAY RECORDS WITH THE AMPLIFIER IN A RADIO RECEIVER • HOW TO BUILD THE HUSH-A-TUNE • REPAIRS AND ADJUSTMENTS TO LOUDSPEAKERS

When Thomas A. Edison invented "a machine that could talk" it brought a new form of entertainment into the world. It provided so much pleasure and happiness that for several decades little attention was paid to its principal defect, namely, the quality of its sounds. The early phonographs were purely mechanical devices and were "squawk boxes" in comparison to the realistic sounding phonographs of today. For a long time there was only one way to engrave the original wax recording from which other records were to be made. It was a purely mechanical method in which the energy used to engrave the wax was the energy of sound. Therein lay the difficulty. Some sounds do not possess enough energy to cut a faithful recording in wax. No better method of making a recording was available until the electronic amplifier was invented.

Modern phonographs are electronic. The energy of electrons is added to the energy of sound in making an original recording. The energy of moving electrons also produces the sounds heard when a record is played.

The cartridge in a phonograph pickup is a tiny electrical generator. When the point of the stylus clamped in the cartridge follows the wavy groove in a record, the sideways motion of the stylus causes the cartridge to produce an electromotive force. This is fed into an audio amplifier which multiplies the electrons and gets enough of them in motion to operate a loudspeaker. The loudspeaker changes the energy of the electrons into sound waves. Modern records are first recorded on a magnetic tape.



THE CARTRIDGE IN A PHONOGRAPH PICKUP IS A TINY ELECTRICAL GENERATOR

This shows a pickup cartridge of the crystal type. Part of the case is shown cut away to reveal the crystal (called a "twister bimorph"). Any sideways movement of the stylus twists the crystal and produces an electromotive force. The case of the pickup is one terminal. The other is a brass pin insulated from the case.

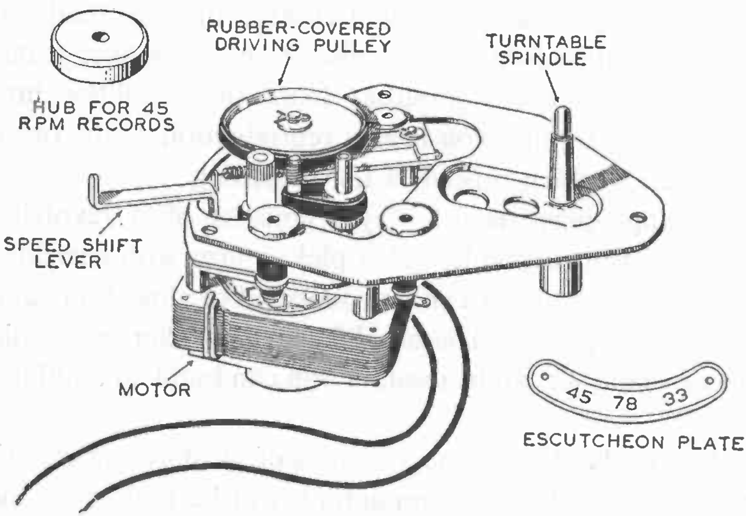
The first magnetic tape recorder was developed in Denmark about 1900 by Valdemar Poulsen. Incidentally, Poulsen made a great many important inventions in the field of wireless telegraphy and telephony. Poulsen's recorder, known as the Telegraphone, was sold and used for commercial purposes (dictation, etc.) in the ensuing years. The Telegraphone made its recordings on a small steel wire. When the Allies occupied Germany they found recorders which substituted a special tape for Poulsen's steel wire. The use of plastic tape, coated with a thin layer of fine particles of magnetic iron oxide, produced recordings far superior to those obtained with wire.

A tape recording can be played back without any loss of quality and artists can listen to the music immediately after it has been recorded. If no "bloopers" have occurred and the "master" tape is approved it is sent to the mold or stamper-making department. The sounds on the tape recording are transferred from the tape to a "master" disk record, via a cutting lathe. The cutting tool or stylus in the lathe is electrically operated. By means of an electronic amplifier it can be supplied with all the energy necessary to cut a faithful record in the wax.

When the original recording has been completed, the wax is plated with a thin layer of gold and copper. The thin metal shell thus formed is then stripped from the wax and backed with a solid metal plate. It has now become a "master record" used to produce a "mother." The "stompers" or molds for pressing a plastic into the records which are shipped to the music stores are made from the mother.

Assembling and installing record players, amplifiers, speakers, etc., to produce highly faithful facsimiles of the sounds which made an original recording is a widespread hobby. There are catalogs which list a great variety of components required for high fidelity sound systems. Most young experimenters must look at these with longing and realize that cost places them out of their reach.

There are also catalogs which list a great variety of popularly priced phonograph components. You do not have to win the Irish Sweepstakes before you can afford to build your own record player or phonograph. There are good phono motors priced at less than four dollars. You can buy a standard pickup and cartridge for less than the cost of a motor.



THREE-SPEED PHONOGRAPH MOTOR

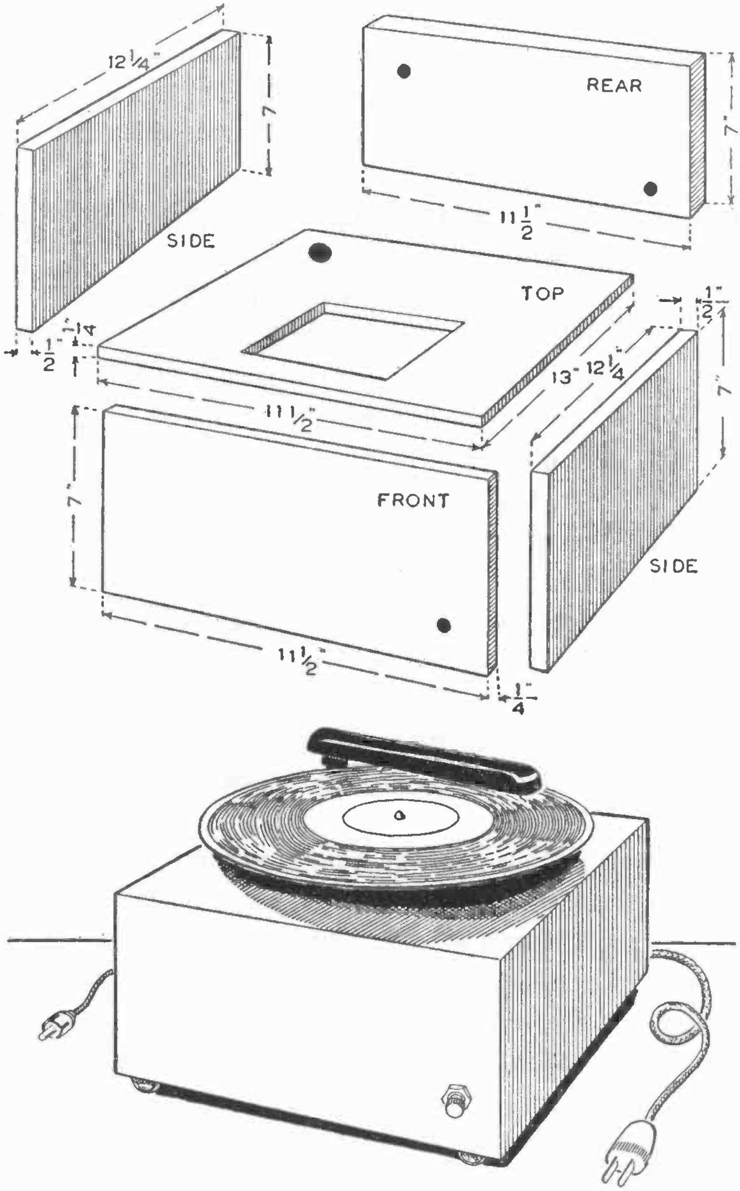
The escutcheon plate is fastened to the mounting board under the speed shift lever to indicate the position of the lever which will produce the desired speed of the turntable.

BUILD YOUR OWN RECORD PLAYER

The modern phonograph consists of a revolving motor-driven turntable, a pickup arm with cartridge and needle, an audioamplifier and a loudspeaker. The needle or stylus, whichever you prefer to call it, is mechanically connected to the cartridge. As the needle follows the wavy groove in the record (the groove on one side of an LP record is ½ mile long)it vibrates from side to side. At times it vibrates 10,000 times per second, which is 50 times faster than the beating of a humming bird's wings. The vibrations of the needle create small electrical impulses in the pickup cartridge. The electrical impulses are an exact electrical replica of the sound vibrations which made the original recording. The electrical impulses are fed into an amplifier. Here they are given additional energy. A good amplifier will enlarge the electrical impulses a millionfold without distortion. A speaker translates the magnified impulses from the amplifier into sound. The result—you hear a reproduction of the original sounds which produced the recording.

A single-play record player consists of a revolving motor-driven turntable and a pickup arm with cartridge and needle. A player can be connected to almost any amplifier and speaker. The amplifier and speaker in a radio or television set can be used, or you can build an amplifier for it.

It is probable that the activities of most young experimenters in building a phonograph will be limited by the cost of the components. Why not start by building a single-play record player? It can be transformed into a complete phonograph later if you desire. When you have



THE HOMEMADE RECORD PLAYER
AND DETAILS OF THE CABINET

the first essential, namely a player, you can spend most of your time and money in building a "hi-fi" amplifier for it. Later, you may wish to replace the single-play player with a player which automatically changes records.

The following parts and materials are required for building the record player:

1	Phonograph motor with 9-inch turntable
1	Pickup arm with crystal cartridge to match speed of turntable (*see text*)
1	6 ft. length attachment cord and plug
2	Phono pin plugs and jacks
1	3 ft. length shielded phono cable
1	Piece plywood 13 in. x 11½ in. x ¼ in. (top)
1	Piece plywood 11½ in. x 7 in. x ¼ in. (front)
1	Piece plywood 11½ in. x 7 in. x ½ in. (back)
2	Pieces plywood 12¼ in. x 7 in. x ½ in. (sides)
4	Rubber head nails
1	Single-pole rotary fixture switch
	Shellac, stain, varnish, screws and brads

The Motor. Before you buy a phono motor you must decide whether you wish to build a player for 33⅓, 45, or 78 RPM records or a 4-speed player which will reproduce the new 16 RPM "talking book" records. Low-priced motors usually come equipped with a 9-inch turntable. All sizes of records up to and including 12-inch records can be played on a 9-inch turntable.

