THE BOYS' THIRD BOOK OF
Radio and Electronics

by ALFRED MORGAN
WITH DIAGRAMS BY THE AUTHOR

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Chapter One

AN INTRODUCTION TO ELECTRICITY—SOME OF THE TERMS USED IN ELECTRICAL SCIENCE AND ELECTRONICS

Electronic devices influence our civilization at almost every turn. Radio and television receivers, tape recorders, and hi-fi phonographs are common applications of electronics familiar to the layman. A few other marvels which are part of the realm of electronics are: X-rays, Geiger counters, radar, guided missiles, "electric eyes," sound motion pictures, electronic computers, long distance telephony, and control mechanisms for automation.

You have probably used or heard such terms as "120-volt current" and "15-ampere fuse" without "volt" and "ampere" having much real significance to you.

It is not essential to know the difference between an ampere and a volt in order to construct the apparatus described in this book. It is necessary only to follow the instructions carefully.

But building and experimenting with electronic apparatus is much more interesting and profitable when the principles involved are well understood. The principles of radio and electronics are basically electrical principles. Anyone who aspires to understand something of electronics or to become eventually a ham radio operator must have a clear idea of elementary electrical action. That is why the first pages of this book discuss electricity and explain such terms as ampere, volt, ohm, etc.

Electronics Defined. The word ELECTRONICS is a broad technical term extending into many fields of modern science. If we look in the dictionary for a definition of electronics we will probably find that it is defined as the science and technology which is concerned with the flow, behavior, and effect of ELECTRONS in vacuums, gases, and semiconductors. This definition is accurate as far as it goes. It is a poor definition from the standpoint that it is incomplete. It should also, at the least, state that electronics is concerned with the flow of electrons in high-frequency or radio-frequency alternating currents and with the production and behavior of radio waves.

What are electrons, vacuums, gases, semiconductors, radio-frequency currents, and radio waves?

Electrons are one of the constituents of atoms. They are a part of all matter. They are very small, light, invisible particles associated with the elementary charge of NEGATIVE electricity. They constitute cathode rays and beta rays and are emitted by hot objects.

A vacuum is a space entirely devoid of matter.

Gases are aeriform fluids. They have the form of air. Oxygen, hydrogen, helium, nitrogen, neon, and krypton are gases.

A clear explanation of the nature of semiconductors cannot be given in few words. It will be sufficient at this point to explain that the crystal detectors, rectifiers, and transistors used in electronics utilize the materials called semiconductors. Silicon, germanium, and selenium are the three semiconductors used most frequently in radio circuits.

High-frequency or radio-frequency currents are alternating currents which change their direction of flow from 100,000 to millions of times per second. Their production is essential in order to create radio waves—the waves which carry radio messages, television pictures, radar signals, etc., through space. Radio-frequency currents and radio waves are discussed at length in a later chapter.

THE NATURE OF ELECTRICITY

A moving electron is an ELECTRIC CURRENT though a very feeble one because BILLIONS of moving electrons are required to produce an electric current which has sufficient energy to do useful work. When we deal with electricity we are dealing with energy. An electric current is a FORM OF ENERGY. So are heat and light. There are also other forms of energy, namely:

Kinetic Energy	Chemical Energy
Gravitation Energy	Magnetic Energy
Energy of Elasticity	Radiant Energy

All of these—electricity, heat, light, magnetism, chemical energy, etc.—are not different energies. They are different FORMS of the same thing. Each one may be converted into any one of the other forms.

In the transmission and reception of radio messages, in the operation of radar and all electronic apparatus several conversions of energy occur. Conversion of energy is a change of one form of energy into another. Electrical and magnetic energy are two of the forms of energy always involved in electronic circuits.

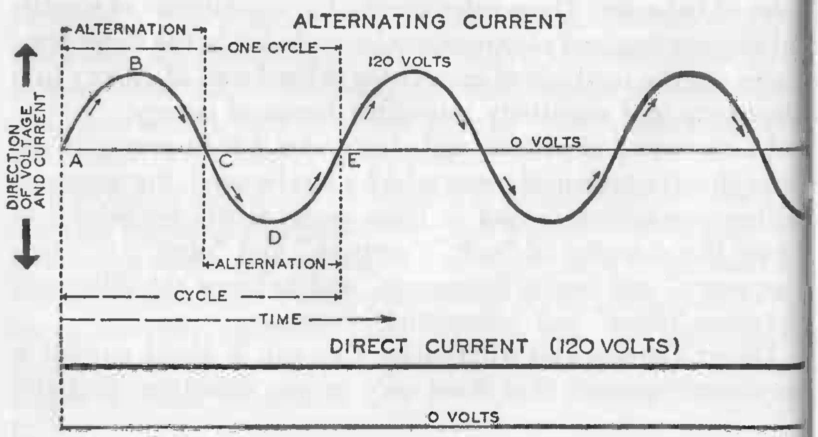
Electrical energy and magnetic energy obey certain fixed rules of behavior. These rules are the basic principles of electrical engineering and electronics. Also included in the basic principles are the methods of converting other forms of energy into electricity and electricity into other forms of energy.

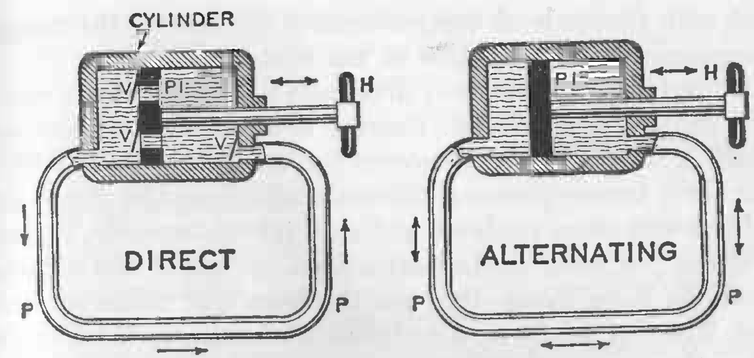
In discussing electricity and electronics it is necessary to explain first the technical terms which must be used. For example, before proceeding farther in these pages it will be helpful to know the meaning of "volt," "ampere," and "ohm," of "radio frequency" and "audio frequency," and to know the difference between "direct" and "alternating" currents.

Direct Current and Alternating Current. A direct current is an electric current that flows only in one direction. Batteries produce direct current, so do some forms of the machines called electrical generators. Direct current can be produced also by passing an alternating current through a device called a rectifier. The portion of a radio receiver called the detector is a miniature rectifier and changes alternating currents into direct current.

An alternating current changes its direction periodically. In other words, the current flow or movement of electrons is alternately in one direction and then in the other, this reversal occurring at regular intervals. The number of complete reversals of direction (called CYCLES) which occur in one second is the FREQUENCY. The frequency of the standard commercial and residential power supply in the United States is 60 cycles per second. The alternating currents which make it possible to send radio messages have a frequency of at least 100,000 cycles. They are known as RADIO-FREQUENCY currents and may reach a frequency of several billion cycles per second.

Alternating currents with a frequency of 40 to 20,000 cycles per second, which is roughly the range of audibility of the human ear, are called AUDIO-FREQUENCY currents.





EXPLANATION OF DIRECT AND ALTERNATING CURRENT

Electrical terms and phenomena often can be made clear to the young scientist by comparison with the behavior of water. Such an analogy is illustrated above.

The water pump in the left-hand diagram represents a direct-current generator. The pipe system P corresponds to an electrical circuit. If the pump handle H is pushed back and forth, the piston P1 will force the water around through the pipe P. The water will always flow in one direction as does a DIRECT current. The valves V which correspond to the commutator in a direct-current generator permit the water to flow in one direction only.

When the handle H in the right-hand sketch is pushed back and forth the piston moves the water back and forth, first in one direction and then in the other. The motion of the water corresponds to that of an alternating current.

The arrows alongside the pipe circuit indicate direction of water flow. The arrows with a head on both ends indicate a flow first in one direction and then in the other.

Electromotive Force—What It Is. If two water tanks are connected together by a pipe and the water is at the same level in both tanks, there is no difference in pressure between the tanks and there will be no current or movement of water in the pipe. But if the water level in one tank is higher than the water level in the other there is a difference in pressure and a current of water will move from the tank with the higher level to the tank with a lower level. THE DIFFERENCE IN PRESSURE MOVES THE WATER AND CAUSES THE FLOW IN THE PIPE.

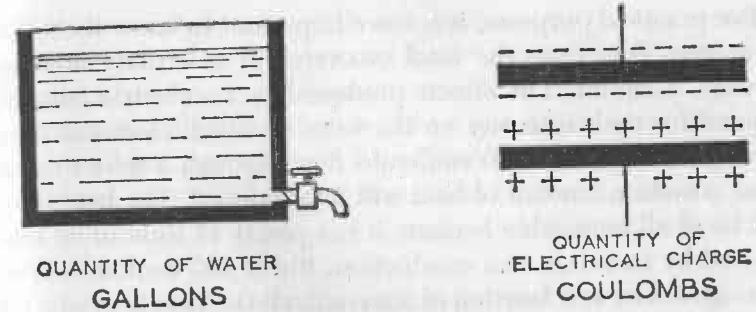
It is POTENTIAL (pressure) difference that causes electrons to flow through a conductor. Because it is an "electron-moving force" it is called ELECTROMOTIVE FORCE (abbreviated EMF). The three terms—potential difference, electromotive force and voltage—are often confused and used interchangeably. For all practical purposes, electromotive force, potential and voltage mean the same thing—they are the force that makes current flow. There is, however, a technical distinction in these terms when they are used correctly.

Mechanical force is usually measured in pounds but electromotive force is measured in VOLTS, so-called in honor of Volta, the Italian scientist who discovered how to produce an electromotive force from chemicals (the primary cell). To be absolutely correct, the term electromotive force should be applied only to the force produced by a generator or battery. For example, "the electromotive force of the car's battery is 12 volts." Potential or potential difference properly used applies only to a total circuit or a part of a circuit. For example, "the potential difference at that point in the circuit is 12 volts." The term voltage applies to the number of volts concerned.

Electromotive force—electrical energy—can be produced by the conversion of some other form of energy, for example, by mechanical energy, chemical energy, light energy, frictional energy, heat energy, etc.

The Volt. Although the volt is a measuring unit for "electrical pressure" or electromotive force, it does not have much significance as a quantity unless it is considered at the same time with two other measuring units: namely, the ampere and the ohm. But first the coulomb must be explained.

The Coulomb—a Measure for Quantity of Electricity. Since electrons cannot be seen, felt, smelled, or heard, they cannot be counted or measured by any of our senses. Electricity cannot be measured by any of the standards used to measure other



THE COULOMB

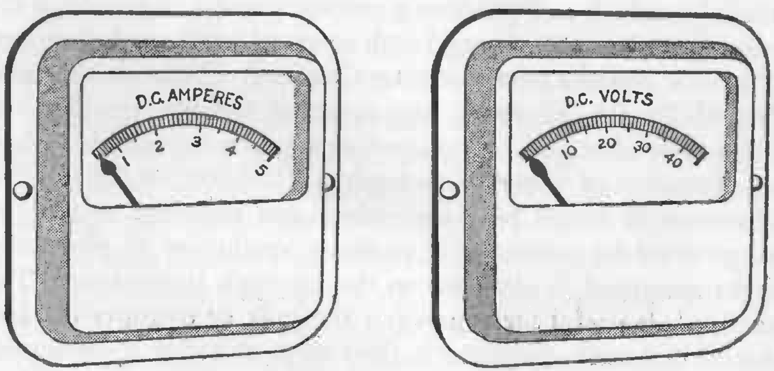
The coulomb is a measuring unit for quantity or amount of electrical charge just as the gallon is a measure for a definite quantity of water.

things. The only way that it is possible to measure electrons or an electric current is by the effects produced. For example, an electrical charge can be measured by the force of attraction or repulsion between it and another electrical charge. This, in fact, may be termed the fundamental electrical measurement. The basic unit of electrical measurement is the quantity of electrons which will produce a certain amount of repulsion toward a similar body charged with an equal number of electrons. This unit, called a COULOMB after Charles A. Coulomb, the celebrated French physicist, represents a definite quantity or amount of electrical charge, just as a gallon represents a definite quantity of water. A coulomb is 6,280,000,000,000,000,000 electrons. It would be inconvenient and awkward to use the large numbers necessary if ordinary quantities of electricity were measured in electrons so the coulomb is employed. The coulomb is useful for expressing the bulk or quantity of electricity in a static charge or in the charge stored in a condenser. It can be used also as a measure for the total quantity of electrons flowing in a circuit. However, it is more useful as a laboratory measuring unit than as a practical measuring unit. Although the coulomb is the measuring unit for quantity it does not take into account the TIME during which electrons flow.

For practical purposes, it is more important to know the RATE of current flow than the total QUANTITY of electricity flowing through a circuit. The effects produced by an electric current depend for their intensity on the RATE at which electrons flow through a circuit. If 100 coulombs flow through a wire in one hour, a certain amount of heat will be produced. The heat may not be at all noticeable because it has plenty of time to be dissipated by radiation and conduction. But if 100 coulombs flow through a wire in a fraction of a second, all the heat is produced in that fraction of a second. Consequently there is not time enough for the heat to dissipate to the extent that it is not noticeable. It might heat the wire red hot or even melt it.

The Ampere—A Measure for Rate of Current Flow. Instead of expressing the rate of current flow as a certain number of coulombs per second, a more convenient term called the AMPERE is used.

An ampere of current is flowing when electrons flow past any



METERS

Amperes, volts, ohms, watts, and fractions thereof can be quickly and conveniently measured by indicating instruments called ammeters, voltmeters, etc.

given point in a circuit at the rate of one coulomb per second. An ampere therefore represents 6,280,000,000,000,000,000 electrons passing a given point IN ONE SECOND.

Nowadays, the rate of current flow in a circuit can be quickly measured by an ammeter. If the rate is very small it may be measured by a milliammeter or microammeter. A milliampere is one thousandth of an ampere; a microampere is one millionth of an ampere.

Before ammeters were devised, a chemical method of measuring the rate of flow of an electric current was employed. An electric current will produce certain chemical changes and the same rate of current flow will always produce the same amount of chemical change in the same length of time. For example, if a direct current is passed through a suitable silver solution by means of dipping two silver electrodes into the solution, silver will be deposited on one electrode and dissolved from the other.

An ampere, which is the unit of measurement for RATE OF CURRENT FLOW, represents the same rate of current flow in the United States as an ampere does in England, Germany, France, Italy, or any other country. By international agreement a current which, when passed through a solution of nitrate of silver in water, deposits silver at the rate of 0.001118 of a gram per second, is called an AMPERE. This is 0.06708 grams of silver deposited per minute.

Electrical Conductors. In order for an electric current to flow, it must be provided with a suitable path. The complete path of an electric current, including usually the source of current, is called a CLOSED circuit. When the continuity of the path is broken it is an OPEN circuit. A popular name for a radio circuit is HOOKUP. Electric currents will not flow through all materials. Through some they pass easily; through others they pass only with difficulty. If a material permits a current to flow through it easily it is called a CONDUCTOR. Those materials which conduct poorly are called PARTIAL conductors. Those which do not conduct at all are termed NONCONDUCTORS and INSULATORS.

There is no perfect conductor at ordinary temperatures.* Not all so-called good conductors are equal in their current carrying capacity and not all insulators are equally good insulators.

Resistance. The difficulties in the path of electrons moving in a conductor are called RESISTANCE. Good conductors offer small or low resistance; good insulators offer great resistance to the flow of current.

The metals are the best conductors but not all of them are equally good. Copper and silver offer the least resistance. That is why electrical wires are commonly made of copper. Weight for weight but not size for size, aluminum is a better conductor than copper. An aluminum wire must be larger in diameter than a copper wire to have equal conducting capacity.

The length and cross section of a wire or a conductor limit the amount of current which can flow through it. The resistance of a conductor to the flow of electrons causes some of the electrical energy to be changed into heat energy. Large wires will carry more current than small wires without developing excessive heat. The size of the wires and conductors used in electronic circuits is always an important consideration.

It is incorrect to say that all materials may be divided into two groups and classified as either conductors or insulators. There is no sharp dividing line. When ability to CARRY CURRENT is the important consideration, the best conductors are used. The poorest conductors are used as insulators to prevent the leakage of current. The following lists name some of the best conductors and best insulators (poorest conductors). The metals are placed in the list in the order of their conductivity. Silver, the best conductor, is at the top and lead, the poorest conductor in the group, is at the bottom.

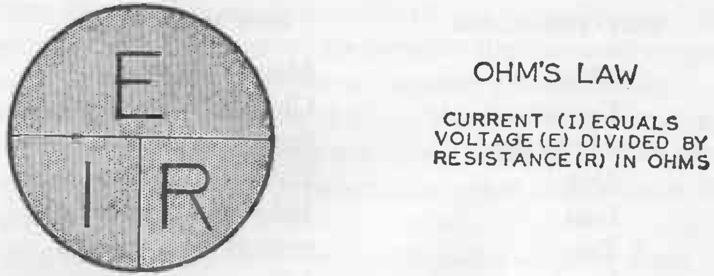
* Among the metals are certain ones, termed SUPERCONDUCTORS, which have zero resistance and conduct electric currents seemingly indefinitely when cooled to temperatures near absolute zero. Absolute zero is 459.7 degrees below zero Fahrenheit.

BEST CONDUCTORS	BEST INSULATORS
Silver	Mica
Copper	Glass
Aluminum	Porcelain
Zinc	Rubber
Iron	Bakelite, Vinylite and certain other plastics
Tin	Silk
Lead	Oil

The Ohm. The measure or unit of electrical resistance is the OHM. The name was adopted in honor of George Simon Ohm, a German physicist who formulated the law of electrical resistance which makes it easy to calculate the current, voltage, and resistance values in a circuit. The international ohm, used the world over, is the resistance offered to an unvarying electrical current by a column of mercury at the temperature of melting ice, 14.4521 grams in mass of a constant cross-sectional area and a length of 106.3 centimeters.

Ohm's Law. The most useful equation in electrical engineering and in electronics is the relationship between volts, amperes, and ohms expressed in "Ohm's Law." Ohm's Law states that the number of amperes of DIRECT CURRENT flowing in a circuit equals the voltage (in volts) divided by the resistance in ohms. Ohm's Law does not hold true for alternating current except when the circuit contains only resistance and not any of the quality called inductance.

Engineers use the capital letter I as a symbol for current in amperes, E for voltage in volts, and R for resistance in ohms. With this knowledge and a pencil you can make an "Ohm's Pie," or in other words a diagram which shows how to solve ampere, volt, ohm problems by simple arithmetic. Draw the diagram as in the illustration. To use the "pie," place your finger on it so as to cover up the quantity which you wish to know. For example, if you know the volts and ohms in a circuit and



OHM'S "PIE"

This chart, resembling a pie cut in three pieces, reveals the three equations used to calculate direct current, voltage, or resistance in the ohms according to Ohm's law. The text explains how to use it.

wish to know the current in amperes, place your finger tip on the "pie" so as to hide the I. This leaves E over R or $\frac{E}{R}$ and signifies mathematically that volts should be divided by ohms. As an illustration, suppose the resistance of a circuit is 5 ohms and 10 volts are applied to the circuit. The current which flows will be 2 amperes.

If you know the current in amperes and the resistance in ohms and wish to know the voltage, place a finger on E. This leaves IR, revealing that if you multiply the current in amperes by the resistance in ohms you will get the answer in volts. By way of illustration, if the amperage is 5 and the ohms 6 the voltage must be 30. To ascertain resistance, cover R. The formula E over I or $\frac{E}{I}$ remains, this signifying that voltage divided by the current in amperes equals the resistance in ohms. An illustrative case would be a circuit in which it is known that 5 amperes are flowing at 15 volts. The resistance in ohms would be indicated by dividing 15 by 5 and the answer would be 3 ohms.

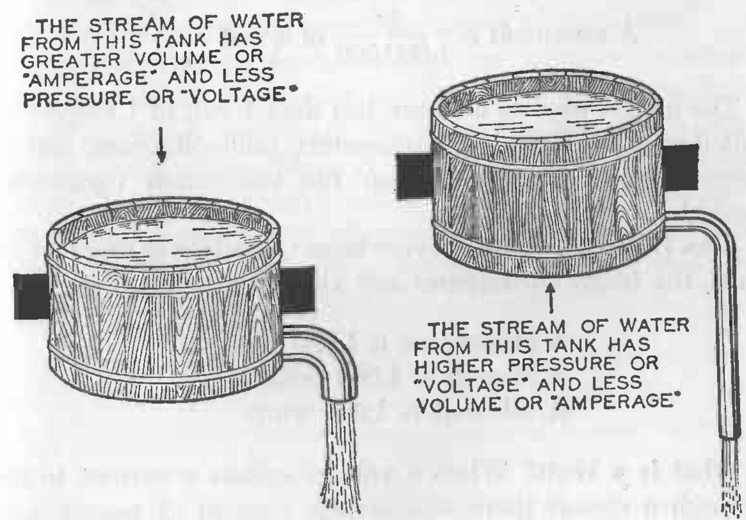
The Volt—a Measure for Electrical Pressure. The unit used to measure the electromotive force or pressure of an electric

current is called a volt. The abbreviation for volt is *v*. The strength of an electric current flowing in a circuit depends upon the voltage or pressure of the current (Ohm's Law). There is no way to translate a volt into some value which is familiar to you. A volt is an invisible measuring unit.

A volt is the "pressure" of electricity required to force 1 ampere of current through a resistance of 1 ohm.

When fresh and not supplying current, the common flashlight cell has an electrical pressure or voltage of approximately 1.5 volts. If you touch the terminals of a single dry cell, you will not receive an electric shock because the electrical pressure of 1.5 volts is not sufficient to overcome the resistance of dry human skin and force through an appreciable amount of current.

On the other hand, the voltage of the power and house lighting current delivered to residences is 80 to 160 times the voltage



The voltage and amperage of an electric current can be likened to the pressure and volume of a stream of water.

of a single dry cell, namely 120 or 240 volts. A voltage of 120 to 240 volts is sufficient electrical pressure to overcome the resistance of the skin and force 80 to 160 times as much current through human tissue as a dry cell can. The house lighting current can give an unpleasant, dangerous, or even fatal shock.

The voltage of an electric current can be measured with an indicating instrument called a VOLTMETER.

Milli and Micro. In radio and electrical work it is often necessary to deal with very small currents and voltages. Such small values are measured in milliamperes, microamperes, millivolts and microvolts.

A milliampere is $\frac{1}{1{,}000}$ of an ampere

A millivolt is $\frac{1}{1{,}000}$ of a volt

A microampere is $\frac{1}{1{,}000{,}000}$ of an ampere

A microvolt is $\frac{1}{1{,}000{,}000}$ of a volt

The meters used to measure less than 1 volt or 1 ampere are called milliammeters, microammeters, millivoltmeters, and microvoltmeters depending upon the calibration (graduation marks).

Kilo. In order to indicate very large quantities of amperes and volts, the terms kiloamperes and kilovolts are used.

A kiloampere is 1,000 amperes
A kilovolt is 1,000 volts
A kilowatt is 1,000 watts

What is a Watt? When a voltage causes a current to flow through a circuit there is a certain amount of energy used. This expenditure of power can be considered as the product of the voltage multiplied by the amperes and is indicated in watts. A current of 5 amperes at 6 volts represents a power of 30 watts.

The filament of a 40-watt, 120-volt lamp requires 40 watts to give forth its proper output of light. Since, as stated above, the watts are the product of the volts and amperes and we know the volts (120), it is easy to find the amperage by dividing 120 volts by 40 watts. The answer is 3 amperes.

A watt is not a small unit of power in a radio receiver but is a very small amount of power in a house lighting circuit. The kilowatt (abbreviation kw) equaling 1,000 watts is used to express large amounts of power.

A total of 746 watts is called an electrical horsepower.

Watt-hour and Kilowatt-hour. In considering power, it is necessary to consider not only the amount of work done but also the length of time during which it is done. The units which express power and take into consideration the time factor are the watt-hour and kilowatt-hour. Watt-hours are the product of the power in watts by the time in hours. The consumption of electrical energy is paid for on the basis of kilowatt hours. The "electric light meter" is a recording kilowatt-hour meter.

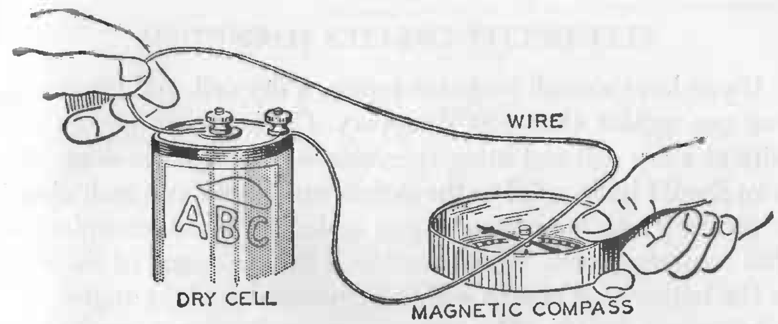
The Joule. The watt-hour is one of the "practical" electrical units. The "scientific" unit for measuring the work done by an electric current is the JOULE. The name was adopted to honor James P. Joule (1818–1889). It takes the time factor into consideration but is too small a unit to be of use in most practical work. A joule is the energy expended in a second by a current of 1 ampere flowing in a circuit having a resistance of 1 ohm.

Chapter Two

INDUCTANCE, IMPEDANCE, CAPACITANCE, AND OTHER QUALITIES OF ELECTRIC CIRCUITS WHICH YOU SHOULD KNOW ABOUT

Very interesting, invisible events occur in electric circuits. This chapter discusses several of them.

Some people develop curiosity about things while others take for granted what they see, or think they see. A young Danish boy named Hans Christian Oersted was one of the lads who have curiosity. He decided to become a scientist in order to understand better things he saw which were mysteries to him. When Oersted grew to manhood he became a professor of physics in the University of Copenhagen. He, like other scientists of those days, wondered how electricity and magnetism might be related. At that time no one knew the answer to such a question or had written anything very satisfactory about the relationship between electricity and magnetism. So Oersted decided to experiment and solve the problem himself. One day in 1819 while he was arranging his wires and batteries to try an experiment, Oersted noticed that when current from one of his batteries flowed through a wire near a magnetic compass something surprising happened. Every time the current-carrying wire was brought near the compass the compass needle moved just as it did when a permanent magnet was brought near it. The movement of the compass needle which he noticed



AN IMPORTANT DISCOVERY

In 1819, Hans Christian Oersted discovered the hitherto unknown fact that an electric current flowing through a wire produces magnetism and will move a compass needle. This discovery led to the building of electromagnets and eventually to electric motors, telegraph instruments, and hundreds of other electrical devices. You can demonstrate Oersted's discovery with a dry cell, a piece of wire, and a small compass. Do not leave the wire connected to the dry cell for more than a few seconds or the wire will become hot and the dry cell will become exhausted.

meant that he had found out something which no one had known before. He had discovered that A WIRE CARRYING A CURRENT OF ELECTRICITY PRODUCES MAGNETISM and it was this magnetism which caused the compass needle to move.

Not long after Oersted made his discovery another scientist, William Sturgeon, found that if a coil of wire is wrapped around an iron bar, the iron will become a magnet whenever an electric current flows through the coil. Such an arrangement is called an ELECTROMAGNET. By winding a current-carrying wire into a coil, the magnetism created by the moving electrons becomes more concentrated and is equal in strength to the combined magnetism of many wires. When a current-carrying wire is wound in a coil around an iron core, the magnetism becomes concentrated largely in the iron and the iron is a powerful magnet as long as the current is flowing through the coil.

ELECTRICITY CREATES MAGNETISM

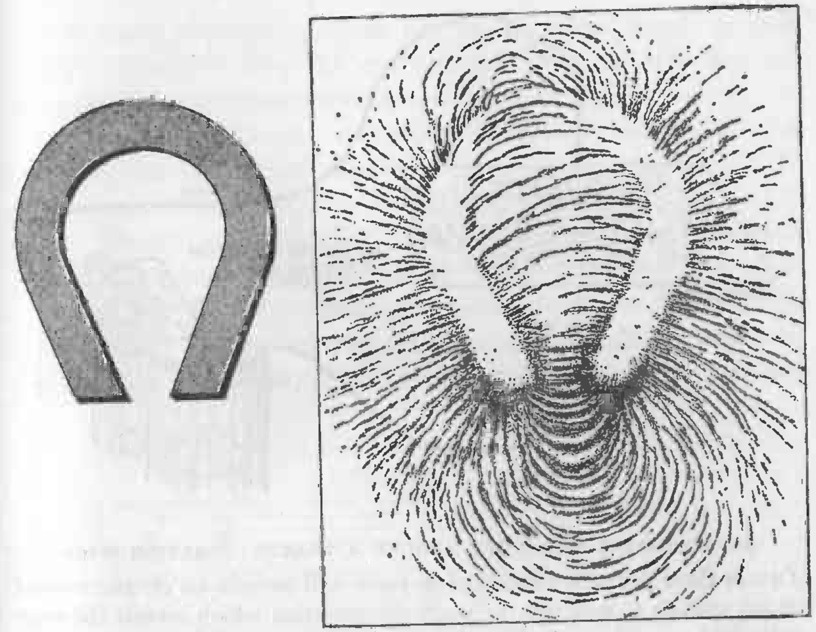
If you have a small pocket compass, a dry cell, and some wire you can repeat Oersted's discovery. Connect one end of the wire to a dry cell and bring the compass close to the wire. The wire should be parallel to the needle and about one inch above it. Nothing will happen until you make the circuit complete so that a current flows. When you touch the other end of the wire to the battery the needle will swing around at right angles.

Magnetic Fields. The space surrounding any magnet in which its attraction and repulsion can be detected is called its magnetic FIELD.

A magnetic field cannot be seen but its existence can be demonstrated by the effects it produces. Sprinkling iron filings on a sheet of smooth cardboard or on a pane of glass laid on a permanent magnet will reveal the presence of the magnetic field and its pattern in space. The filings will arrange themselves in lines curving from one magnet pole to the other. They cluster most thickly at the poles, showing that the magnetic force is strongest at those locations. The alignment of the filings is aided if the cardboard sheet or glass pane is tapped gently. The pattern formed by iron filings in a magnetic field is called a magnetic PHANTOM.