A full-size printed diagram, called a mounting template, is usually packed with each motor. This pattern shows the size and shape of the holes which must be cut in the motor board to accommodate the motor. When you buy a motor, get a template for it.

The Pickup. The pickup which you use in building your record player should match the motor. If you decide upon a 78 RPM motor the pickup should be one made for 78 RPM records. If you have a three-speed motor, buy a pickup which will play the standard 78 RPM records and also the microgroove long-playing records (33⅓ and 45 RPM). Some models of three-speed pickups are called "turnover pickups" and are provided with a knob for turning the cartridge to either the long-playing or the standard 78 RPM position. A turnover pickup is fitted with two needles. The needle for 78 RPM records is larger in diameter than the needle used for long-playing records.

Choose a pickup with a crystal cartridge, not a magnetic cartridge. The latter requires a pre-amplifier in addition to the regular amplifier. Pickup arms and cartridges vary greatly in price. A cartridge capable of responding to a wide range of sound frequencies is most desirable but frequency range largely determines the price. A cartridge having a frequency range of 40 to 10,0000 cps will pick up recorded sounds ranging in pitch from 40 to 10,000 cycles per second. The player which you are building in this instance is not a high fidelity instrument. The speaker and amplifier do not have a frequency range of 40 to 10,000 cps. A pickup with a cartridge having a frequency range of 50-4,000 costs less than one with a wider range and will prove satisfactory for this player.

The Cabinet. This part of the player is not difficult to make. It is merely a box and a box is considered to be one of the simplest woodworking projects. The only skill necessary is that required to saw straight and accurately. It is for you to decide how carefully you wish to make the cabinet and how well you wish to finish it. The player will operate as well if the cabinet is unfinished lumber as it will if the cabinet is polished mahogany.

The cabinet for the model which was built for this book was made entirely of plywood. It was smoothed with fine sandpaper, then given a coat of light maple stain, a coat of white shellac and a coat of varnish. The shellac coat was rubbed with fine steel wool before the varnish was applied. It has been much admired.

It is not necessary to use plywood but it is difficult to find thin lumber which can be substituted for plywood. It is advisable to make the front of the cabinet and the motorboard of plywood. The motorboard is the flat top that supports the motor and pickup. These parts are only ¼-inch thick and solid lumber of that thickness would not be strong and rigid enough. The sides and back can be ½ to ¾-inch pine or any other wood.

If you do not have woodworking tools, perhaps you can make the cabinet in your school workshop. The secret of making a neat cabinet is to cut the parts accurately and smoothly. Sawing plywood often leaves a rough edge but it can be cut smoothly. It can be cut by hand satisfactorily by using a sharp fine-toothed saw. Lay the plywood on a piece of thin scrap lumber and cut through both pieces. This will prevent splintering the underside of the plywood. If a power circular saw is used, the saw blade should be one made for cutting plywood.

The location, size and shape of the holes in the motorboard depend upon the motor and pickup which is used. Use the templates which come with the motor and pickup to locate the holes. Cut the large motor hole with a power jig saw or a hand fret saw.

Use a piece of paper the same size as the top of the cabinet to make a pattern. Lay the templates for the pickup and motor on the pattern and move them into position so that:

1. When the pickup arm is swung from side to side, a needle in the pickup would move in an arc which passes through the center of the turntable.

2. The distance from the left hand edge of the cabinet top to the center of the turntable equals the distance from the right hand edge.

3. The center of the turntable will be 6 inches from the front edge.

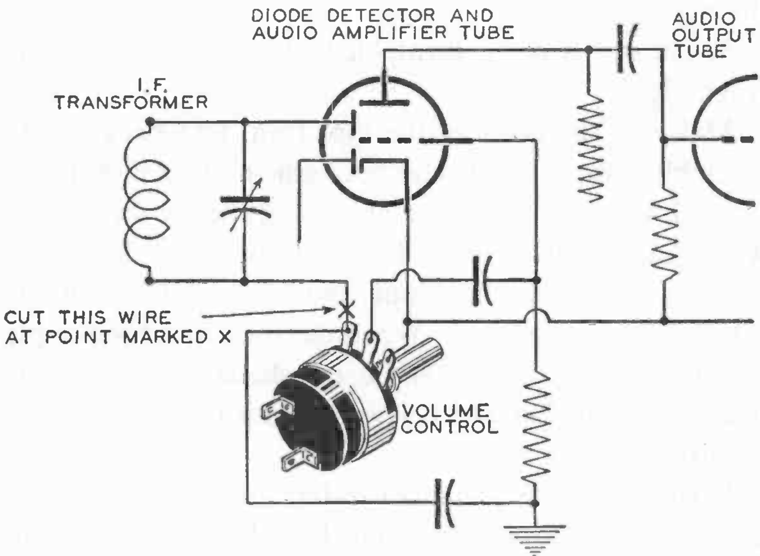
Make all the holes in the top, front and back before assembling the cabinet. Use both glue and small brads to fasten it together. Drive the brad heads below the surface with a small nail set and fill with plastic wood. When the glue has dried smooth the outside of the cabinet with fine sandpaper. Then stain it. When the stain has dried apply a coat of white shellac. When the shellac has dried rub it smooth with No. 0 steel wool. Finish with a coat of varnish.

If you prefer, the cabinet can be painted. Apply first a coat of shellac to fill the wood. Use the variety of paint made for furniture and interior woodwork.

Drive the rubber head nails into the under edge of the front and back near the corners so that the cabinet is raised above any flat surface upon which it is placed.

This is necessary so air can move in and out of the cabinet freely and cool the motor.

Home-made rubber washers act as shock absorbers and prevent vibrations of the motor from being transmitted to the motorboard and so reaching the pickup. The washers can be cut from a piece of inner tube from an automobile tire. Six pieces ¾ inch x ¾ inch are required. Drill a hole through each with a ⅛ inch drill. The motor is fastened on top of the motorboard by three ¾ inch 8-32 R.H. machine screws. Place a rubber washer on each screw between the motor and motorboard and also between the underside of the motorboard and the washer which is slipped over the screw before placing the nut.



HOW TO USE THE AMPLIFIER IN A RADIO RECEIVER TO PLAY PHONOGRAPH RECORDS

If the receiver is not equipped with a phono-jack, cut the wire leading from the I.F. transformer to the volume control at the point marked **X** in the illustration. (*See also next illustration.*)

The power cord passes through a ⅜-inch hole in the back of the cabinet. One of the power wires is connected to the motor. The other is connected to the fixture switch mounted near the front of the cabinet. Run a wire from the other terminal wire on the switch to the motor. When the plug on the power cord is pushed into an outlet the motor can be started or stopped by turning the switch.

YOU CAN PLAY PHONOGRAPH RECORDS WITH YOUR TABLE MODEL RADIO

If you have a record player but no amplifier and loudspeaker for it you can use the audio-amplifier and speaker in a broadcast receiver. Many broadcast receivers are equipped with a phono jack and switch at the factory. Push a phono pin plug connected to a record player into the phono jack, move the switch to the correct position and you have a phonograph.

If your broadcast receiver is not equipped with a phono jack you can install one at a cost of about $1.00. **You will need the following parts:**

- 1 Shielded phono pin-plug jack
- 1 Single-pole, double-throw (SPDT) toggle switch
- 1 12-inch length shielded phono wire
- 2 ½ inch No. 8 self-tapping screws
- 1 .05 mfd., 600 DC working volts tubular by-pass capacitor
- 1 12-inch length of spaghetti which will slip over the shielded phono wire
- 1 Piece of ¼-inch plywood approximately 3 in. x 3½ in.
- Rosin-core solder

Spaghetti is the trade name for varnished cambric tubing used for insulation in radio and electronic circuits.

Mount the phono jack and the STDP switch on the plywood panel and fasten the panel to the rear of the receiver chassis. Drill two holes with a No. 28 drill through the panel and through the rear edge of the steel chassis. Use the No. 8 self-tapping screws to clamp the panel against the chassis.

The jack is to be connected to the input circuit of the audio amplifier. Most broadcast receivers employ a superheterodyne circuit and the input to the audio amplifier in that type of receiver should not be difficult to locate. Suppose that we operate on a 5-tube, table model AC-DC superheterodyne. Here is the procedure:

First, remove the control knobs so that you can take the chassis out of its cabinet after the four screws which hold it in place have been extracted. Turn the exposed chassis upside down and locate the volume control.

There is an ON-OFF switch on the back of the control. There are two terminal lugs on the switch. We are not interested in the switch except that it may be helpful to the novice to identify it and not confuse it with the control. The control has THREE terminal lugs in a row. We are not concerned with the center terminal.

Trace the wires connected to the two OUTSIDE terminals. You will find that one of the outside terminals is connected to a tube and the other is connected to a coil called an IF transformer.

Now you can start "operating." Cut this wire at the point where it is attached to the volume control and solder it to one of the contacts on the SPDT switch. If the wire is not long enough to reach the switch add a piece to it.

Connect the terminal on the volume control from which the wire to the IF transformer was removed to the center terminal on the SPDT switch.

Connect the other switch contact to the phono jack using a piece of shielded phono wire for the purpose. Connect the center wire to the center terminal of the jack. Connect the shield to the outer terminal of the jack.

The shielding on the wire must not touch any of the other terminals or components in the receiver or it will cause a short circuit. To prevent this, slip a piece of insulating spaghetti over the shield.

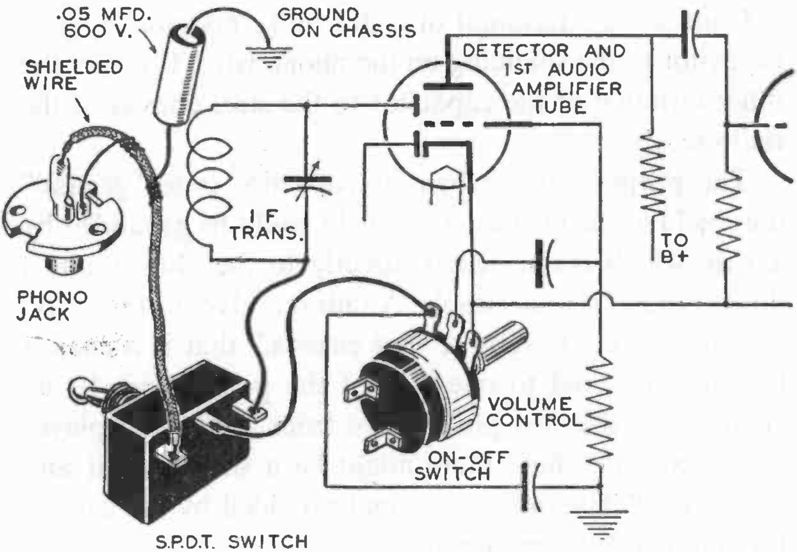
Connect one terminal of a .05 mfd., 600-volt by-pass capacitor to the shielding on the phono wire. Connect the other terminal of the capacitor to the steel chassis of the radio receiver.