Electromagnetism. One of the important but invisible effects of an electric current is the creation of a magnetic field. The magnetic field is the direct result of the MOTION of electrons and is formed regardless of whether the electrons move through air or a gas, through a metal conductor, or through a vacuum. Although the magnetism created by an electric current is identical in nature with the magnetism of a permanent magnet, it is termed ELECTROMAGNETISM in order to indicate its origin.

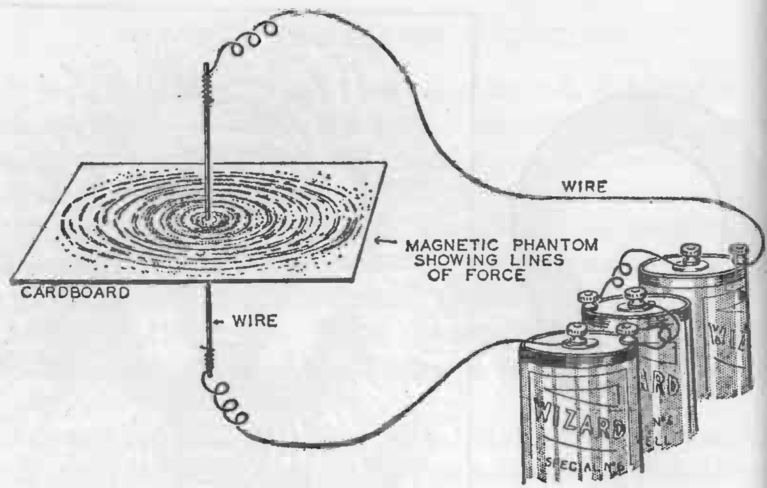
Two or three No. 6 dry cells will provide sufficient current to produce a magnetic phantom about a wire. Pass a No. 16 or 18 B.S. gauge wire through a hole in the center of a piece of smooth cardboard. Connect one end of the wire to the battery.



THE MAGNETIC FIELD OF A HORSESHOE-SHAPED PERMANENT MAGNET
This illustrates a simple and interesting method of revealing the presence of a magnetic field in the space surrounding a permanent magnet. Place a magnet under a piece of cardboard or stiff paper and sprinkle fine iron filings on the paper. If the paper is gently tapped, the iron filings will arrange themselves in curving lines showing the lines of magnetic force.

Sprinkle some iron filings on the card and connect the free end of the wire to the battery. Tap the card. As soon as the phantom forms, disconnect the wire from the battery. Do not allow the current to flow for more than a few seconds or the wire will become very hot and the battery may be injured by the heavy current drain.

The fact that a conductor carrying an electric current produces an electromagnetic field had been known for some time when in 1832 Michael Faraday made the important discovery



INVESTIGATING THE SPACE AROUND A CURRENT-CARRYING WIRE

Two or three dry cells connected in series will provide an electric current strong enough to produce the magnetic phantom which reveals the magnetic field around a wire. Pass the wire through a small hole in the center of a piece of cardboard. Sprinkle fine iron filings on the card, turn the current on and tap the card lightly. As soon as the filings form in circles around the wire, turn the current off. Do not allow the current to flow for more than a few seconds at a time or the wire will become very hot and the battery will be injured by the heavy current drain.

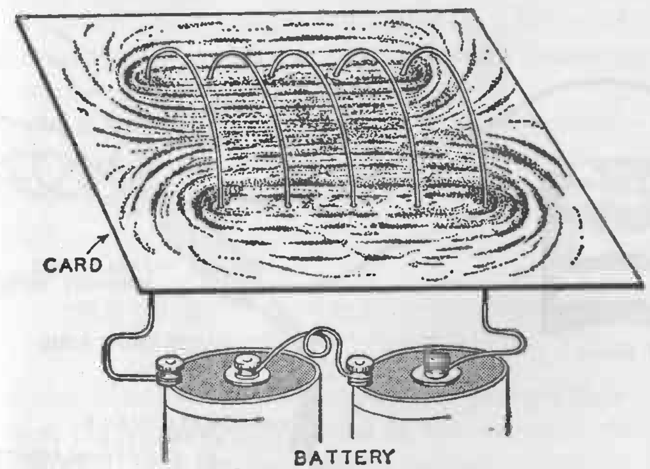
that the action is reversible. Faraday discovered that A MAGNETIC FIELD CAN GENERATE AN ELECTRIC CURRENT IN A CONDUCTOR. This occurs only when the magnetic field is increasing or decreasing in strength or the magnetic field and the conductor are moving in relation to each other. This action, called ELECTROMAGNETIC INDUCTION, may be said to be the foundation of modern electrical engineering. It is of great importance in electronics. Explaining this importance brings us to the subject of:

Inductance and Self-inductance. When a direct-current electromotive force is applied to the terminals of a circuit or to a

coil of wire, the current does not immediately reach its full strength. Neither does the current die away to zero the instant that the electromotive force is removed.

The property or quality of an electric circuit or of some device in the circuit which produces this delaying action is called its SELF-INDUCTANCE.

Any circuit containing self-inductance is an INDUCTIVE CIRCUIT as distinguished from a circuit which has resistance only (called a NONINDUCTIVE CIRCUIT). Self-inductance is a sort of electrical inertia or obstinacy. It gives a circuit the characteristics of a heavy weight. A heavy weight is hard to start moving,

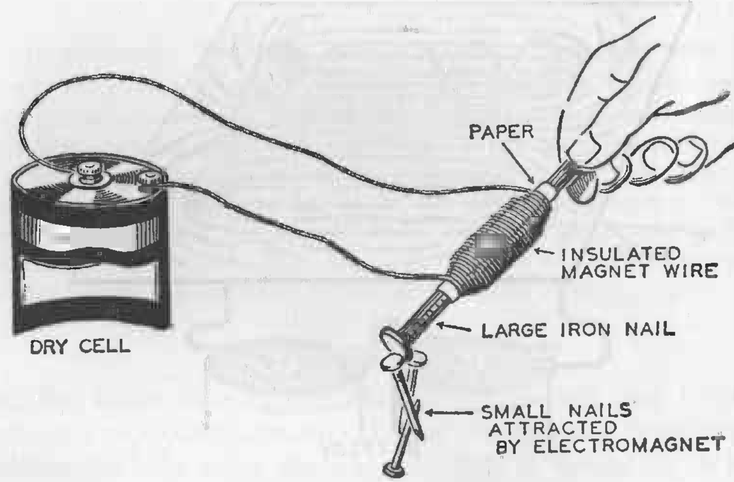


THE MAGNETIC FIELD ABOUT A COIL OF WIRE

Punch two rows of small holes in a piece of stiff cardboard and weave a piece of No. 18 or 20 B.S. gauge magnet wire in the holes so as to form a helix of 5 or 6 turns. Sprinkle a few fine iron filings on the card in and around the helix. Connect the terminals of the coil momentarily to a battery of two dry cells and tap the card gently. As soon as the phantom of the magnetic field forms, disconnect the battery.

and, once started, it resists an effort to stop it. The delaying effect of self-inductance is due to the fact that an electric current generates a magnetic field about a conductor, and, conversely, an electric current is generated by a changing magnetic field about the conductor. When a current flows through a wire, or a coil of wire, the current builds up a magnetic field. During the period when this field is building up or increasing in strength it induces a current in the wire or coil in the opposite direction to the original current. This induced current is a "back" voltage; it opposes the original current and prevents it from flowing at its full strength IMMEDIATELY.

As soon as the circuit is broken so that the original current ceases to flow, the magnetic field which it built up around the



AN EXPERIMENTAL ELECTROMAGNET

If a coil of insulated wire is wrapped around an iron or soft steel core, the metal becomes a magnet while current is flowing through the coil. An experimental electromagnet can be made in a few minutes by wrapping two layers of paper around a large iron nail and then winding on 40 or 50 turns of No. 20–22 B.S. gauge magnet wire. Anchor the outside terminal wire so that it does not unwind.

circuit collapses and disappears. As the magnetic field dies away it induces a current in the circuit which flows in the same direction as the original current. This induced current tries to help the original current to continue flowing. It succeeds for a fraction of a second. As a consequence of this induced current, the original current does not become zero the instant the circuit is broken.

The effects of self-inductance are present in a circuit only when the circuit is made or interrupted or the strength of the current is changing.

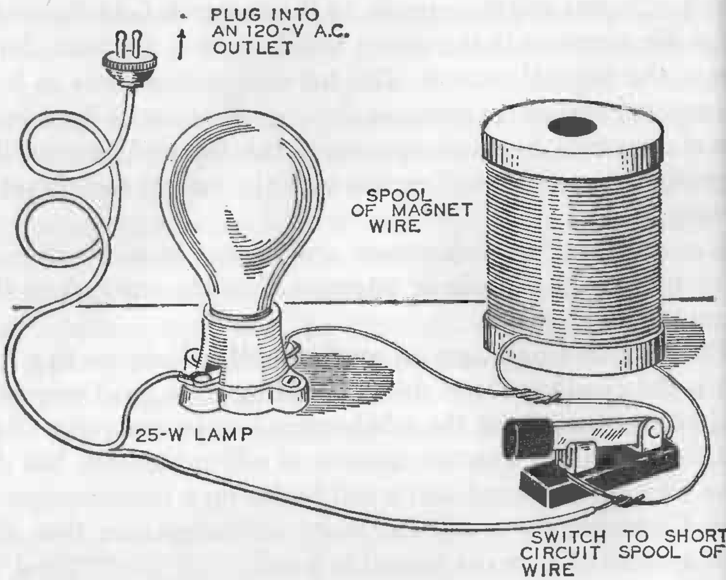
The condition necessary to produce self-inductance in a circuit is the condition favorable to building up a good magnetic field either throughout the whole circuit or in some part of it. A straight wire has a certain amount of self-inductance, but the same wire when wound into a coil builds up a better magnetic field. Consequently a coil has more self-inductance than the same amount of wire not wound in a coil.

A core of iron or steel concentrates and strengthens the magnetic field which a coil can build up, and as a result a coil with an iron core has more self-inductance than a similar coil with an air core.

THE EFFECT OF SELF-INDUCTANCE IN AN ALTERNATING-CURRENT CIRCUIT

Since the effects of self-inductance are present in a circuit only when the value of the current in the circuit is changing, they are evident in a direct-current circuit only when the circuit is made or broken or the strength of the current is changed. Inductance is an important factor in all alternating-current circuits. In radio and electronics it makes "tuning" possible.

If an alternating current is substituted for direct current in a circuit the effects of inductance are more noticeable while the alternating current is flowing than while the direct current is flowing. The current strength and the accompanying magnetic



AN EXPERIMENT WHICH WILL DEMONSTRATE THE CHOKING EFFECT OF IMPEDANCE

Connect a spool of magnet wire in series with a 25-watt lamp. Connect switch to the spool of wire so that the switch can be used to short circ the coil. When this arrangement is connected to the 120-v A.C. th lamp will not light to full brightness when the spool of wire is in circui The impedance (self-inductance and resistance) chokes the curren When the spool of wire is short circuited with the switch the lamp w light with full brilliance.

field of an alternating current are changing constantly, so th effect of the inductance is constant and not momentary as i the case of direct current.

Inductance in a circuit chokes or limits the flow of an alte nating current. This action increases as the frequency of th current is increased. In fact, a coil of wire having a sufficie number of turns and a suitable iron core may completely chok

or prevent an alternating current from passing but will permit a direct current or an alternating current of lower frequency to pass.

Impedance. This is a word which is used frequently in electronics. Impedance is a quality of an alternating-current circuit. The choking action of the self-inductance combined with the ohmic resistance of a circuit is called its IMPEDANCE. It is a good term, one whose meaning is quickly evident if it is thought of as the quality of an alternating-current circuit which impedes the current.

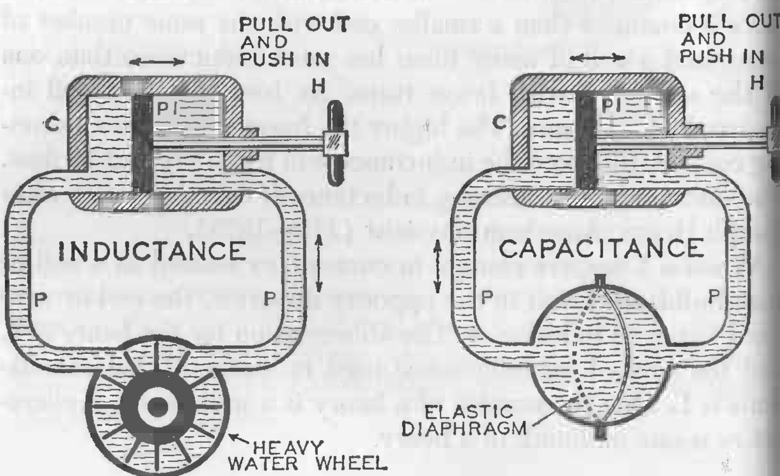
The Henry. The amount of inductance possessed by a coil or winding is determined by the number of turns it contains, the length of the coil, the average diameter and the nature of the core on which the coil is wound. A coil of large diameter has more inductance than a smaller coil with the same number of turns, and a coil of many turns has more inductance than one of the same size with fewer turns. An iron core in a coil increases its inductance. The higher the frequency of an alternating current, the more the inductance will try to prevent its flow. The unit used for measuring inductance is called a HENRY after Joseph Henry, American physicist (1798–1878).

When a 1-ampere change in current per second in a coil or wire builds up 1 volt in the opposite direction, the coil or wire has 1 henry of inductance. The abbreviation for the henry is h, and the symbol for inductance used in mathematical calculations is L. One thousandth of a henry is a millihenry; a microhenry is one millionth of a henry.

THE OPPOSITE EFFECTS OF INDUCTANCE AND CAPACITANCE

Inductance is the quality of an electric circuit which opposes a change in CURRENT, and CAPACITANCE opposes a change in VOLTAGE. Inductance gives a circuit a sort of inertia, makes it sluggish. Capacitance makes a circuit "springy" or elastic. It gives a circuit the ability to store a certain amount of ENERGY which can be transformed into an electric current. Inductance and capacitance give opposite characteristics to an alternating current circuit and consequently are extremely useful in electronics. They enable a radio circuit to be "tuned" so that it will conduct alternating currents of a desired frequency but block alternating currents of other frequencies. Tuning a transmitter so that it will transmit radio waves of a desired frequency or wave length is accomplished by adjusting the inductance and/or capacitance of some of the transmitter circuits.

Tuning a radio receiver by adjusting the inductance and



EFFECTS OF INDUCTANCE AND CAPACITANCE

Inductance and capacitance give opposite characteristics to an alternating current circuit. Inductance gives it inertia, makes it sluggish. Capacitance makes a circuit "springy."

This may be illustrated by an analogy between an alternating-current circuit and a hydraulic system as shown in the sketches above. Two cylinders C are each fitted with a piston P1 which can be moved back and forth by pushing and pulling on the handle H.

capacitance of some of its circuits eliminates undesirable or interfering messages and gives a receiver SELECTIVITY. The selectivity of a receiver is its ability to discriminate between several frequencies that are close together—the ability to concentrate on one signal and reject all others.