The purpose of the by-pass capacitor is to "ground" the shield to the chassis. The shield could be grounded by a wire which connected it directly to the chassis but a direct ground is undesirable. A radio receiver of the AC-DC variety is likely to have a "hot chassis," that is a chassis that is connected to one side of the power line. If, by chance, the shielded phono wire from the record player should also be "hot" there might be a short circuit and "fireworks." The indirect ground provided by the capacitor eliminates this possibility.

All connections should be soldered with rosin-core solder. When the hookup is complete, restore the receiver to its cabinet, fasten it in and replace the control knobs.

If the SPDT switch which has been added at the back of the set is thrown so that the IF transformer is connected to the volume control, the receiver can be used to pick up broadcast programs in the usual manner. If connections have been made properly the addition of the jack, switch and capacitor will not interfere in any way with the reception of broadcast programs.

To play records through the receiver is no trouble. Push the pin plug connected to the record player into the phono jack. Throw the SPDT switch so that the volume control is connected to the phono jack, turn on the ON-OFF switch on the volume control, put a record on the player and you are "in business." The volume control will regulate the sound of records in the same way that it controls the sound



HOW TO USE THE AMPLIFIER IN A RADIO RECEIVER TO PLAY PHONOGRAPH RECORDS

When the wire from the I.F. transformer to the volume control has been cut, install a SPST switch, phono-jack and capacitor as shown above. To play a record, push the phono-plug connected to the record player into the phono-jack. One position of the switch connects the phono-jack to the amplifier. The other position eliminates the jack so that the receiver can be used for radio again.

of a radio program. Connect a shielded phone wire to the other switch contact. Connect the other end of this shielded wire to the phono jack. Connect the center wire to the center terminal of the jack and the shield to the outer terminal.

It is best to avoid a direct ground. Connect one terminal of a .05 mfd., 600 volt by-pass capacitor to the shielding on the phono wire and the other terminal to the chassis of the radio receiver. This cap is used to avoid making a direct ground between the chassis and the shield.

The shielding on the wire must not touch any of the other terminals or components, or it will cause a short circuit. To prevent this, slip a piece of "spaghetti" over the shield.

BUILD YOUR OWN PORTABLE PHONOGRAPH

This is a complete phonograph unit. It does not have to be connected to anything but the 117-v A.C. power supply. Push the plug into an outlet, put a record on the turntable and it is ready to play. The quality of its reproduction is good—equal to that of many factory-built phonographs which cost five or six times the price you pay for parts to build this unit.

With the exception of a few additional holes, a cabinet of the same size and form is used as that described for the record player in preceding pages. The cabinet encloses a phono motor, 3-tube amplifier and 6-inch loudspeaker. There are complete 3-tube AC-DC phono amplifiers on the market, priced at less than ten dollars. These give good reproduction and you can use one of them or use the equally good 3-tube phono amplifier described in Chapter

Fourteen. The instructions which follow are based upon the use of the homemade amplifier. It does not require a great deal of ingenuity to substitute a ready-made amplifier.

The following parts and materials are required:

1	Phonograph motor with 9-inch turntable
1	Pickup arm with crystal cartridge and stylus
1	6 ft. attachment cord and plug
1	Single pole 125-v rotary fixture switch
1	6-inch permanent magnet speaker
2	1 phone pin plugs
1	2 ft. length shielded phono cable
1	Piece rubber inner tube 2 in. x 2 in.
1	8 in. x 8 in. piece of grille cloth
1	3-tube phono amplifier
1	Piece plywood 13 in. x 11½ in. x ¼ in. (top)
1	Piece plywood 11½ in. x 7 in. x ¼ in. (front)
1	Piece plywood 11½ in. x 7 in. x ½ in. (back)
2	Pieces plywood 12¼ in. x 7 in. x ½ in. (sides)
4	Rubber head nails
1	2-terminal Bakelite tie-point
	Shellac, stain, varnish, rosin-core solder, glue, rubber cement, screws and brads.

The information covering the choice of a phono motor and pickup for the record player should be used in their selection for the phonograph.

To make the cabinet, follow the instructions for making the record player cabinet. Make all holes in the top, front, sides and back before assembling the cabinet. The location, size and shape of the holes in the motorboard depend upon the motor and pickup which is used. Use the template which comes with the motor and pickup to locate the holes. Cut the large hole for the motor with a power jig saw or a hand fret saw. (*See instructions for building record player cabinet.*)

The 5⅝-inch diameter circular hole in the front of the cabinet for the loudspeaker can be cut with a power jig saw or by hand with a fret saw. After cutting, smooth the edges of the hole with sandpaper.

Grille cloth to stretch across the hole in the front of the cabinet can be purchased from almost any radio repair shop. The cloth should not be put in place until the cabinet has been stained and varnished.

Cut a paper circle the same size as the hole for the loudspeaker and place it in the center of an 8 inch x 8 inch piece of grille cloth to act as a shield when spreading the cement. Spread rubber cement on that portion of the cloth which is not covered by the template. Also spread rubber cement on the back side of the cabinet front around the edge of the hole over an area (including the hole) equal in size to the piece of grille cloth. When the cement on both the grille cloth and the cabinet has dried for about 10 minutes, put the cloth in place on the back of the cabinet front. There will be a small surplus of cloth at the lower edge of the cabinet front. Trim this off with a safety razor blade.

Another method of putting the grille cloth in place is to cement it to an 8 inch x 7 inch piece of cardboard which has a 5¾-inch hole in the center.

Drill four holes in the cabinet front which will line up with the four holes in the loudspeaker when the latter is centered over the hole. Fasten the speaker to the back of the cabinet front with four ¾-inch 8-32 machine screws. Push the screws through the holes from the front of the cabinet. Place an 8-32 hex nut on the end of each screw and tighten.

Use homemade shock-absorbing washers in mounting the motor.

The power cord passes through a hole in the back of the cabinet and terminates on a two terminal Bakelite tie-point strip fastened to the inside of the cabinet back. One of the motor terminal wires is connected to one of the tie-point terminals. A wire from the other tie-point terminal goes to the fixture switch on the cabinet front. The other switch terminal is connected to the remaining motor terminal. The fixture switch serves as an on-off switch to stop and start the motor but does not interrupt the power supply to the amplifier.

The amplifier is fastened inside the cabinet at the lower edge of the right hand side. First fasten a strip of plywood 3 inch x ¾ inch x ¼ inch to the front edge of the amplifier base so as to make it flush with the plywood panel which supports the volume and tone controls.

Drill three ⅛-inch holes ½ inch up from the bottom edge of the right hand side of the cabinet as indicated in one of the illustrations. The amplifier is held in place inside the cabinet by three 1¼-inch No. 6 round head wood screws which pass through the holes from the outside and into the edge of the amplifier base. Drill two 5/16 inch diameter holes in the right hand side of the cabinet for the shafts of the volume and tone controls.

Connect a phono pin plug to the end of the shielded phono wire which is connected to the crystal cartridge in the pickup arm. Push the plug into the INPUT jack on the amplifier. Use shielded phono wire to connect the loudspeaker to the amplifier. Connect a phono pin plug to one end of the wire and push the plug into the OUTPUT jack on the amplifier. Connect the other end of the wire to the speaker.

One of the wires connected to the output jack should be permanently connected to the No. 1 terminal on the secondary winding of the 50L6 matching transformer. Determine which of the secondary terminals the other wire should be connected to by test and experiment. Connect it permanently to the terminal which produces the best tones from the speaker when a record is played.

Run a wire from each of the terminals on the tie-point, to which the power cord is connected, to the terminals on the tie-point marked **(23)** on the plan of the amplifier.

The phonograph is now ready to use.

THE HUSH-A-TUNE

Do you ever wish to play a phonograph record but must restrain yourself because the sound would annoy someone who is studying or sleeping or someone who does not approve of your taste in music?

Here is the answer to your problem. Equip your phonograph with a "Hush-a-tune." Then you can play the phonograph and you alone can hear it.

A double-pole, double-throw toggle switch and a phone jack are needed. You can use two binding posts in place of a phone jack. The jack is more convenient.

Drill three holes in the side of the phonograph cabinet so that you can fasten the switch and phone jack there.

An illustration on page 237 shows the connections. One position of the switch will connect the amplifier to the speaker voice coil so the phonograph can be played in the usual manner.

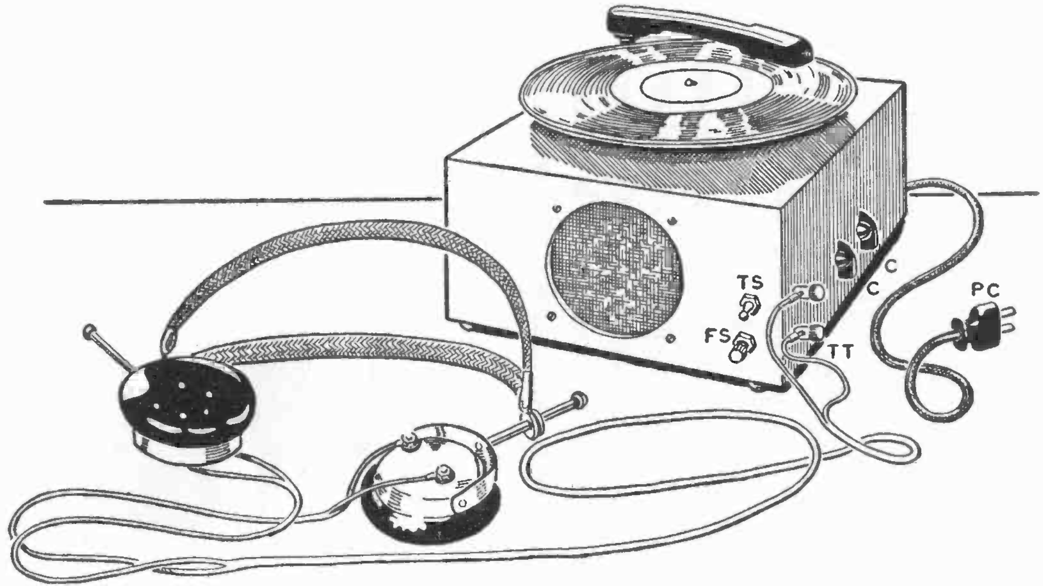
When the switch is thrown to the opposite side, the amplifier is connected to the phone jack. Push the tips on a radio headset, slip the phones on and you are equipped to listen to the phonograph music. The volume control on the amplifier will adjust the sounds in the headphones to suit you. Too much volume will produce distorted sounds.

LOUDSPEAKER REPAIRS AND ADJUSTMENTS

Loudspeakers do not require frequent repairs but they are sometimes damaged and occasionally get out of adjustment. The simplest way to remedy a defective loudspeaker is to replace it with another of the same model. The most economical method, if you have the time, is to repair it yourself.

Off-center Voice Coil. The most common defect is "off-center voice coil." This may be caused by rough handling or a bent frame but more frequently it is due to humidity changes which cause the paper cone to warp. If the voice coil is off center, it will rub against one of the magnet poles and the sound from the speaker will be distorted and "fuzzy." Radio repairmen are familiar with this sound and recognize it immediately.

Old style speakers are equipped with a "centering screw," located either behind the magnet or in the middle of the paper "spider" at the center of the cone. A centering screw makes readjustment simple. You will need a few centering shims. These are narrow strips of thin fiber or



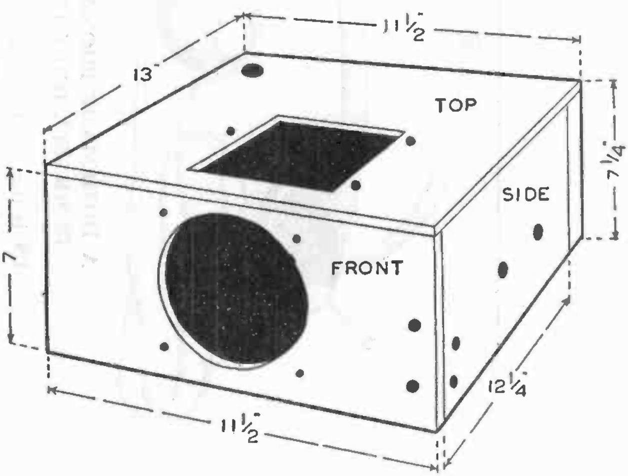
A HOMEMADE PHONOGRAPH ARRANGED SO THAT WHEN DESIRABLE ONLY ONE PERSON CAN HEAR ITS SOUND

FS is the fixture switch for starting the motor. **TT** are terminals for a pair of headphones. **TS** is a toggle switch for disconnecting the speaker and connecting the headphones. **CC** are the tone and volume controls. **PC** is the plug on the power cord.

metal of varying thickness. They are available from radio supply dealers and are priced at about forty cents for a set of twenty.

Loosen the centering screw and insert three shims between the voice coil and the pole piece. Space the shims about 120 degrees apart. Tighten the centering screw, remove the shims and the job is finished.

When the voice coil becomes off center on one of the newer speakers which has no centering screw, the whole cone assembly must be loosened by applying cement solvent to the rim of the paper cone where it is fastened to the frame. The solvent must soak in for several minutes before it will loosen the cement sufficiently to free the cone. Do not try to move the cone until it is entirely free or you will risk tearing it. Another warning which should

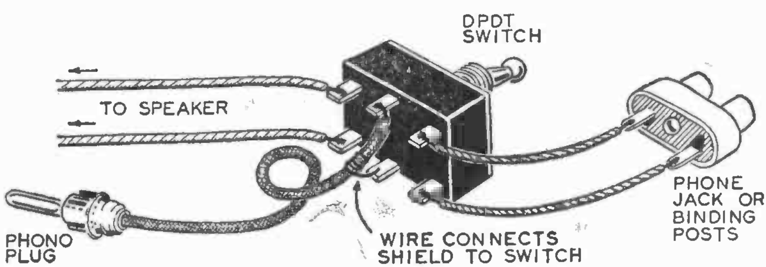


CABINET FOR THE PHONOGRAPH WITH "HUSH-A-TUNE" ATTACHMENT be heeded is: Do not try to lift the cone from the frame or you will break the connection to the voice coil.

Apply cement solvent to the small circular dust felt in the center of the cone and remove the felt when the cement has softened. When the felt has been removed the pole piece will be exposed.

When the cone is loose, center the voice coil by inserting three shims of the proper thickness between the voice coil and the pole pieces. Space the shims about 120 degrees apart. With the shims in position recement the cone. When the cement has thoroughly set, remove the shims. Cement and cement solvent in small bottles for loudspeaker repair can be purchased from dealers in radio supplies. The dust cap should be replaced after the shims have been removed. The dust felt prevents dirt, etc., from lodging between the pole piece and the voice coil. Foreign matter in this small space will cause distortion.

Cone Repairs. Some cones are molded and have no seam.



THE "HUSH-A-TUNE" ATTACHMENT

This consists of a phono-plug, double-pole, double-throw switch and a phone jack or pair of binding posts. One position of the switch connects the output of the amplifier to the speaker. The other position connects the amplifier to a radio headset.

Others, of the formed type, have an overlapping seam which is cemented. The cement sometimes dries out and the seam opens. This causes a rattling sound when the speaker is in operation. Put fresh cement along the seam and press the edges together. Use speaker cement or household Duco. Give the cement time to set thoroughly before using the speaker.

Torn cones can often be mended by pushing the torn edges together and applying cement along the tear on both the front and back of the cone.

If the tear or hole is a large one, it is advisable to have a radio repairman install a new cone in the speaker.

Broken Voice Coil Lead. This can be repaired by soldering with rosin-core solder. This defect will cause a "dead" receiver or phonograph. An "open" voice coil where the break is in the coil and not in a lead calls for a new cone and voice coil assembly.

CHAPTER SIXTEEN

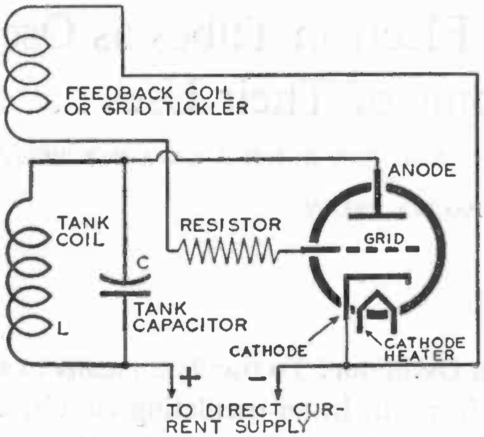
Electron Tubes as Oscillators and Some of Their Uses . . .

CAPACITY RELAYS • YOU CAN BUILD A CAPACITY RELAY • FUN WITH A CAPACITY RELAY

What Is an Oscillator? To oscillate means to swing backward and forward. In an oscillating circuit, current and voltage surge back and forth, generally at a high frequency. In radio and electronics the term oscillator means any device for producing electric oscillations, or more specifically, a radio-frequency generator. Edwin H. Armstrong was first to reveal that a properly arranged circuit containing an electron tube could be made to OSCILLATE and thus become a means for converting direct current and voltage into high-frequency alternating current and voltage.

Electron-tube oscillators which generate radio-frequencies are indispensable in radio, industry and warfare and are part of the equipment of scientific, educational and commercial laboratories.

The radio-frequency currents and voltages generated by electronic oscillators are used in transmitters to produce the radio waves which carry radio-telegraph, radio-telephone, broadcast, television and radar signals. There is a small radio-frequency oscillator in every superheterodyne radio receiver.



THE SIMPLEST FORM OF ELECTRONIC OSCILLATOR

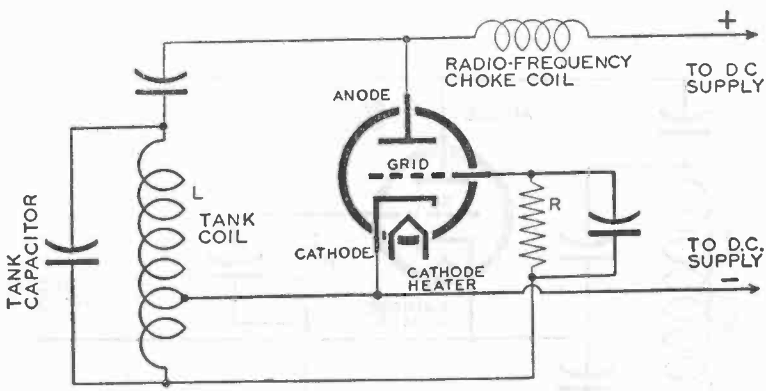
"There are several types of electron tube oscillators. All provide some means in their circuit to feed part of the power passing through the plate circuit back to the grid. Most oscillators are named for the inventor who first demonstrated the particular type of feedback which is used in the oscillator. The illustration shows the circuit of the simplest type." It is called the magnetic or inductive feedback oscillator. A "tickler coil" which is part of the plate circuit feeds energy from the plate circuit to a "tank coil" which is part of the grid circuit. The energy fed from the plate circuit to the grid circuit appears again in the plate circuit in amplified form. This swinging to and fro of energy is sustained oscillation and will continue as long as power is supplied to the plate circuit. The frequency of the oscillations depends upon the amount of inductance and capacitance in the circuit. An electron tube can be made to oscillate as rapidly as 500,000,000 times per second under proper conditions.

Radio-frequency currents originated by electron-tube oscillators generate the healing heat employed in diathermy treatments. Heat produced in the same manner is used in industrial processes for curing plastics, drying lumber, gluing plywood, surface-hardening steels, to obtain a uniform thin coating of tin on the sheet iron used for cans and in many other ways.

Oscillators are no longer limited to the original type invented by Armstrong. There are several different fundamental types of oscillator circuits and many modifications of each fundamental type.