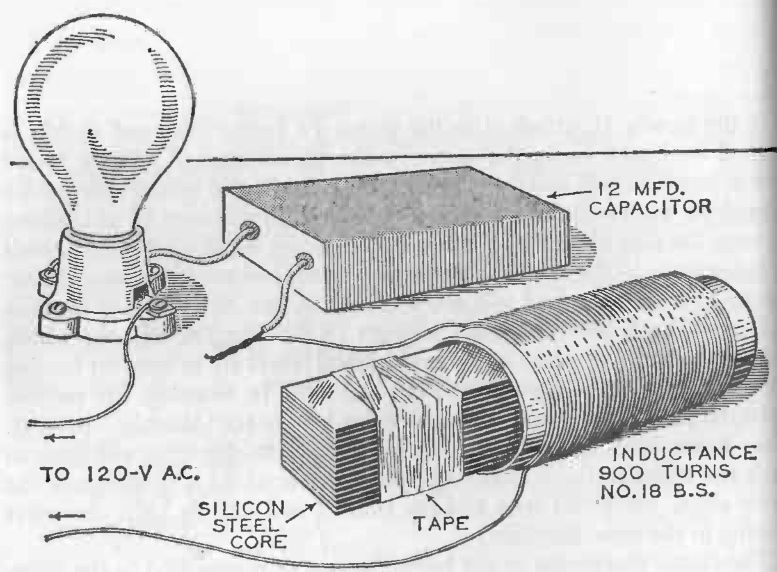
Tuning radio apparatus can be accomplished to some extent by increasing or decreasing the physical length of the antenna and some of the circuits. But the most efficient and convenient method is to use adjustable inductances and devices called CAPACITORS (see Chapter Three) which have adjustable capacitance.

If the handle H, attached to the piston P1 in the left-hand sketch, is pushed back and forth, the water in the pipe system P will be forced first in one direction and then in the other as indicated by the arrows with a head on each end. The pump corresponds to a source of alternating current; the loop of pipe to the circuit. The heavy water wheel corresponds to inductance in the circuit. The surging current of water pushing against the paddles of the wheel will move it first in one direction and then in the other. Each time the water changes its direction, so will the wheel, but not instantly. Because it is a heavy wheel it will try to keep on turning for a moment. It is slow in starting and slow in stopping. Its paddles resist the push of the water when the water tries to start the wheel moving. They resist the water when the latter changes its direction and tries to push the wheel in the opposite direction. If the wheel is turning and the water stops, the wheel tries to keep turning and also to keep the water moving in the same direction.

The elastic diaphragm in the hydraulic system represented in the right-hand sketch may be likened to capacitance in an electrical circuit. When the handle H of the pump is pushed in and out the water in the pipe loop P is sent surging first in one direction and then in the other. The water cannot pass the diaphragm. It can only stretch it, first in one direction and then in the other. It resists toward the end of each stroke of the piston as the elastic diaphragm becomes stretched tighter but each time the water changes its direction, the elasticity of the diaphragm helps to start it moving.

Resonance. Since capacitance and inductance produce opposite effects, a combination of the two in proper proportion can be used to neutralize each other's effects and bring about a state of RESONANCE. A circuit in resonance behaves as though it had neither inductance nor capacitance. Alternating current of the proper frequency flowing in a resonant circuit obeys Ohm's law and its strength depends upon the electromotive force and resistance only.

The phenomenon of resonance in a 60-cycle A.C. circuit can be shown by the following experiment. Because of the cost



A DEMONSTRATION OF RESONANCE

Moving the steel core in and out of the coil will vary the inductance in the circuit. A position of the core will be found at which the lamp burns brightly. At this point, the inductive reactance of the coil and the capacitative reactance of the condenser are equal and neutralize each other. This is a condition of resonance.

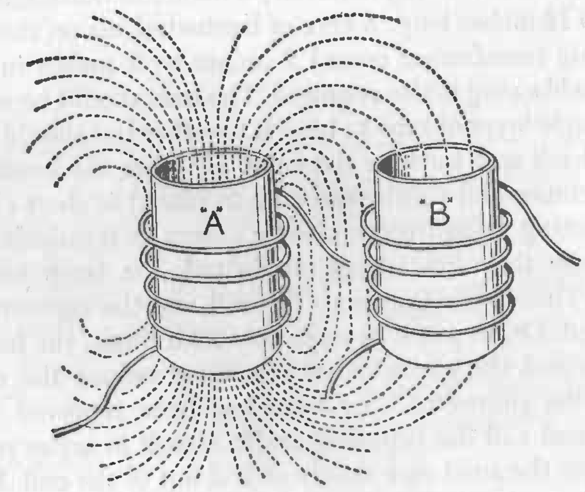
of materials this demonstration is more suitable as a high school classroom demonstration than an amateur demonstration.

Connect a 12 mfd. capacitor in series with a variable inductance of at least 0.5 henry and a 60-watt incandescent lamp bulb to the 120-volt A.C. line as shown in the diagram. Lamp, capacitor, and inductance are connected in series. In series means all the current must flow in turn through each device. The capacitor can be enough 1 or 2 mfd. filter capacitors connected in parallel to aggregate 12 mfds. Do not use electrolytic capacitors. The inductance should consist of 900 turns of No. 18 B.S. enamel covered magnet wire wound on a cardboard tube (or other insulating material) 3 inches in outside diameter and 10 to 12 inches long. A core of laminated silicon steel (used for making transformer cores) 2 inches by 2 inches in section and 12 inches long is also required. The core should be wrapped with a single layer of tape to bind it together but should be able to slide back and forth in the tube. If either the capacitor or the inductance coil (with steel core in place) is short-circuited by connecting a short piece of wire across its terminals and its influence in the circuit thus eliminated, the lamp will glow brighter. This shows that both the coil and the capacitor limit the current. Or, to put it in more scientific terms, the inductive reactance and the capacitative reactance reduce the current.

When the short-circuiting wire has been removed so that both the coil and the capacitor are in circuit in series with the lamp, move the steel core slowly in and out of the coil. Moving the core in and out of the coil will vary the inductance of the coil. A certain position of the core will be found where the inductance of the coil will be such that the lamp will burn brightly. At this point the inductive reactance of the coil and the capacitive reactance of the condenser are equal and neutralize each other. This is a condition of resonance and the current flowing through the lamp is limited only by the ohmic resistance of the coil and lamp.

A QUALITY OF TWO COILS CALLED MUTUAL INDUCTANCE

If two coils of wire are placed so that the magnetic field of one coil, A, carrying an alternating current, is interlinked with the turns of the other coil, B, an electromotive force will be INDUCED in B. Energy is transmitted across the space between the two coils by means of the changing magnetic field. Two coils or circuits arranged in this manner are said to be INDUCTIVELY COUPLED. The closer together the coils are, the "tighter" or



A QUALITY OF TWO COILS OR CIRCUITS CALLED MUTUAL INDUCTANCE This diagram shows two coils of wire placed alongside each other. Coil (A) is connected to a source of alternating current. When two coils are placed so that the magnetic flux of one coil (A) is linked with the turns of wire on the other coil (B) the linkage between the two coils (inductances) is called their mutual inductance. When two coils have mutual inductance energy can be transferred from one coil to the other. The mutual inductance will vary greatly with the position of the coils relative to one another.

"closer" the coupling is said to be. The coupling is closest when the entire magnetic field of one coil links with all the turns of the other coil.

The magnetic linking between two inductances is called their MUTUAL INDUCTANCE. Another way of saying the same thing is to define mutual inductance as the common property of two inductances which gives them "transformer action" so that energy is transferred from one to the other without any actual electrical connection or conducting path between them.

The mutual inductance between two coils or circuits varies with the shape and size of the coils or circuits, their distance apart, their relative positions, the number of turns, and the nature of the surrounding medium, whether air, iron, etc.

Transformers. The fact that a coil carrying an alternating current can INDUCE a current in a nearby coil makes possible the extremely useful device called a TRANSFORMER.

A transformer is a device for transferring energy in an alternating-current system from one circuit to another, for raising or lowering alternating current voltages and amperages, and for matching the impedance between two portions of a circuit. The transmission of alternating-current power, the sending and receiving of radio signals, the operation of much electronic apparatus, the production of X-rays, and the electrical welding of metals are only five uses out of thousands for which transformers are utilized.

Energy in the form of a low-voltage electrical current may be transformed to electrical energy at high voltage by means of a transformer—or vice versa, from energy at high voltage to energy at low voltage. In like manner, current in one circuit may be transformed into current of either smaller or greater volume in another circuit.

A transformer usually consists of two coils of wire having a common area of magnetic field. In order to understand how this device operates, it is only necessary to remember that when an electric current passes through a coil, a magnetic field is set up.

Also that when a magnetic field passes through a coil, a curren is induced in the coil while the magnetism is changing i strength—growing either weaker or stronger.

If an alternating current is sent through one of the coi (called the PRIMARY) of a transformer, the magnetic field pr duced increases and decreases with each alternation. This in creasing and decreasing magnetic field will induce an alterna ing current in the second coil (called the SECONDARY).

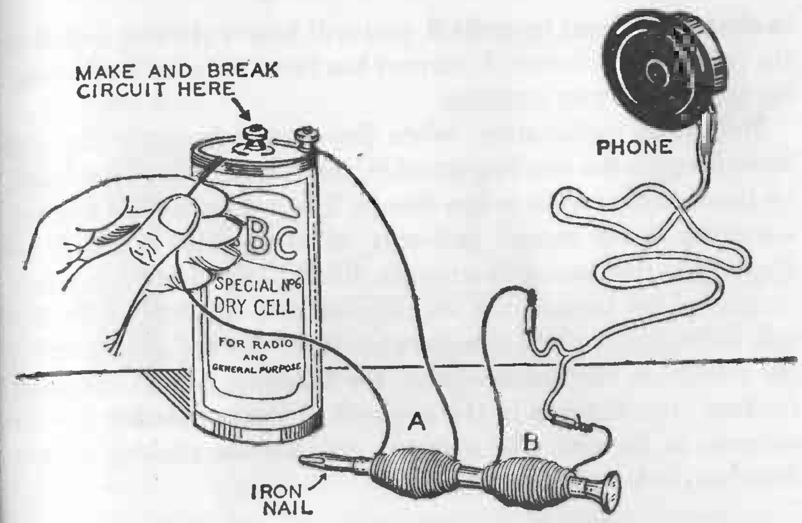
The coil which furnishes the inducing magnetic field in transformer is called the PRIMARY WINDING. In an engineer language, the winding connected to the supply circuit is th primary. The winding in which current is induced is th SECONDARY.

Transformers are constructed both with and without an iro core in the center of the windings. (It is customary to speak o "iron" transformer cores, actually they are SOFT STEEL.) I circuits where the frequency of the primary current is low, (6 cycles) as in power transformers, soft steel cores are employe because of their higher efficiency in transferring energy fro the primary to the secondary coil. Radio circuits use tran formers with soft steel cores in the 60-cycle and audio-frequen sections and use transformers with air cores or powdered ir oxide in the radio-frequency circuits.

AN EXPERIMENT WITH ELECTROMAGNETIC INDUCTION

You can demonstrate the principle of the transformer by experiment which will show that an electromotive force can induced in a circuit by another circuit not connected to electrically.

Wrap two or three layers of paper around a large iron na The paper will insulate the nail from the wire which is to wound around it. Wind 40 or 50 turns of fine magnet wi around the nail (any size of wire, from No. 20 to No. 36 B gauge, will be suitable) so as to form a coil near one end. W



A DEMONSTRATION OF ELECTROMAGNETIC INDUCTION

The two coils of insulated magnet wire wound around the iron nail are not electrically connected. They are, however, coupled or linked magnetically by the iron nail, and a change in the current flowing through coil A will change the magnetic field and induce a current in coil B, as will be indicated by the sounds in the telephone receiver. The text tells how to perform the experiment.

a second and similar coil around the other end of the nail. The terminals of each coil can be anchored with adhesive tape and prevented from unwinding. The two coils are not electrically connected. They are separate coils which are wound on the same core and therefore MAGNETICALLY linked.

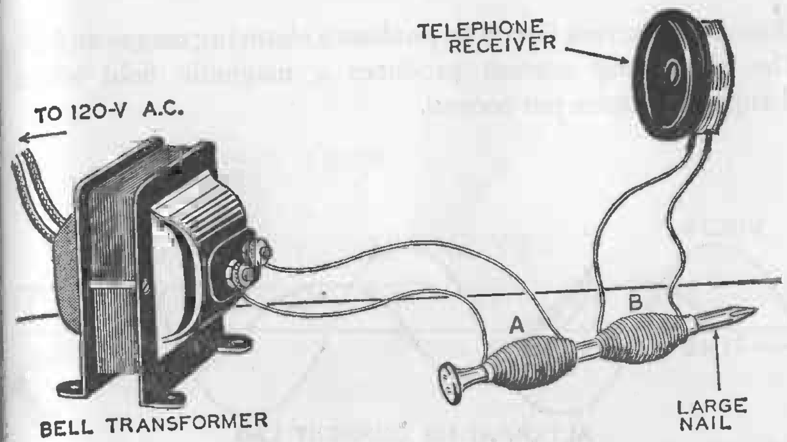
Connect the terminals of one of the coils (the primary) to a dry cell and the terminals of the other coil (the secondary) to a telephone receiver. Hold the telephone receiver to your ear. You will not hear any sounds in the receiver while the current from the dry cell is flowing steadily through the coil. But if you disconnect one wire from the cell and make and break the circuit by tapping the wire against the terminal of the cell so as to shut the current on and off, you will hear a clicking sound in the telephone receiver. A current has been induced in the coil CONNECTED TO THE RECEIVER.

Here is an explanation: when the current from the dry cell flows through the winding steadily, the magnetic field produced by the flow of current is also steady. The magnetic field induces a current in the second coil only when the field is either increasing or decreasing in strength. But when the current is shut on and off by tapping the wire against the terminal of the dry cell, the magnetic field changes each time. The coil connected to the telephone receiver is within the influence of this magnetic field and the changes in the strength of the magnetism induce currents in the coil. The currents produce the clicking sounds heard in the telephone receiver.

AN EXPERIMENT DEMONSTRATING THE PRINCIPLE OF A TRANSFORMER

If a bell-ringing transformer connected to the 120-v alternating current supply is substituted for the dry cell used in the experiment just described it will demonstrate the operation of a transformer. Connect one of the coils (primary) wound around the nail to the secondary terminals of a bell-ringing transformer or to the secondary of a small step-down transformer of the type used to operate miniature railways and electrical toys. Connect the other coil (secondary) wound on the nail to the telephone receiver. Connect the primary of the bell-ringing or step-down transformer to the A.C. house-lighting circuit.* Listen in the

* A bell-ringing transformer has four terminals. Usually, two of them are wires and two are screws or nuts. The wires are the primary terminals and should be connected to a piece of double conductor lamp cord. The other end of the lamp cord should be connected to an attachment plug. All connections should be covered with insulating tape. Do not push the plug into the power outlet until all connections have been made.