CAPACITY-OPERATED RELAYS

An electronic oscillator can be arranged and adjusted so that its oscillations cease when a metal plate is brought between its coils. If the circuit includes a relay, the relay

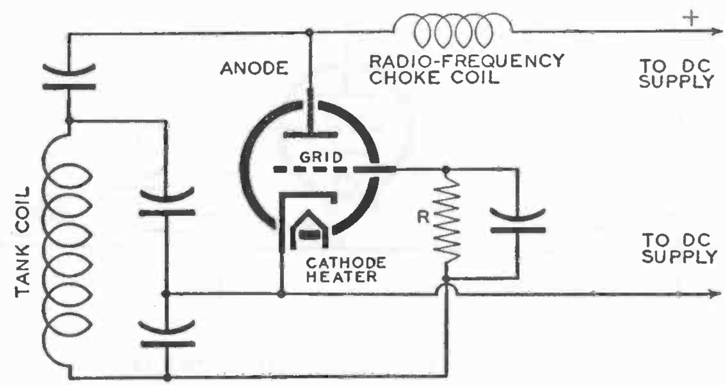


BASIC HARTLEY OSCILLATOR CIRCUIT

This is one of the circuits usually found in high-frequency heating units. A Hartley oscillator utilizes inductive coupling to feed back energy from the plate to the grid circuit. The tank coil is divided so that part of it is in the grid circuit and part is in the plate circuit. The magnetic coupling between the two sections of the tank coil furnishes the feedback which causes oscillations.

will remain open while oscillations occur and will close when the oscillations cease. This arrangement is called a capacity-operated relay. It has several practical industrial applications. It can operate a burglar alarm; it will stop and start machines and perform other useful services WITHOUT BEING TOUCHED. The next time that you ride in an elevator car it may be one which is stopped automatically by CAPACITY RELAYS.

Elevators are often controlled automatically by capacity relays. When the car approaches a floor where a stop is to be made, the elevator's slow-down relays are the first to be actuated. Then the stopping relay stops the car and levels it at the floor. Several capacity-operated relays assembled in a unit and mounted on the top of the car are required to accomplish this. Metal plates are mounted on the hoistway wall or elevator guide rails to actuate the



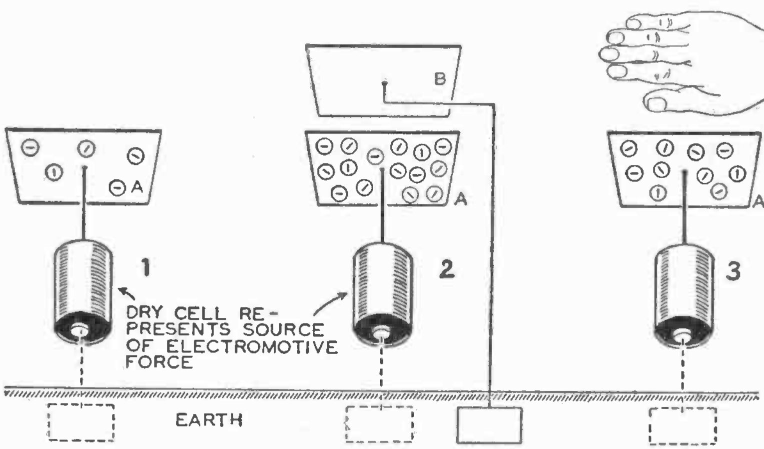
COLPITTS OSCILLATOR

The Colpitts oscillator circuit is also widely used for electronic heating units. By coupling the tank coil to an antenna, the Colpitts oscillator becomes a radio-telegraph transmitter. The Colpitts circuit usually has less frequency drift (change in frequency) with changes in load than some other oscillators.

relays. The metal plates are located so that as the elevator car approaches a floor the plates pass between but do not touch several pairs of coils. Each set of coils is part of a capacity relay circuit. When a plate passes between two coils a relay closes.

The operation of a capacity relay depends upon the action called BODY EFFECT. The effect which the presence of the hand or body near electronic apparatus has upon the circuit is called body effect.

Explanation of Body Effect. A metal plate which is insulated from the ground and from other surrounding ob-



EXPLANATION OF BODY EFFECT

1. If a metal plate (A) is insulated from the ground and other surrounding objects it can be given an electrical charge. If a source of direct electromotive force is connected to the plate a few electrons will flow into the plate. In the illustration above, the source of direct current is represented by a dry cell. The circles with a negative sign represent electrons.
2. If a grounded plate (B) is brought near plate (A), a greatly increased number of electrons will flow into plate (A).
3. The presence of the human hand or body near plate (A) has much the same effect as plate (B) and increases the number of electrons which flow to plate (A).

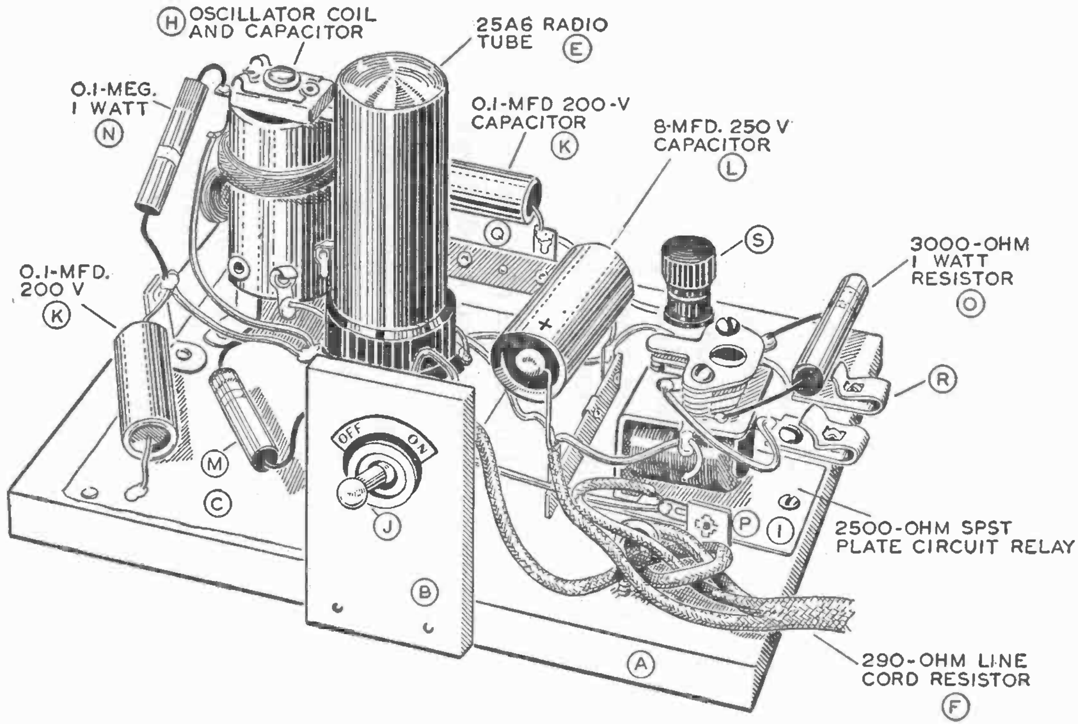
anyone who gets close to the screen or touches it will set off an alarm such as a red light or a bell.

If the capacity plate is placed under a rug, the relay will be actuated when anyone steps on the rug over the plate. If the relay is connected to a bell, it will serve as an alarm. For amusement, the relay can be connected to a table lamp or a floor lamp and the light will flash on momentarily when a hand or foot is placed on the rug over the capacity plate. Or, the capacity plate can be placed under a slipcover on an upholstered chair located near a table lamp. If the relay is connected to the lamp, the latter will light when anyone sits in the chair and continue to burn as long as he remains.

A capacity plate larger than 6 inches x 6 inches can be used. The maximum size which is practical will have to be determined by experiment. If too large, the relay will not be sensitive.

COMPONENTS AND MATERIALS USED IN BUILDING THE CAPACITY-OPERATED RELAY

1 Shellacked wood base 6½ in. x 5 in. x ½ in. **(A)**
1 Piece plywood (shellacked) 2½ in. x 1⅜ in. x ¼ in. **(B)**
1 Piece plywood (shellacked) 2 in. x 1¼ in. x ¼ in.
For mounting relay **(D)**
1 Piece thin sheet metal 4 in. x 3 in. **(C)**
1 25A6 radio tube **(E)**
1 290-ohm line cord resistor **(F)**
1 Octal wafer socket **(G)**



AN EXPERIMENTAL CAPACITY RELAY

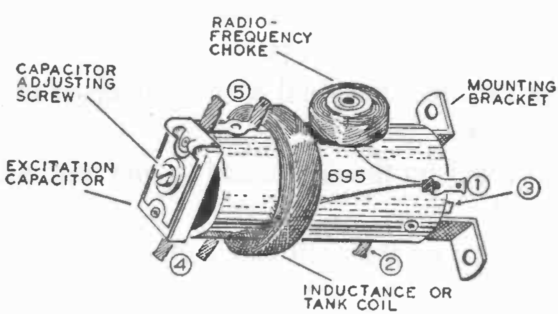
1 Miller Cat. No. 695 oscillator coil for capacity relay (**H**)
1 SPDT plate circuit relay with 2,500-ohm coil (**1**)
1 Ball handle SPST-125-v toggle switch (**J**)
2 0.1 mfd. tubular paper by-pass capacitors (**K**)
1 8 mfd. 250-volt single section electrolytic capacitor (**L**)
1 50-ohm, 1 watt carbon resistor (**M**)
1 0.1 megohm, 1 watt carbon resistor (**N**)
1 3,000-ohm, I watt carbon resistor (**O**)
2 Single-lug Bakelite tie points (**P**)
2 5-lug Bakelite tie-points (**Q**)
2 Fahnestock spring connectors (**R**)
1 Eby type 30 binding post (**S**)
1 Small screw eye (**T**)
2 ⅜-in. round head 6-32 machine screws
2 ½-in. No. 4 round head wood screws
7 ⅜-in. No. 4 round head wood screws
2 1-in. No. 6 round head wood screws
2 ¾-in. spacers to raise socket above base
Hook-up wire, rosin-core solder

The Relay. Any sensitive SPST electromagnetic plate circuit relay with a coil of not less than 1,000 ohms or more than 2,500 ohms resistance can be used. The same plate relay used in building the experimental Photoelectric Relay described in Chapter 12 can be used in this circuit.

Plate relays are usually fastened down by two machine screws which fit into threaded holes at the bottom. When the relay is mounted directly on the wood base it is necessary to drill two holes through the base and counterbore them from the underside so that the screw heads will not project below the surface. A more convenient method is to mount the relay on a small metal sheet or plywood sub-base of its own and fasten the sub-base to the larger base.

The Tube. 25A6 is an amplifier tube of the class known as a power pentode. It is used frequently in the output stage of AC-DC receivers. The tube has a metal envelope and requires an octal socket. The heater is designed for 25 volts and at that voltage consumes 0.3 amperes. When used alone and operated on 117 volts it must be connected to the power source with a 290-ohm line cord resistor.