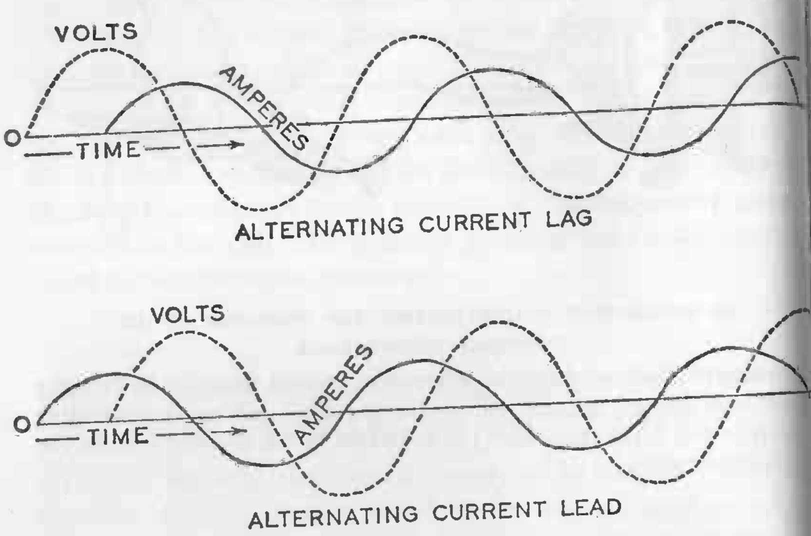


AN EXPERIMENT DEMONSTRATING THE PRINCIPLE OF AN IRON-CORE TRANSFORMER

The magnetic field produced by alternating current from the bell-ringing transformer flowing through coil A (the primary) induces an alternating current in coil B (the secondary) as indicated by the 60-cycle hum in the telephone receiver.

telephone receiver and you will hear the low-pitched musical note called the "60-cycle hum." This sound has a pitch of 120 vibrations per second; in the musical scale it is the note B in the octave below middle C. The hum is produced by 60-cycle alternating current induced in the secondary by 60-cycle alternating current flowing in the primary.

The 60-cycle A.C. fed into the primary from the bell-ringing transformer produces a continuously changing magnetic field which builds up and dies away 120 times per second. The secondary coil connected to the telephone receiver is within the influence of this changing magnetic field, and consequently currents are induced in the coil which produce sounds in the telephone receiver. It is unnecessary to make and break the alternating-current circuit to produce a changing magnetic field. The alternating current produces a magnetic field which changes 120 times per second.



LAG AND LEAD, EFFECTS OF INDUCTANCE AND CAPACITANCE IN AN ALTERNATING-CURRENT CIRCUIT

The dotted curve represents the VOLTAGE impulses of an alternating current. The CURRENT or amperage impulses are the solid line curve. The upper diagram shows the current impulses occurring a little later or lagging behind the voltage impulses, an effect called LAG which is produced by inductance.

Capacitance has the opposite effect. It produces LEAD. The CURRENT or amperage impulses lead the VOLTAGE impulses.

CHAPTER THREE

SOME OF THE COMPONENTS WHICH COMPRISE ELECTRONIC CIRCUITS

All the parts used in building the apparatus described in this book are standard parts which are manufactured in large quantities. Dealers who handle amateur radio equipment have them in stock or can obtain them for you in a few days. Send for the catalogs of some of the firms which advertise in the radio and popular scientific magazines. In these catalogs you will find various tubes, sockets, transistors, capacitors, resistors, and other components you may need. You can purchase them by mail if you wish. Radio repair- and servicemen have a stock of parts used in repairing radio and television receivers and can supply tubes, capacitors, and resistors.

The principal parts, or components, of electronic circuits are described in this chapter and the two chapters which follow.

RESISTORS

Resistance in some circuits is a nuisance and objectionable. It wastes energy by converting electrical energy into heat energy at times when the conversion is undesirable. It also limits the volume of current which can flow.

On the other hand, resistance is useful in some circuits. It can be a means of limiting or controlling the flow of current; it can regulate voltage and generate heat where heat is wanted.

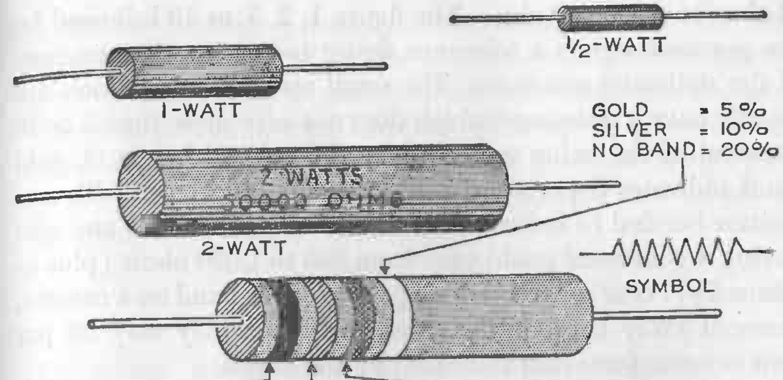
Small units of resistance called RESISTORS are used in radio circuits to:

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
4. Prevent a circuit from oscillating
5. Provide a leakage path for currents

These five uses will not be explained in detail at this point. Further information about resistors themselves is more important. Resistors are usually more numerous in electronic circuits than any other single component. The common form of fixed resistor is a small cartridge-shaped unit but the name also applies to the various forms of adjustable voltage dividers, rheostats, potentiometers, volume controls, and ballasts used in electronic circuits.

Resistors are rated according to their resistance in ohms, their power-carrying capacity in watts, and their accuracy. The rating in watts is the maximum number of watts which can be carried safely by the resistor without its becoming overheated. Radio resistors are made in various sizes to handle from ¼ watt to 100 watts. The physical dimensions vary in accordance with the wattage rating. Those with the highest wattage rating are the largest. One of the illustrations shows the exact size of ½-, 1- and 2-watt resistors. These are the wattage ratings used most often in radio receivers, amplifiers, and other low-power electronic apparatus. Because of the small size of cartridge-type resistors rated at 1 watt and less, there is not room on them for printed specifications. Therefore the values are indicated by several colored rings starting at one end. The color code for resistors is illustrated nearby. It is easy to use.

When resistors are listed in a catalog, the figures showing their resistance values are usually followed by the Greek letter omega (Ω). Omega is the symbol for ohms. The letter K is often used to indicate 1,000 where space is restricted. MEG is an abbreviation for ONE MILLION. A 3 meg. resistor has a resistance



FIRST NUMBER	
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

SECOND NUMBER	
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

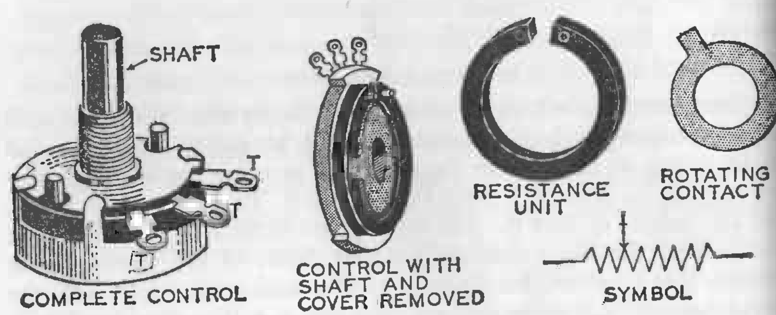
MULTIPLIER	
BLACK	1
BROWN	10
RED	100
ORANGE	1,000
YELLOW	10,000
GREEN	100,000
BLUE	1,000,000

RESISTOR COLOR CODE

You can ascertain the capacity of a resistor by its size by comparing it with the resistors in the above sketches which are full size. You can find out its resistance in ohms by the numerals or color bands with which it is marked. Each band is code for a numeral. To interpret the bands, hold the resistor so that the end bearing the bands is at your left. The band nearest the end represents the first figure of the resistance; for example, if it is yellow, the figure is 4. The second band represents the second figure. If it is violet, the second figure is 7. The third band indicates the number of zeros to be placed after the first two figures. If it is red, place two zeros after 47. The resistance is therefore 4700 ohms. If there is a fourth band and it is silver, it indicates that there may be a 10 per cent variation in resistance. A gold fourth band indicates a 5 per cent variation in resistance and no fourth band tells that the resistance may range 20 per cent either above or below 4700.

of close to 3,000,000 ohms. The figure 1, 2, 5, or 10 followed by the per cent sign is a tolerance figure indicating the accuracy of the indicated resistance. The small resistors in common use usually have a resistance which does not vary more than 5 or 10 per cent of the value indicated by the colored bands. A gold band indicates 5 per cent; a silver band 10 per cent. Thus a resistor banded to indicate a resistance of 1,000 ohms and also having a gold band could vary from 950 to 1,050 ohms (plus or minus 5 per cent). If there is no gold or silver band on a resistor, throw it away because its actual resistance may vary 20 per cent or more from that indicated by the bands.

Variable Resistors. A variety of variable resistors called CONTROLS are used in electronic circuits. Controls are provided with a rotary knob. Turning the knob varies the resistance. Variable resistors have three terminals and can be connected to control either current or voltage. When used to control voltage,



CONTROLS

Variable resistors called controls are required in many electronic circuits. They can be adjusted by turning a knob attached to the projecting shaft. Controls have three terminals (T, T, T). The two outer terminals are connected to the ends of a circular resistor. The middle terminal is connected to a rotary contact which slides over the resistor when the control knob is turned. Controls can be fitted with an "on" and "off" switch when desired. Directions for attaching the switch are packed with it.

a control is termed a potentiometer. Many controls are constructed so that they can be fitted with a switch. It is necessary merely to remove the metal cover and put the switch in place. The switch is used to open and close a circuit. Variable resistors are made in many sizes and types ranging from 2 to 300 watts in capacity and from a few ohms to 10,000,000 (10 meg.) in resistance.

CAPACITORS

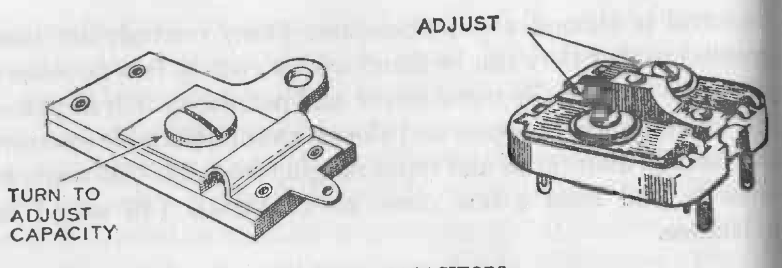
Capacitors are an essential part of radio transmitting and receiving circuits, automobile ignition equipment, amplifiers and other electronic devices—telephone, telegraph, railway signaling equipment, etc.

Essentially, a capacitor consists of two metal conductors, usually metal sheets or plates, separated by an insulating material such as air, paper, oil, mica, porcelain, etc., called the DIELECTRIC.

In order to have a partial understanding of the action and effect of a capacitor in a circuit it is necessary to know the meaning of the term ELECTROMOTIVE FORCE. Electromotive force was discussed in a preceding chapter but is explained again at this point so that its meaning will be in mind when reading about capacitor action.

Two words in common usage for electromotive force are VOLTAGE and POTENTIAL but they do not convey the meaning quite accurately. Electromotive force is the name for the force that causes electrons to move. It almost explains itself, for "motive" means "causing motion."

If a direct-current electromotive force is applied to the plates of a capacitor, the capacitor becomes CHARGED. For a very short time electrons move along the conductor connecting the source of electromotive force to the capacitor. The electrons attempt to flow through the dielectric and back to their source. But since the dielectric is an insulator the circuit is incomplete



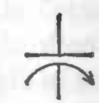
TRIMMER CAPACITORS

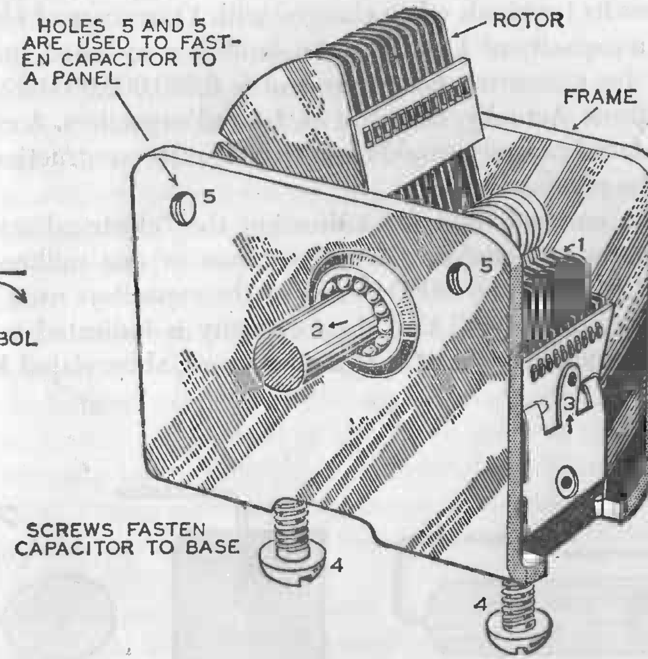
Trimmer capacitors are small adjustable capacitors whose capacity can be increased or decreased by turning an adjustment screw. Certain types of radio-frequency transformers and gang-tuning capacitors are fitted with trimmer capacitors which are used, for example, to align the tuned circuits of superheterodyne receivers so that moving the tuning control produces the same frequency change in each circuit.

and no electron flow occurs THROUGH THE CAPACITOR. Instead, a surplus of electrons builds up on the negative plate and a shortage of electrons is established on the positive plate. Electrons always have a tendency to move about and establish a state of balance. They try to establish a state in which there are the same number of electrons on both sides of the capacitor. They cannot establish a state of balance by passing through the dielectric because it is an insulator.

The surplus of electrons on the negative plate stresses or strains the dielectric. This stress or strain is known as ELECTROSTATIC STRESS. It is a form of stored energy. The dielectric tries to rid itself of the strain and resume its normal state. It will do so if the terminals of the capacitor are connected by a wire. The surplus of electrons on the negative plate, which is the cause of the strain, rushes through the wire and equalizes the shortage of electrons on the positive plate. The strain on the dielectric is relieved; the dielectric returns to its original condition and in so doing its stored electrostatic energy is converted into electric energy in the form of an electric current.

The discharge current charges the capacitor in the opposite direction so that the dielectric is again stressed. Under proper conditions, this discharging and recharging action may occur several times, each surge of electrons becoming much weaker than the preceding one. The current produced in the discharge





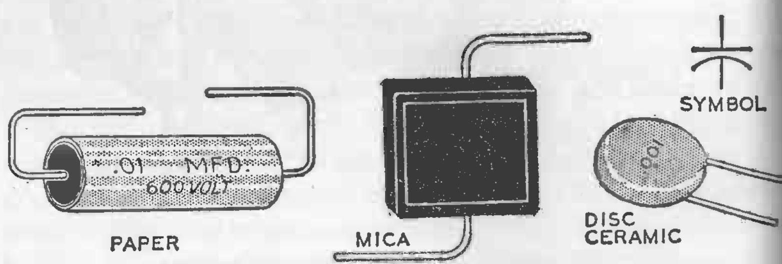
MIDGET ONE-GANG TRF VARIABLE CAPACITOR

Used for tuning radio receivers. Has a minimum and maximum capacity of 10 to 365 mmfd. May be either base or panel mounted. The dielectric between the fixed and rotary plates is air. The tuning capacitors made by different manufacturers may vary slightly in some details but their basic design is essentially the same. (3) indicates the terminal of the fixed plates. The shaft (2) should be provided with a plastic knob. 4 and 4 are base mounting screws. (1) indicates the stator.

circuit thus may be a high-frequency alternating or oscillatory current of short duration.

The Meaning of Capacity or Capacitance. Capacitors are measured by their CAPACITY to be charged with energy. The unit of capacity or CAPACITANCE as it is also called, is the FARAD, so named in honor of the scientist Michael Faraday. A capacitor of such dimensions that it would have a potential of 1 volt across its terminals when charged with 1 COULOMB of electricity has a capacity of 1 FARAD. A coulomb is a so-called "practical" unit for measuring electricity and is 6,280,000,000,000,000,000 electrons. Actually, there are no 1-farad capacitors. A capacitor of 1-farad capacity would be so large that its construction would not be practical.

The common unit for indicating the "electrical size" of a capacitor is therefore the MICROFARAD or one millionth of a farad, abbreviated MFD. Many of the capacitors used in electronics are so small that their capacity is indicated in micromicrofarads or millionths of a microfarad, abbreviated MMFD.



SMALL FIXED CAPACITORS

These three types of small capacitor represent three methods of manufacturing and employ three different materials as dielectric—paper, mica, and a ceramic. Paper capacitors are usually made in larger sizes than mica and ceramic capacitors. Mica fixed capacitors have the smallest internal losses.

The area of capacitor plates, the distance between them, and the substance of which the dielectric is made determine the capacity of a capacitor.

Capacitors are manufactured in a great variety of types and sizes but those for use in electronics may be divided into two classes:

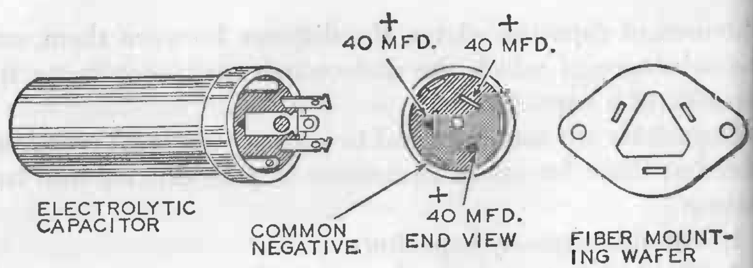
1. Variable capacity capacitors
2. Fixed capacity capacitors

Variable capacitors are used for tuning. The common type is so constructed that the capacity may be gradually and continuously increased or decreased by turning a knob. It consists of a number of movable, semi-circular metal plates which rotate between another group of rigid or fixed plates so as to interleave. The movable plates do not touch or make electrical contact with the fixed plates. The air between the plates is the dielectric.

There are many varieties and sizes of fixed capacitors. Their capacity cannot be changed. Some have paper, mica, or porcelain dielectric. Others may be of the wet or dry electrolytic type and employ a thin layer of aluminum oxide as the dielectric. They may be cylindrical, rectangular, or disk-shaped and enclosed in paper, plastic, porcelain or metal cans. Fixed capacitors are usually marked with numerals or with a color code to indicate their capacity.

The Purpose and Action of Fixed Capacitors. As stated previously, variable capacitors are used in electronic circuits to tune or adjust circuits so that they will respond to a desired frequency.

Fixed capacitors are not used for tuning. They have other purposes. Fixed capacitors can be used to prevent direct currents from passing through a circuit but IN EFFECT to let alternating current pass. The qualifying words "in effect" are used in the previous sentence because alternating currents do not actually pass through capacitors with a high-resistance dielec-



ELECTROLYTIC CAPACITORS

Electrolytic capacitors are large-capacity fixed capacitors. Their principal use is in power supply circuits. The dielectric is a thin film of aluminum oxide formed by electrolytic action. More than one capacitor is often enclosed in the same aluminum or cardboard container. The capacitor illustrated above consists of three 40 mfd. capacitors enclosed in the same aluminum can. It is used in building the 5-watt push-pull amplifier described in a later chapter. The polarity of electrolytic capacitors is marked on the container and must be considered when the capacitor is used. If connected "backward" the electrolytic type has no capacity.

tric but the effect in the circuit is the same as if they did. This action of a capacitor cannot be explained in simple language and an attempt to do so would be out of place at this point.

Condensers of small capacity will "in effect" pass radio-frequency currents but not audio-frequency currents. They also block direct current. Condensers of greater capacity "pass" audio-frequency currents as well as radio-frequency currents but block direct currents. It is therefore possible by using a capacitor of correct capacity to permit radio frequencies to pass and to block audio-frequency and direct currents. Capacitors used for this purpose are usually termed "bypass" capacitors. The capacities used for bypassing radio frequencies in broadcast receivers usually range from 0.1 mfd. to .002 mfd. (depending upon the frequency of the current). Those for bypassing audio frequencies vary from 0.25 mfd. to 1 or 2 mfd.

TRANSDUCERS

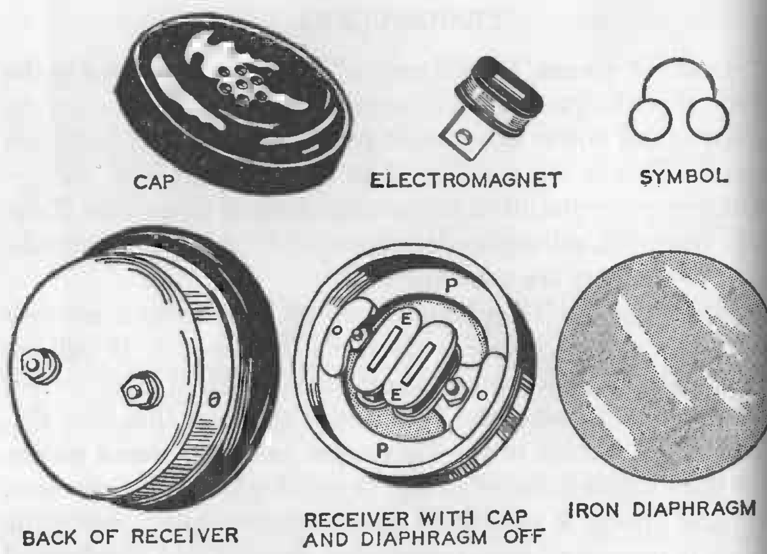
Transducer means "to lead across." The term is applied in the science of physics to devices actuated by power from one system and supplying power to a second system. In everyday language a transducer can be considered to be a converter of energy.

Electronic circuits often utilize some form of transducer. Telephone receivers, microphones, phonograph pickups, photocells, and loud-speakers are transducers.

Electromagnetic Telephone Receivers. A telephone receiver is one of the most sensitive electrical instruments. It will respond to an almost infinitesimal amount of current. The current creates an electromagnetic field which moves a thin iron diaphragm. The motion of the diaphragm produces sound waves. Thus three conversions of energy occur in a telephone receiver. Electrical energy is converted into magnetic energy, magnetic energy is converted into mechanical energy, and mechanical energy is converted into sound.

The telephone receivers used in radio are the round flat form called "watch-case receivers" which may be held against the ear by a headband.

Amateur (ham) radio operators call them "cans." A "can" designed for radio use does not differ in principle from the common telephone receiver. It consists of a circular sheet-iron diaphragm which rests on the edge of the receiver case close to the poles of two small electromagnets. An electromagnet is a coil of wire wound around an iron core. The electromagnets in a telephone receiver are mounted on the poles of a small permanent magnet. The magnetic flux of the permanent magnet exerts a pull on the diaphragm at all times. When current flows through the coils of the electromagnet the coils produce a magnetic field which increases or decreases the pull of the permanent magnet on the diaphragm depending upon the direction of the current. The variation in the magnetic-pull on the diaphragm causes it to move. When the diaphragm moves, it produces sounds.



INSIDE A TELEPHONE RECEIVER

A telephone receiver is a transducer which changes electrical currents into sounds. The telephone receivers used for radio work are the flat type commonly known as "watch-case" receivers. A complete radio headset consists of a pair of watch-case receivers fitted with a headband. The receivers are connected in series by a flexible wire or cord.

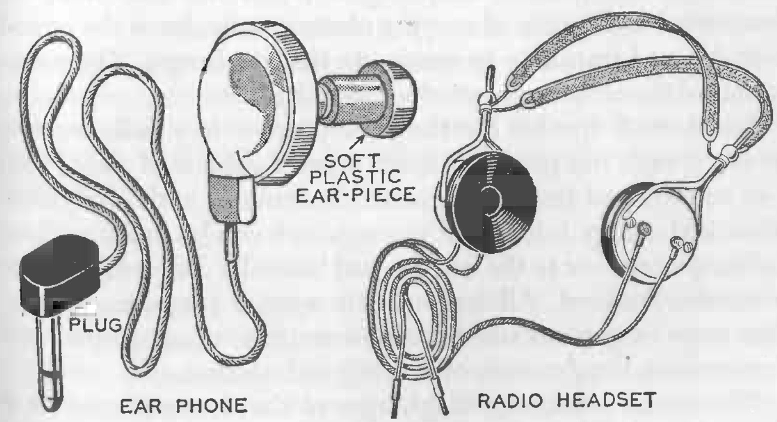
A complete radio headset consists of a pair of watch-case receivers fitted with a headband so that a receiver is held close to each ear. The receivers are connected in series with each other by a flexible wire called the "cord." The free end of the cord terminates in two metal tips. These tips are the terminals used to connect the headset to radio receivers, amplifiers, etc.

The electromagnets in a telephone receiver for radio use are wound with many more turns of wire than the electromagnets in the ordinary telephone receiver. Consequently a radio headset will respond to much weaker currents than an ordinary

telephone receiver. The direct current resistance of a radio headset is usually 2,000, 3,000, or 4,000 ohms. The retail price, depending upon the brand, ranges from $2.00 to $10.00 per set.

A radio headset requires care if it is to retain its sensitivity. Do not drop it and do not unscrew the caps and handle the diaphragms. Keep the caps screwed tightly on the case. A diaphragm is easily bent and the receiver thereby thrown out of adjustment.

Crystal-Type Headphones. These might be termed laboratory-type phones. They respond to a wide range of frequencies, are very sensitive, and produce sounds of greater fidelity than electromagnetic receivers. Although they are used for the same purpose, the construction of the crystal-type headphones differs



EARPHONE

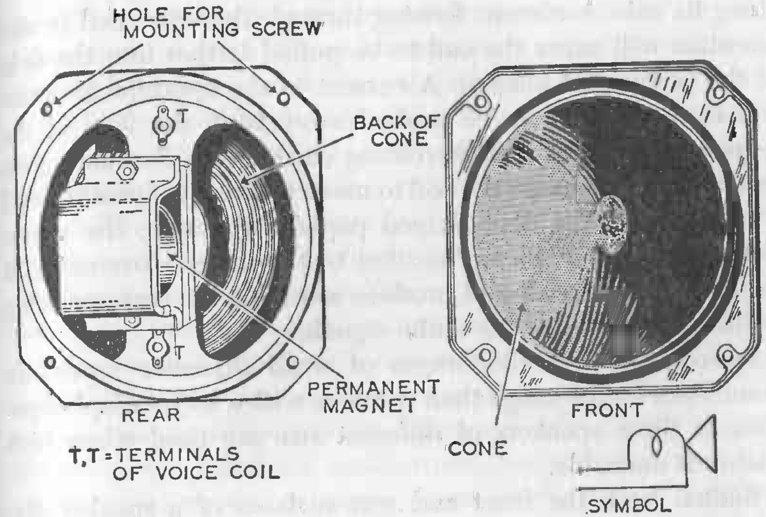
There are two types of earphone, crystal and dynamic. Both are miniature editions of the common telephone receiver built for radio use. Compact, miniature radio receivers utilizing transistors are usually equipped with an earphone. The above sketch of an earphone is full size. The right-hand sketch shows the common radio headset (not full size) complete with cord and headband.

from that of the electromagnetic type. The fact that certain crystals will be distorted mechanically if an electromotive force is impressed upon them is used in the construction of "crystal" phones.

One of the most interesting electrical phenomena is that known as PIEZO-ELECTRICITY. Piezo is a Greek word which means "pressure" and piezo-electricity means "pressure electricity." Certain crystals, such as quartz, tourmaline, Rochelle salts, and cane sugar, are called piezo-electric crystals because they produce electricity when squeezed or subjected to pressure. These same crystals become distorted mechanically each time that an electromotive force is impressed upon them. This characteristic is used in the construction of crystal telephone receivers. No coils or magnets are used. A crystal of Rochelle salts is mounted between two electrodes. One electrode is mechanically connected to the receiver diaphragm. When the electrodes are connected to a source of varying electromotive force the crystal vibrates and transmits its motion to the diaphragm. The movements of the diaphragm produce sound waves.

Speakers. A speaker has the same purpose in a radio receiver as the phones but produces much greater volume of sound than can be obtained from headphones. It converts audio-frequency electrical energy into sound waves which can be heard without holding a receiver to the ear. Several basically different speakers are manufactured. All but one are special purpose speakers. The type in general use in radio receivers, phonographs, and intercoms is the dynamic or moving-coil speaker.

The sound-producing diaphragm of the dynamic speaker is cone-shaped and made of paper. It is supported along the edge of the open end by a metal ring. A small coil of wire, called the voice coil, is attached to the small end of the paper cone. The voice coil is an exceedingly light cylindrical coil of small diameter wire. It usually consists of about 50 turns of .007-inch diameter wire wound in a double layer on a small paper tube. The coil is mounted so that it "floats" in the magnetic field of a



REAR AND FRONT OF A SMALL SPEAKER

A speaker, also called a loud-speaker, is quite similar to a telephone receiver in principle. It is a transducer for converting electric currents into sound waves. It produces much louder sounds than a telephone receiver but is not as sensitive to weak currents and so is usually connected to an amplifier.

strong permanent magnet. The magnet is a short cylinder-shaped steel bar slightly smaller in diameter than the internal diameter of the voice coil. The permanent magnet is mounted in an iron frame with a circular opening in front. The opening is slightly larger than the outside diameter of the voice coil. The coil is located between the poles of the magnet and close to them but does not touch them.

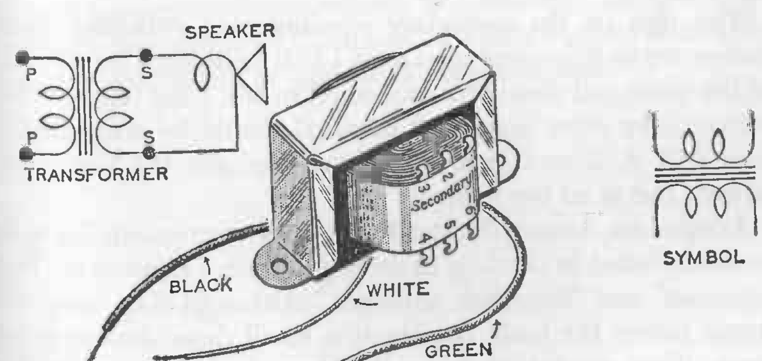
When an electric current passes through the winding of the voice coil, the coil produces a magnetic field of its own. The reaction of this field with that of the permanent magnet produces forces which move the coil back and forth a short distance along its axis. A current flowing through the voice coil in one direction will cause the coil to be pulled farther into the field of the permanent magnet. A current in the opposite direction will cause the coil to be pushed away from the field of the permanent magnet. An alternating current or a fluctuating direct current will cause the coil to move to and fro. Since the coil is attached to the cone-shaped paper diaphragm, the movements of the coil are transmitted to the cone. Movements of the cone push the air and produce sound waves corresponding to the fluctuations of the audio signals.