The Oscillator Coil. This is an inexpensive factory-made coil wound on a plastic tube and comes complete with capacitor and radio-frequency choke coil. An instruction sheet comes with the coil showing how to use it in both a single-tube and two-tube circuit. The coil is manufactured by the J. W. Miller Company, 5917 S. Main St., Los Angeles, California. If your dealer cannot supply the coil, write direct to the manufacturer.



MILLER NO. 695 OSCILLATOR COIL

The Capacity Plate. This may be a square piece of WIRE screen or metal sheet about 6 inches x 6 inches or a disk of the same materials about 6 inches in diameter. Copper, brass, aluminum, iron, in fact any metal can be used as the capacity plate. A suitable plate can be made by covering a piece of cardboard with aluminum foil. Solder a flexible insulated wire to the plate. If foil is used, the wire cannot be attached by soldering, it must be clamped to the foil.

The plan of the oscillator is the best guide for assembling the components on the base.

The line cord resistor is tied to a screw eye in the forward right hand corner so that there will be no strain on the soldered connections. The Eby binding post near the back edge is the terminal to which the wire leading to the capacity plate is attached.

Use push-back wire for the connections. The ends of all wires except those which are clamped under the Fahnestock connectors and the binding post should be soldered. Use rosin-core solder. Make all wires as short and as direct as possible.

Make connections to the oscillator coil as follows:

Connect lug 4 on the oscillator coil to one terminal of a 0.1 mfd. by-pass capacitor (**K**).

Connect the other terminal of the condenser to the Eby binding post (**S**).

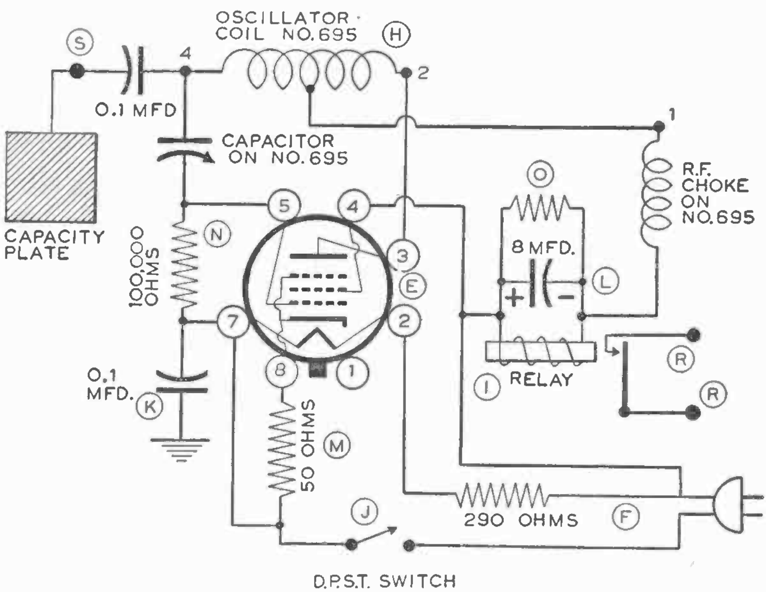
Connect lug 3 on the choke coil to one terminal of the relay (**H**) coil.

Connect lug 2 on the oscillator coil to No. 3 socket (**G**) terminal.

Connect lug 5 to the capacitor on the oscillator coil to No. 5 socket (**G**) terminal.

Operation. When the wiring has been completed check it carefully and if correct, the instrument is ready for a test. Connect a dry cell and an electric bell or a 1.5-v flashlight lamp to the Fahnestock connectors and push the armature of the plate relay so as to close the contacts. If the contacts are clean and touch each other the bell should ring or the lamp should light, as the case may be.

Place a 25A6 tube in the socket, push the plug on the resistor cord into a power outlet and turn the on-off switch to the ON position. Give the tube 3 or 4 minutes to warm up before making any adjustments. Connect the wire attached to the capacity plate to the binding post provided for it at the back of the base. Lay a newspaper or magazine



CIRCUIT FOR THE EXPERIMENTAL CAPACITY RELAY

The 290-ohm resistor is one of the conductors in the line cord resistor.

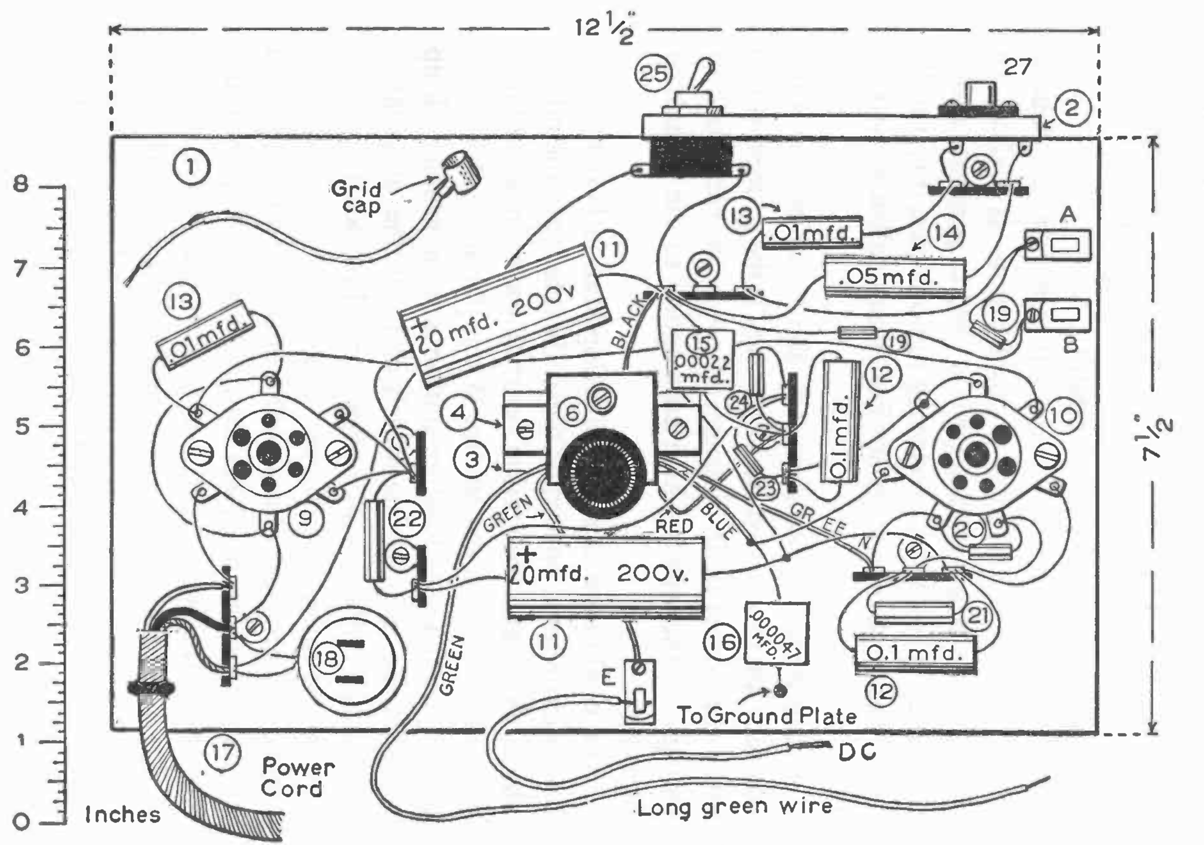
on the table and place the plate on this. The paper will insulate the plate from the table. Turn the adjustment screw on the excitation capacitor counterclockwise two or three revolutions. Use a screwdriver with a plastic handle and do not let your fingers touch the metal blade. The best screwdriver to use for this purpose is a nonmetallic screwdriver made of fiber and called an aligning tool. This tool is used by professionals for adjusting electronic equipment. Loosening the capacitor adjustment screw reduces the capacitance to a point where the circuit cannot oscillate and the bell should ring or the lamp light. If this occurs, turn the adjusting screw very slowly in a clockwise direction until the bell stops or the lamp is extinguished. Do not turn the screw beyond this point. The increase in capacitance should provide sufficient excitation for the circuit to oscillate. When oscillating, the tube will draw about 4 to 5 milliamperes plate current and at this current a common plate relay of 1,000 to 2,500 ohms should not operate. But when the hand or any large electrical conductor is brought near (1 to 3 inches) the capacity plate, the loading caused by body effect will decrease the excitation and stop oscillation. The plate current will then be about 18 to 25 milliamperes. This should be enough current to close the relay and set any device connected to it into operation. If necessary, a stabilizing resistor (**O**) of 1,500 to 5,000 ohms may be connected across the coil of a 1,000-ohm relay. A resistor of 3,000 to 5,000 ohms should be used with a relay which has a 2,500-ohm coil.

The relay and the excitation capacitor (on top of the coil) should not be adjusted until after the capacity plate has been installed in position and connected. If the relay has a tendency to remain closed when it should open, it may be that the armature touches the end of the iron core in the relay coil. This can be remedied by slipping a piece of tissue paper between the core and the armature.

How to Build and Operate a Miniature Home Broadcasting Station

Radio signals of all sorts, telegraph code, speech, music and television, are sent out into space by radio waves appropriately called CARRIER waves. The carrier waves are produced by sending alternating currents into an antenna. The currents used for this purpose alternate at high frequency, hundreds of thousands, even millions of times per second, and are known as HIGH-FREQUENCY or RADIO-FREQUENCY CURRENTS. They are generated by an electron tube.

A radio tube which will amplify can also be made to oscillate or generate sustained radio-frequency currents. It is merely necessary to connect the tube in a proper circuit and supply the filament and plate circuits with suffi-



PLAN OF THE PHONO-OSCILLATOR

cient current. The energy represented by the radio-frequency currents is taken from the energy in the electric current supplied to the plate circuit.

A tube and circuit which will generate continuous radio-frequency currents or oscillations is called an OSCILLATOR. When an oscillator is used to generate radio-frequency currents for producing radio waves, it is usually associated with an energy-storing circuit called a TANK or TANK CIRCUIT.

Radio waves do not carry any signals or messages unless they are modulated. MODULATION is the process which gives the waves their message. It produces variations or changes in the waves which correspond to the signals or messages.

The modulator at a broadcasting station is controlled by a microphone. Speech or music directed into the microphone modulates the station's carrier waves in accordance with the sounds in the studio. When phonograph records are played at a broadcasting station a phonograph pick-up replaces the microphone which controls the modulator.

You can build a small, low-powered broadcasting transmitter and operate it in your own home. Because of its low power, programs from your transmitter will be picked up only by radio receivers 20 to 50 feet away, in other words, by receivers located in your house or apartment. If the transmitter were more powerful, it could be heard on receivers all around the neighborhood and would be illegal. Federal laws forbid using a device of this kind which has any greater power.

Any first-class, factory-built broadcast receiver can be used to receive your programs. Records can be played in a room adjoining that where the receiver is located or in a room on another floor in the same building and their music will come out of the radio receiver. You can make announcements and your voice will be heard via the radio receiver. This will amaze those who do not know how it is accomplished.

The miniature broadcasting station is a device termed "wireless phonograph oscillator." It is actually a low-powered radio transmitter which sends out signals in the broadcast frequency band. The signals are picked up by a receiver nearby when the receiver is tuned to the oscillator's signals.

You can purchase a factory-built phonograph oscillator. You can build one yourself at much lower cost. With a phono oscillator, any broadcast receiver will perform as an electric phonograph without connecting it to a record player and without altering the receiver in any way.

PARTS AND MATERIALS REQUIRED TO BUILD THE WIRELESS PHONOGRAPH OSCILLATOR

- 1 Wood base, 12½ in. x 7½ in. x ¾ in. (**1**)
- 1 Wood strip, 5 in. x 2½ in. x ¼ in. (**2**)
- 1 Wood strip 2½ in. x ¾ in. x ¼ in. (**4**)
- 2 Wood blocks 1 in. x ¾ in. x ½ in. (**3**)
- 1 Piece of thin sheet metal 11½ in. x 6½ in. (**5**)
- 1 6F7 radio tube
- 1 25Z5 radio tube
- 1 6-prong tube socket (**9**)
- 1 7-prong tube socket (**10**)
- 1 Phonograph oscillator coil (Meissner No. 17-9373) (**6**)
- 2 20 Mfg. 200-volt electrolytic capacitors (**11**)

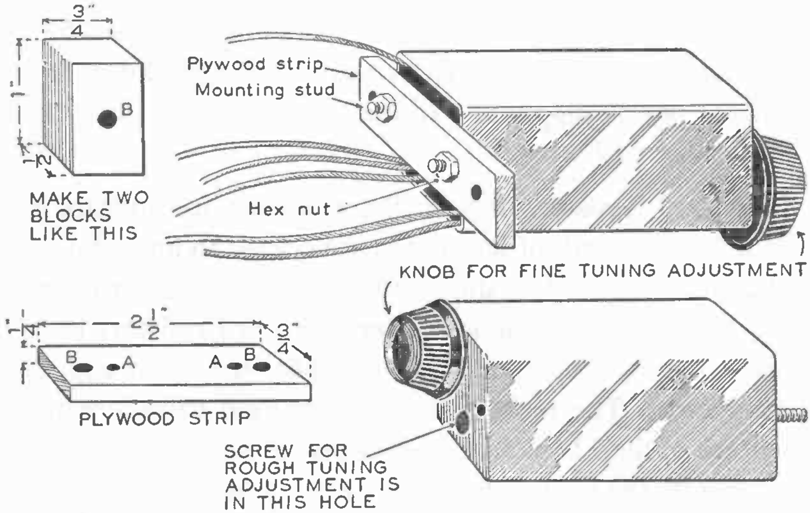
1 Female plug receptacle for 120 volts **(18)**
2 0.1 mfd., 200-volt tubular by-pass capacitors **(12)**
2 0.1 mfd., 400-volt tubular by-pass capacitors **(13)**
1 .05 mfd., 400-volt tubular by-pass capacitor **(14)**
1 .00022 mfd., mica capacitor **(15)**
1 .000047 mfd., mica capacitor **(16)**
1 290-ohm line cord resistor **(17)**
2 470,000-ohm, ½-watt resistors **(19)**
1 390,000-ohm, ½-watt resistor **(24)**
1 68,000-ohm, ½-watt resistor **(20)**
1 2,400-ohm, ½-watt resistor **(21)**
1 39,000-ohm, ½-watt resistor **(23)**
1 10,000-ohm, 1-watt resistor **(22)**
3 Binding posts or Fahnestock connectors
5 Solder-lug mounting strips with four lugs
1 Small single-pole, single-throw switch **(25)**
1 Phonograph jack **(27)**
4 Rubber head tacks
4 ½-inch, No. 5 round head wood screws
13 ⅜-inch, No. 5 round head wood screws
1 1½-inch, No. 6 round head wood screw
2 ¼-inch, No. 2 round head wood screws
Shellac, varnish, push-back wire and rosin-core solder

The Oscillator Coil. The "heart" of the oscillator is a No. 17-9373 Phono Oscillator Coil.* The coil can be ordered from the factory or from any dealer who sells

* Manufactured by Thordarson-Meissner, Mt. Carmel, Illinois

amateur and experimental radio equipment. The coil is actually three small coils and two small capacitors enclosed in a metal case or shield. One of the capacitors is a double trimmer capacitor which can be adjusted by means of a knob and a small screwdriver. Adjusting the trimmer capacitors tunes the oscillator. In other words, the adjustment changes the frequency and wavelength of the signals the oscillator sends forth.

Six wire terminal leads emerge from the bottom of the metal shield enclosing the coil. These are the terminals of the coils and colored so that they can be identified. There are four short solid wires, colored respectively black, blue, red, and green. The two other wires are both colored green, are stranded and are longer than the four short wires. One of the stranded green wires is about two feet long.



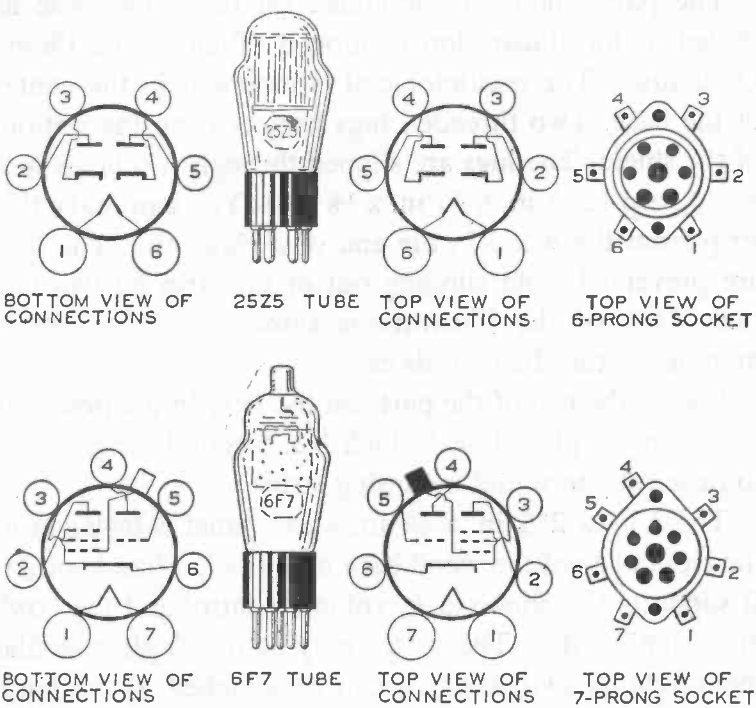
MEISSNER NO. 17-9373 PHONO-OSCILLATOR COIL

The screw which adjusts the capacitor is visible through a small hole in the top of the shield and can be turned with a small screwdriver. Turning the screw gives a rough or coarse adjustment of the frequency and wavelength. A tuning knob projects through the top of the shield. Turning the knob gives a fine adjustment of the frequency and wavelength.

The Tubes. The phono oscillator employs two tubes: a 6F7 and a 25Z5. Both are the heater type and consequently can be operated on alternating current (the heater circuits only). A 6F7 tube is actually two tubes in one, a triode and a pentode enclosed in the same glass envelope. The 6F7 is the oscillator tube and generates the radio-frequency currents which produce the waves that carry the phonograph music through space from the phono oscillator to the radio receiver. Although the heater of the 6F7 tube operates on alternating current, the tube requires high voltage direct current in the plate circuits. The 25Z5 tube is a rectifier tube. It changes the 117-volt alternating current power supply into direct current for the plate circuit of the 6F7.

Line Cord Resistor. At first glance, this device appears to be a 6-foot length of lamp cord connected to an ordinary attachment plug. It is different. Common lamp cord contains two copper conductors but line cord resistors have one or more resistance wires in addition to two copper conductors. The resistance wires are used to reduce the voltage of the 117-volt power supply so that it can be used to operate the heaters in 6F7, 35Z5 and other tubes. Line cord resistors complete with attachment plug are available in several resistances ranging from 135 ohms to 960 ohms. The line cord resistor purchased for the phono oscillator should have a resistance of 290 ohms.

The Base. The first step in building the phono oscillator is to make a smooth wooden base 12 in. x 7 in. x ¾ in. and give all its surfaces a coat of white shellac varnish. When the shellac has dried, fasten a piece of thin sheet metal (11½ in. x 6½ in.) to the underside of the base. Use thin galvanized or tinned sheet iron. You can cut a suitable piece of tinned sheet iron out of the sides of a one-gallon can. Fasten the metal to the underside of the base with small brads. Do not try to drive the brads