Speakers with a diaphragm of small diameter reproduce sounds in a higher range than speakers with a larger diaphragm. Two or three speakers of different size are used when high fidelity is desirable.

Baffles. Both the front and rear surfaces of a speaker diaphragm generate sound waves. Unless the speaker is mounted correctly the sound waves from the back of the diaphragm may mingle with those from the front and alternately reinforce and neutralize each other. This undesirable action can seriously interfere with the volume and fidelity of the low notes of voice and music. It can be avoided by the use of a BAFFLE. This device is a partition, flat surface or open-backed box, so designed that it delays the meeting of the front and rear sound waves by lengthening the sound path which the rear set of waves must travel. It does not prevent the two sets of sound waves from mixing; it changes the TIME of their meeting, so that they do not interfere with each other. In many radio receivers the baffle arrangement is part of the receiver cabinet.

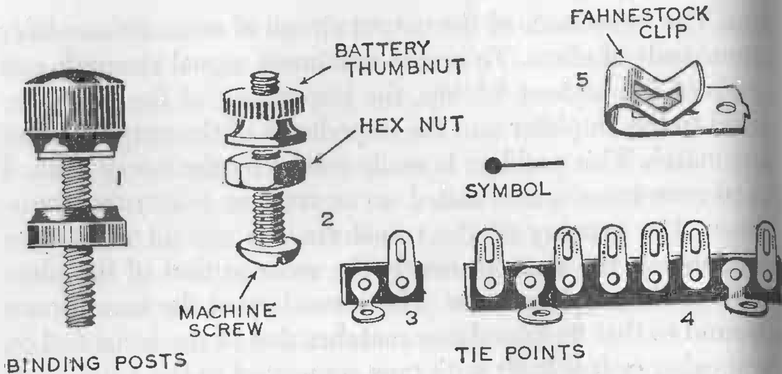
Impedance Matching and Output Transformers. A speaker requires much greater energy to produce an audible signal than a pair of headphones does. In order to create sounds of satisfactory volume, the voice coil of a speaker is usually connected to the output of an audio-frequency amplifier. The voice coils in standard speakers are designed to have an impedance (remember that this is not direct current resistance) of 3.2, 8, or 16

ohms. The impedance of the output circuit of an audio amplifier is thousands of ohms. To secure maximum signal strength and sounds of the highest fidelity, the impedance of the load connected to the amplifier and the impedance of the output circuit must match. This problem is easily solved by the use of a small closed-core transformer called an OUTPUT or MATCHING transformer. The primary of the transformer is wound so that its impedance is the same or nearly the same as that of the plate circuit of the amplifier tube. The secondary of the transformer is wound so that its impedance matches that of the voice coil on the speaker or it is built with taps connected to the winding so that different impedance values are available and the one which matches the impedance of the voice coil most closely may be utilized. Some matching transformers are manufactured with a center tap on the primary. Consequently there are three primary leads. Center-tapped transformers are intended for use in the output circuit of a "push-pull" amplifier.



OUTPUT TRANSFORMER

The secondary winding is tapped so that the impedance of the portion included in the circuit may be matched with the speaker voice coil or other load.

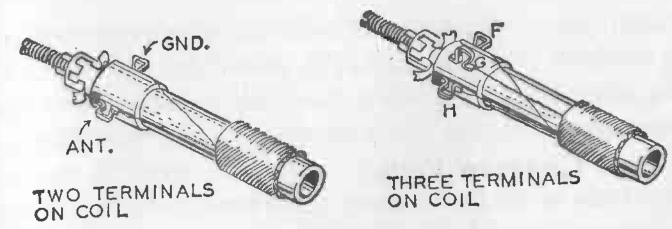


BINDING POSTS AND TERMINALS

Wires can be quickly and conveniently connected or disconnected with-out the use of a screwdriver when binding posts are used as circuit termi-nals. When several wires must be soldered together, tie points (with 1 to 6 lugs) are used. All the parts illustrated above are available from dealers in electronic supplies.

The taps on the secondary winding of a matching trans-former are usually numbered from 1 to 6 inclusive. One terminal of the voice coil should be connected to No. 1 tap on the trans-former. The other voice coil terminal should be connected to taps 2, 3, 4, 5, or 6, whichever one produces the best result when a test of all five is made.

Loopsticks. Among the great variety of components for radio receivers listed in catalogs of radio parts are a number of "loop antennas" and "loopstick antennas." Although they have dif-ferent names the basic construction of all these devices is the same. They consist of a small rod made by compressing a powdered iron compound called ferrite. The rod forms the core of a small winding which serves as an antenna coil in miniature and transistor receivers. Some of the loop antennas can be used as an antenna which has a frequency range of 540 to 1650 kilo-cycles, or in other words, the entire broadcast band, when used



LOOPSTICKS

These are variable inductances used for tuning and antennas. Both types are used in building the simple radio receivers described later.

with a variable capacitor having a maximum capacity of 365 mmfd. The wire forming the coil on the adjustable loopsticks is wound on a paper or plastic tube. The position of the movable ferrite core inside the tube can be shifted in relation to the coil. This adjustment alters the impedance of the coil and can be used to improve the selectivity of a receiver. Variable loop-sticks are described and illustrated in a later chapter which de-tails the construction of four small radio receivers.

Chapter Four

ELECTRON TUBES—THEIR PURPOSE—HOW THEY WERE DEVELOPED—HOW THEY FUNCTION

On the ground, in the air, or below the surface of the seas, electronic devices are in daily use for both military and civilian purposes, and in every one of these uses the ELECTRON TUBE is a vital element. With the exception of some low-powered, lightweight, portable transmitters, compact receivers, and tape recorders, which employ transistors in place of tubes, the operation of present-day radio transmitters and receivers and much electronic apparatus including television equipment centers around the ELECTRON TUBE.

Fundamentally, an electron tube is a VALVE which provides means for producing electrons and conducting them under control through the space enclosed within a glass or metal container. As the electrons move from one electrode or metallic terminal across the intervening space to the other electrode or electrodes (there may be two to five electrodes), they are controlled more easily than if the same electrons were passing through a wire or any other type of conductor, except a suitably arranged semiconductor. It is this power to CONTROL electrons or electron currents and their accompanying voltages that makes the electron tube the most useful device in modern methods of communication.

An electron tube is unrivaled in sensitivity by any other electrical or mechanical device. It can discriminate in terms of millionths of a second in time and when designed for the purpose can handle electrical energy in large quantities amounting to thousands of watts.

Electronic tubes have three main functions in electronic circuits. One is to act as a RECTIFIER and change alternating-current voltage into a pulsating direct-current voltage. This process is called RECTIFICATION.

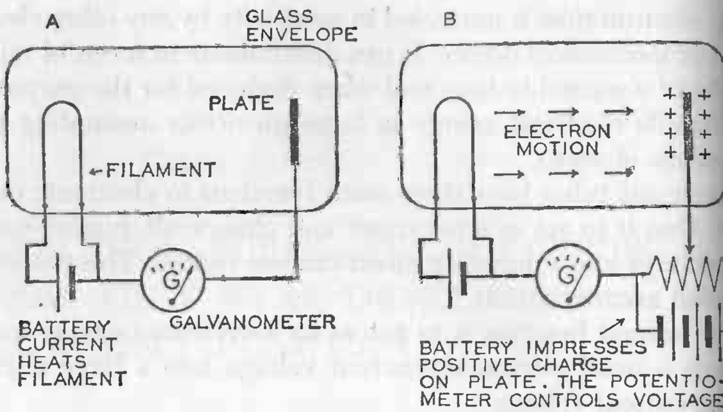
The second function is to act as an AMPLIFIER or relay and change a small alternating-current voltage into a large alternating-current voltage.

Last but not least, is the use of electron tubes as OSCILLATORS. In this application, they change a direct-current voltage into an alternating-current voltage of almost any desired frequency ranging from a few to millions of cycles per second.

Several volumes larger than this one would be required for a complete discussion of electron tubes. This chapter is only a brief outline of the subject.

EARLY EXPERIMENTERS

The Edison carbon-filament incandescent lamp may be considered, in a sense, to be the forerunner or prototype of the modern electron tube. Many years before wireless telegraphy was a reality, Edison noticed that the glass bulb of these first incandescent lamps darkened with age and that the carbon filament burned out at the point where the filament entered the glass bulb. While trying to find the cause and improve the lamp Edison sealed a metal electrode or plate into some lamps. (This is basically the construction of the DIODE or two-electrode tube of today.) He thereupon found that when this plate was connected to a sensitive current meter and to the positive terminal of a battery there was a flow of current across the space between the filament and the plate. According to the



THE EDISON EFFECT

If an incandescent lamp filament and a metal plate are sealed in an evacuated envelope and connected to a sensitive galvanometer as shown at A, the galvanometer will indicate a small current flowing between the filament and plate when the filament is red hot. If a positive charge is placed upon the plate (B) it will increase the rate at which the electrons emitted from the filament flow to the plate.

knowledge of electrical circuits at that time, the space between the filament and lamp would cause an OPEN circuit and therefore current flow was an impossibility. Electrons had not been discovered at that time. Why electricity passed from the hot lamp filament to the plate was a mystery. There was no good explanation for the phenomenon and it became known as the "Edison effect."

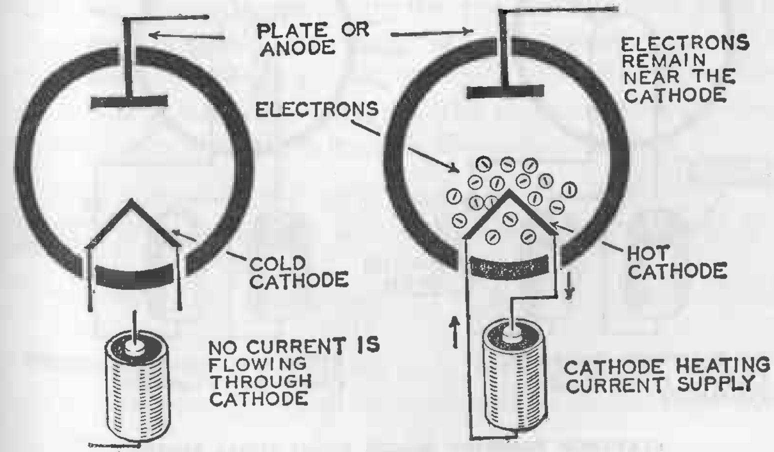
We know the answer now. In 1899, Sir J. J. Thompson, a British scientist, suggested the theory that small negative particles of electricity called ELECTRONS were emitted by the filament in the lamp as a result of operating it at a white heat. He further proposed that the electrons, since they were negative, were attracted to the positive plate. Thompson's theory became known as the ELECTRON THEORY. We know this one-time theory

to be a fact. We also know that red-hot metals and some other heated objects throw out millions of electrons and that if the hot object is enclosed in a vacuum the quantity of electrons thrown off is greatly increased.

Edison did not find any practical application for the Edison effect. Equipped with the knowledge of his discovery and the electron theory, other scientists explored further and developed the Aladdin's lamps with which we are most familiar as the electron tubes in radio and television receivers. All radio tubes depend upon the Edison effect for their operation.

THE FLEMING VALVE

The first electron tube used for detecting radio signals was the work of Professor J. A. Fleming. When Fleming was a young engineer with the Edison and Swan Lighting Co. in London,

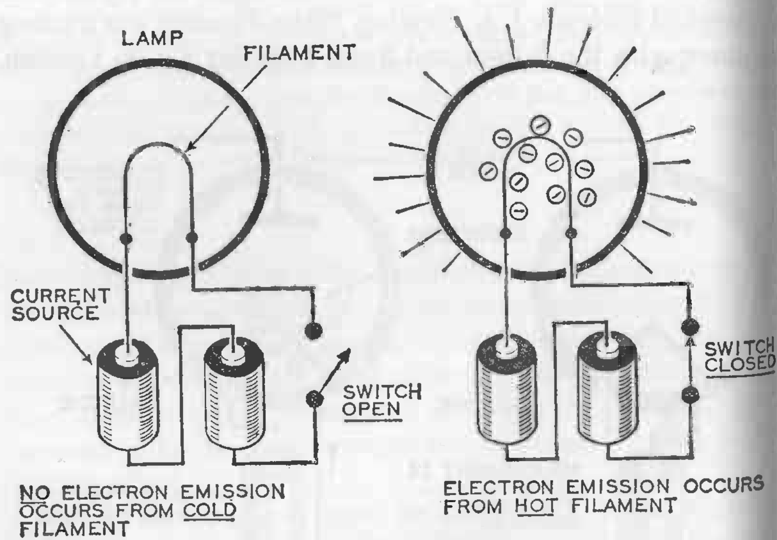


A HEATED CATHODE IS NECESSARY

The filament or sleeve which supplies the electrons in an electron tube is called the CATHODE. The cathode is heated by an electric current. When the cathode is cold no electrons are emitted.

he experimented with some of the lamps which Edison had built to demonstrate the Edison effect. While investigating these lamps Fleming first became familiar with the Edison effect. Several years later, he thought of a practical purpose for Edison's, until then, practically useless discovery. It occurred to him that the lamp might make a good detector for Marconi's new wireless telegraph.

Fleming placed a small metal cylinder inside the bulb of an incandescent lamp and around the hot filament. He found that, through the same sort of valve action which Edison had discovered in 1884, the lamp was a sensitive and stable device for detecting wireless telegraph signals.



ELECTRON EMISSION MAKES RADIO TUBES POSSIBLE

Amateur radio experimenters sometimes jokingly refer to an incandescent lamp as a single-element tube. The operation of the electron tubes used in radio circuits is based upon the fact that a filament of heated metal and also certain metallic compounds throw off free electrons while hot and enclosed in a vacuum tube or envelope.

The Fleming valve, an electron tube having two electrodes, one hot and one cold, for detecting wireless telegraph signals was patented by Fleming in 1905. The patent became very important. The Marconi Company purchased it and put the "valve," as it came to be known, to work receiving wireless telegraph signals aboard ships and in commercial wireless telegraph stations.

Fleming's valve was only the modern electron tube in swaddling clothes. It had to grow up and undergo many improvements before it became widely used. The valve did not begin to grow up until 1906 when Lee De Forest added a third element to it in the form of a spiral of wire which he called the control grid. The tube now contained a filament or cathode, a grid, and a plate or anode. The third element made the tube much more sensitive as a detector and enabled it to perform as an amplifier and an oscillator in addition to being a detector. De Forest called his three-electrode tube an AUDION, a name which has been superseded by the present-day term TRIODE.