THE TUBES USED IN THE PHONO-OSCILLATOR

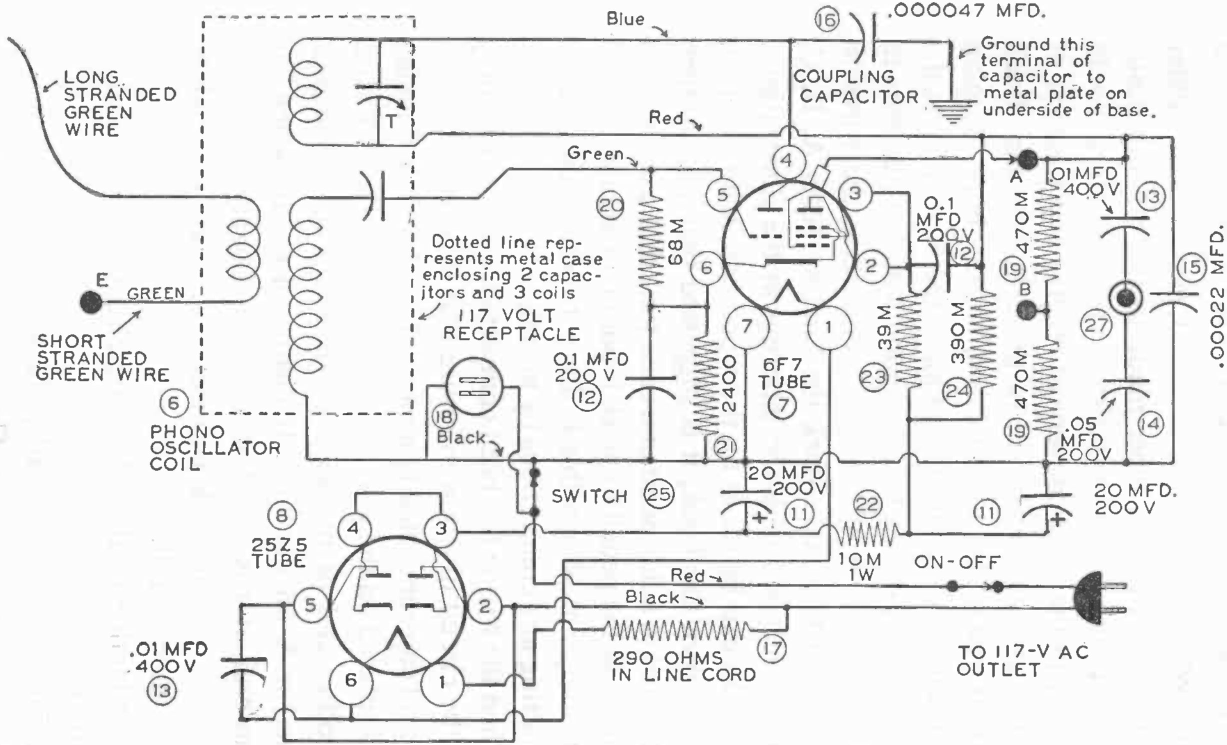
through the metal. Punch a small hole in the metal wherever you wish to place a brad. Make the holes with a nail. Hold the point of the nail against the metal, hit the nail head with a hammer and the hole is made. Use care not to drive the nail so hard that it makes holes larger than the heads of the brads you are using.

After fastening the metal sheet, drive a rubber headed tack into the underside of the base at each corner. They will insulate the metal sheet from any object upon which the phono oscillator rests. The metal plate must not be grounded because it is part of the antenna system from which the waves radiate.

The parts should be mounted on the wood base as shown in the illustration captioned "Plan of the Phono Oscillator." The oscillator coil is mounted in the center of the base. Two threaded lugs project from the bottom of the shield. The lugs are slipped through two holes in a wood strip (2½ in. x ¾ in. x ⅛ in.). You can make this strip from the wood in the end of a cigar box. The lugs are prevented from slipping out of the strip by two hex nuts. One of the illustrations shows how the coil is mounted better than words can.

Locate the rest of the parts on the base in the positions shown in the plan. Use ⅜-inch No. 5 round head screws to fasten the terminal mounting strips.

The 5 in. x 2½ in. x ¼ in. wood panel is fastened to the front edge of the wood base near the left hand corner. It supports the phono-jack, volume control and the "ON" and "OFF" switch. The switch may be the single-pole filament-lighting switch which can be attached to the back of the volume control or the common 120-volt "canopy" switch used on lamps and wall brackets.



SCHEMATIC CIRCUIT DIAGRAM OF THE PHONO-OSCILLATOR

Wiring. When all parts are mounted, start wiring. Solder all connections except those made to the binding posts. The wire terminals on the resistors and capacitors should be cut off to the most convenient length. The position of the wires should correspond to those in the plan. Each time that you make a connection, consult both the plan and the circuit diagram. If you mark the terminals on the sockets **1, 2, 3, 4,** etc. to correspond with the numbers in the illustrations, it will help in connecting the wires to their correct terminal. Mark the binding posts **A, B, C,** etc. to correspond with the lettering in the illustrations. The marks can be made on the wood base with a pencil.

If you own this book, it is suggested that you sharpen a red pencil to a fine point and each time that a connection is made, use the pencil to mark it both on the plan and the circuit diagram. When this is done it reduces the chance of omitting any connections by mistake.

When the wiring has been completed, check it carefully with the circuit diagram to insure that it is correct.

A grid cap connected to a piece of flexible wire 6 inches long is placed on the grid terminal on top of the 6F7 tube. The other end of the wire is connected to Fahnestock connector **A** on the base. If distortion occurs when the phono oscillator is tested, it may be necessary to connect the wire to Fahnestock connector **B.** This is explained later in more detail.

Examination of the schematic circuit diagram will reveal that:

1. There is a single-pole, single-throw switch in the heater circuit of the tubes. The switch turns the heaters on and off.

2. The heaters of the two tubes are connected in series.

3. Current from the 117-volt A.C. circuit reaches the heaters (when the switch is closed) after passing through a resistance of 290 ohms in the line cord. This resistance prevents the full 117-volt current from flowing through the heaters and burning them out.

4. Two 470,000-ohm resistors provide a voltage dividing network to accommodate to some extent the difference there is in pickups.

The use of this network is discussed in the paragraph DISTORTION.

The Record Player for the Phono Oscillator. The record player used with the phono oscillator should be equipped with a high-impedance crystal pickup. The player described in Chapter 15 may be used. Crystal pickups and magnetic pickups may both have high impedance but a magnetic pickup will not usually give good results when connected to the phono oscillator unless a preamplifier is used. The energy produced by a magnetic pickup is less than that produced by a crystal pickup and the preamplifier is necessary to strengthen the feeble energy. The magnetic pickup is connected to the input terminals of the preamplifier. The output terminals of the amplifier are connected to the pickup terminals on the phono oscillator.

A crystal pickup does not require a preamplifier. A low impedance crystal pickup requires a small step up transformer of the audio or interstage type between the pickup and the phono oscillator. Connect the pickup to the primary of the transformer. Connect the secondary terminals of the transformer to the terminals on the phono oscillator marked "pickup."

A high impedance crystal pickup does not require a preamplifier or a transformer. The terminals of the pickup are connected to a phono-plug which is pushed into the phono-jack.

To Operate the Phono Oscillator. If a checkup of the wiring on the phono oscillator shows it to be correct, the oscillator is ready for a test. When making the first test, place the phono oscillator close to a radio receiver or close to the antenna lead-in connected to the receiver provided the lead-in is not shielded wire. The base of the phono oscillator should rest where the metal plate will not be grounded. Sometimes the phono oscillator will not operate unless it rests on a piece of window glass (7½ in. x 12½ in.).

Push the 6F7 and 25Z5 tubes into their sockets on the phono oscillator. Connect the flexible grid connection to the terminal on the top of the 6F7 tube and to the Fahnestock connector marked **A** on the base of the phono oscillator. Connect the pickup plug of a record player to the pickup jack. Push the line cord plug of the phono oscillator into a 117-volt outlet. Push the plug connected to the line cord on the record player into the 117-volt outlet on the oscillator. Turn the ON and OFF switch on the phono-oscillator to the ON position so that the tubes start to warm up. When the tubes have been warm for about one minute, start a record playing. If the record player is equipped with a volume control, turn the volume control to maximum.

Turn the volume control on the radio receiver to the approximate position used when receiving local broadcasting stations. Tune the receiver by moving the tuning control slowly through its entire range as if looking for a distant broadcasting station. At some point on the dial, the phonograph record will be heard.

It is possible that a broadcasting station may be heard simultaneously with the record. If such interference occurs it is a simple matter to change the frequency of the oscillator so that it will be heard at a position on the dial of the radio receiver where no broadcasting is heard.

Turning the screw which can be seen through the hole in the top of the coil shield, and turning the tuning knob which projects from the shield will change the frequency of the oscillator. Turning the screw makes a much greater change in frequency than turning the knob. The knob is the fine adjustment.

Distortion. The phono oscillator can be overmodulated by a microphone or phonograph pickup which generates too great an output voltage. Overmodulation produces raspy distortion. If the reproduction of loud tones is of poor quality and sounds raspy, release the flexible grid connection on the 6F7 tube from Fahnestock connector **A** and connect it to **B.**

Trouble Shooting. Some radio receivers lack sufficient sensitivity to reproduce good signals from a phono oscillator. Weak reproduction will occur if a receiver is shielded from the oscillator by metal laths, pipes, etc., in walls and partitions. Either of these conditions may reduce the useful range of the phono oscillator to less than 20 to 50 feet.

The noise from static due to thunder storms, vacuum cleaners, motors, etc., can be greatly reduced and sometimes entirely eliminated by disconnecting the antenna from the radio receiver and connecting the long green stranded wire on the oscillator coil to the antenna post on the receiver in place of the antenna.

The terminal "E" to which a green wire from the oscillator coil is connected, is used to connect the phono-oscillator directly to a radio receiver. Disconnect the antenna from the "A" or "Ant" terminal on the receiver. Connect a wire from terminal "E" directly to the "A" or "Ant" terminal on the receiver. When the oscillator is used connected directly to the receiver, it is recommended that the .00005 mfd. coupling capacitor (16) be short-circuited by connecting a wire across its terminals. Shorting this condenser will reduce the likelihood of interference with your neighbor's radio receiver.

NOTE: Radio repair shops and service men rarely have a 6F7 or 25Z5 tube in stock. Both tubes are listed in the catalogs of Allied Radio and Lafayette Radio (*see page 269*) and may be ordered by mail from those firms.

Where to Obtain Materials

The average radio and television service shop can furnish any of the tubes, fixed capacitors, resistors, volume controls and batteries required to build the apparatus described in this book. Other components such as transistors, coils, relays, phototubes, transformers, phonomotors, etc., can be obtained from the large distributors of electronic equipment. Six reliable firms which issue mail order catalogs are listed below. They will send you a catalog if you write and request it. Neither the author nor the publisher has any interest in these business firms and does not assume any responsibilty in your dealings or transactions with them.

Write for catalog to:

Allied Radio, 100 N. Western Avenue, Chicago 80, Illinois.

Lafayette Radio, 165 Liberty Avenue, Jamaica 33, New York.

Burstein Applebee Co., 1012 McGee Street, Kansas City, Missouri.

Radio Shack Corporation, 167 Washington Street, Boston 8, Massachusetts.

Concord Radio Corporation, 45 Warren Street, New York 7, New York.

Newark Radio, 223 W. Madison Street, Chicago 6, Illinois and 4736 W. Century Blvd., Inglewood, California.

Lens for Phototube Relay

Various lenses are listed in the catalog of the Edmund Scientific Co., Barrington, New Jersey. If interested, write for catalog.

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