Electron tubes have now been in use for more than half a century and have been greatly improved through the work of countless scientists and engineers. The characteristics of modern electron tubes make it possible to employ them as:

1. Extremely sensitive DETECTORS of weak currents
2. RECTIFIERS to change alternating currents into direct currents
3. VALVES which permit currents to flow in a circuit in one direction only
4. AMPLIFIERS to magnify currents and voltages
5. RELAYS whereby small currents control much larger currents
6. OSCILLATORS to create alternating currents from a direct-current source of energy

More than 1,200 types of radio tubes are regularly manufactured in the United States. They all fall under the general classification of ELECTRON TUBES but may be divided into groups according to their use or the number of electrodes within the glass or metal envelope, the degree of evacuation, etc. For example, they may be divided into DETECTORS, RECTIFIERS, AUDIO AMPLIFIERS, RADIO-FREQUENCY AMPLIFIERS, AND OSCILLATORS. Or they may be divided into groups as DIODES, TRIODES, TETRODES, and PENTODES depending upon the number of electrodes. *Di, tri, tetra,* and *penta* are from Greek words meaning respectively, "two," "three," "four," and "five." *

ELECTRON EMISSION

The operation of all except a few specialized forms of electron tubes depends upon the EMISSION OF ELECTRONS from a hot metal and the control of those electrons.

Readers who are familiar with the fundamental principles of chemistry are probably aware that the elements called metals, for example, the metal tungsten, are made up of atoms clustered together in molecules and that scattered about in the spaces between molecules are many "free" electrons. The free electrons are those which are not part of any of the atoms. At a temperature of absolute zero which is 459.6 degrees below zero on the Fahrenheit scale there is no motion of the atoms, molecules, and free electrons in metals. At higher temperatures there is random motion of these elementary particles. As the temperature of a metal rises, the electrons increase the speed of their motion and collisions occur with other electrons or with some of the atoms and molecules. The speed and direction of travel of most of the electrons changes constantly as a result of these collisions.

* *The RCA Receiving Tube Manual,* a 432-page book listing all receiving tubes and giving their uses and specifications, can be purchased from radio dealers or by writing direct to Radio Corporation of America, Electron Tube Division, Harrison, N.J. Price: $1.00. It will prove interesting and valuable to experimenters, radio amateurs, and hobbyists.

Some of the electrons close to the surface of the metal have no collisions with other electrons or with atoms and molecules. When their velocity is great enough, these electrons are able to break through the surface of the metal. There is no detectable escape or emission of electrons at ordinary room temperatures. At a dull red heat, there is sufficient emission or escape of free electrons from the hot metal to be useful in electronics.

When sufficient electric current is sent through a tungsten wire, the wire becomes hot. At a dull red heat some of the free electrons near the surface of the tungsten move with sufficient speed to break through the surface. Thus a heated tungsten wire or filament often provides the electrons required in an electron tube.

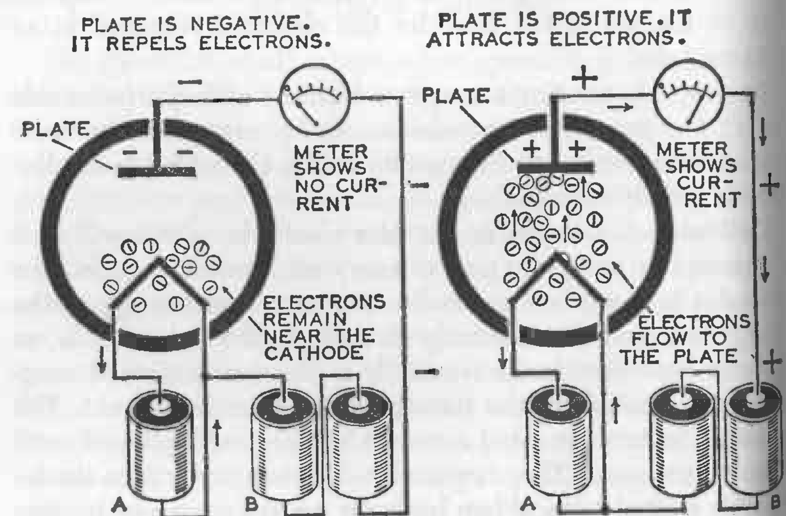
By properly treating a tungsten filament with thorium oxide during the process of manufacture or by using a nickel wire coated with barium and strontium oxides the emission of electrons is greatly increased.

Cathodes. A cathode, or negative electrode, which will emit electrons is a necessary part of every electron radio tube. The cathodes in the tubes in a radio receiver are of two types, the filamentary and the indirectly heated. A filament cathode, or directly heated cathode, is usually a chemically treated tungsten wire heated by the passage of an electric current. The tubes in battery operated receivers usually are equipped with filament cathodes. They require less heating power than the indirectly heated type. When batteries are the source of heating power it is desirable to impose as small a current drain as possible upon them.

The indirectly heated cathode or heater-type cathode is used in tubes designed for operation on alternating current. In this arrangement the tungsten filament is surrounded by a chemically treated sleeve. The filament supplies the heat and the sleeve supplies the electrons. This construction eliminates the 60-cycle hum of the alternating current.

THE DIODE

The action of electron tubes is based upon the fact that any positively charged object in the vicinity of an electron emitter attracts the electrons. The simplest form of vacuum tube consists of two electrodes, a cathode or electron emitter and an anode. The anode may be a metal plate or a metal cylinder, sealed within an evacuated glass bulb or metal tube. This form of tube is called a DIODE.



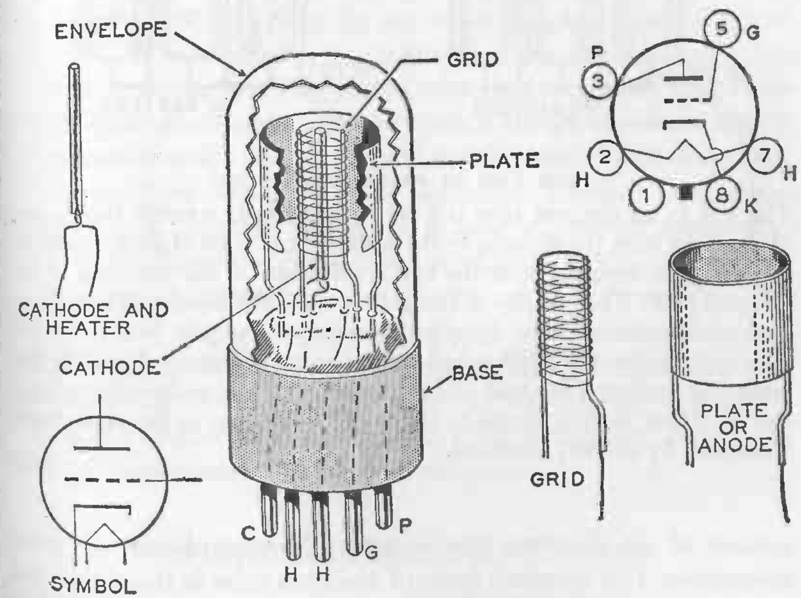
THE OPERATION OF THE FLEMING VALVE AND THE DIODE

If the plate is neutral or negative in respect to the cathode, the electrons emitted from the cathode remain close to it. Some re-enter it. None reaches the plate and no current flows in the plate circuit. If the plate is positive in respect to the cathode, electrons pass across the space from the cathode to the plate. Under this condition a current flows in the plate circuit. Battery A in both diagrams heats the cathode. Battery B in the left-hand diagram puts a negative charge on the plate. Battery B in the right-hand diagram makes the plate positive.

Most broadcast receivers in use today use a diode as a detector. The illustrations and the accompanying captions explain the action which occurs in a diode.

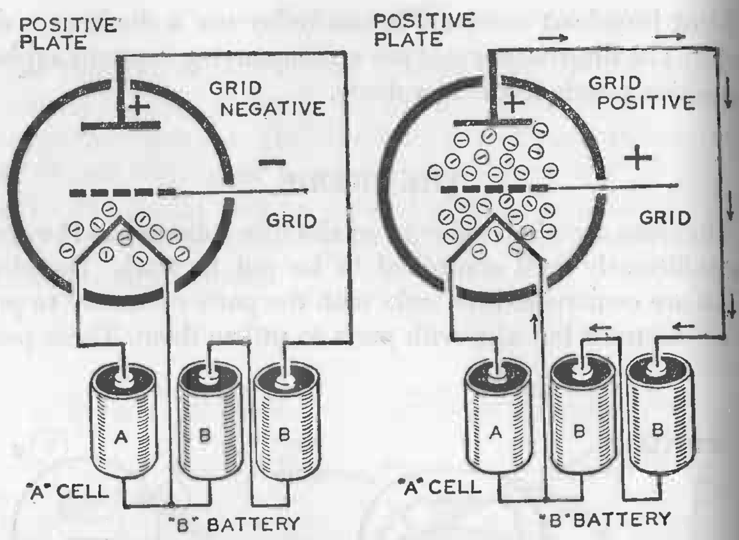
THE TRIODE

Electrons are of no value in an electron tube unless they can be sufficiently well controlled to be put to work. Therefore tubes are constructed not only with the parts necessary to produce electrons but also with parts to utilize them. These parts



DETAILS OF A TYPICAL TRIODE RECEIVING TUBE

A portion of the glass envelope and the cylindrical plate or anode are shown as cut away in this illustration to reveal the arrangement of the cathode, grid, and plate. The diagram in the upper right-hand corner shows the connections of the filament or heater, cathode, grid, and plate to the base pins.



THE GRID IN AN ELECTRON TUBE

The grid in an electron tube is a control device. It controls the passage of electrons from the cathode to the plate. The volume of electrons reaching the plate depends upon the combined effect of the polarities of the grid and plate. The polarity of the plate is normally positive. The polarity of the grid varies with the signal impressed upon the grid. When the grid is more negative, the plate is less able to attract electrons from the filament and THROUGH the grid. When the grid is more positive the plate is able to attract more electrons to itself and the current in the plate circuit (indicated by arrows) increases.

consist of an electron-producing cathode and one or more electrodes. The simplest form of electron tube is the diode just discussed. As already explained, it contains two electrodes, a cathode and an anode (plate).

When a third electrode, called the GRID, is placed between the cathode and plate, the grid will control the plate current and give the tube a most useful function—the ability to AMPLIFY.

A three-element tube is called a TRIODE. The grid usually consists of a fine wire wound in a spiral around two supporting rods. The spaces between the wires in the spiral are large enough so that a flow of electrons from the cathode to the plate is practically unobstructed. The volume of electrons reaching the plate from the cathode depends on the combined effect of the grid and plate and their effect depends upon their polarity.

The polarity of the plate is normally positive. It is connected to the positive terminal of the "B" battery. The grid may be connected to a tuner, microphone, phonograph pickup, matching transformer, etc., depending upon whether it is used as a detector or amplifier, etc. In any case the polarity of the grid will vary. When the plate is positive and the direct-current grid voltage becomes more negative, the grid has more and more tendency to repel electrons; the plate is then less able to attract electrons to itself and the current in the plate circuit decreases. When the grid becomes more and more positive and consequently less negative the plate is able to attract more electrons to itself and the current in the plate circuit increases.

Thus when the voltage on the grid varies with a signal, the plate current varies correspondingly. A very small voltage applied to the grid can control a comparatively large amount of current in the plate circuit and in that way amplify the signal.

When a triode is used as an amplifier a negative direct current or bias is usually applied to the grid.

INTERELECTRODE CAPACITANCE

In a triode, the grid, plate, and cathode each act as one plate of a small capacitor and create conditions known as INTERELECTRODE CAPACITANCES. In radio-frequency amplifier circuits the capacitance between the grid and plate of a triode may produce undesired coupling in the amplifier circuits, coupling which results in instability and unsatisfactory performance.

When triodes were the only tubes available, the capacitance between the plate and the grid prevented the development of satisfactory radio-frequency amplifiers.

TETRODES

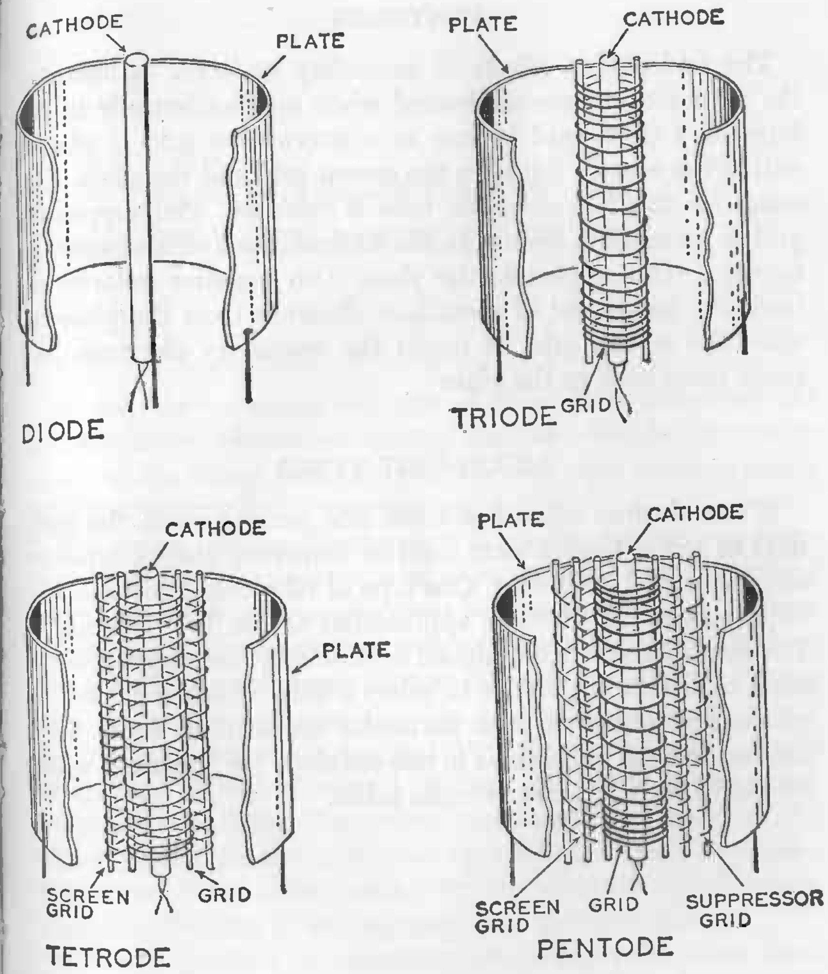
The problem of interelectrode capacitance in triodes was finally solved by mounting an additional electrode, called the SCREEN GRID (grid No. 2). When a second grid is mounted between grid No. 1 (the control grid) and the plate, the tube has four electrodes and is known as a TETRODE, the family name for a four-electrode tube. The screen grid acts as an electrostatic shield and makes the capacitance between grid and plate very small.

In addition to reducing capacitance, the second grid has another desirable effect. It makes plate current almost wholly independent of plate voltage over a certain range and thereby makes it possible to obtain much higher amplification with a tetrode than with a triode.

SECONDARY EMISSION

Electrons striking the plate in an electron tube, if moving with sufficient speed, may dislodge electrons from the plate. This secondary emission, as it is called, does not cause trouble in a diode or pentode because the plate in those tubes is the only positively charged electrode. Consequently any electrons dislodged by secondary emission are immediately drawn back to the plate.

In a tetrode, the screen grid is operated at a positive voltage and its proximity to the plate offers a strong attraction to secondary electrons. If secondary emission occurs in a tetrode, the effect lowers the plate current. As a result tetrode tubes have been replaced to a considerable extent in radio receivers by five-electrode tubes called PENTODES.



THE ELECTRODES IN ELECTRON TUBES FOR RECEIVERS AND AMPLIFIERS

Part of the plate in each tube in these sketches is cut away to reveal the arrangement of the cathode and grids.

PENTODES

The undesirable effects of secondary emission in lowering the plate current are minimized when a fifth electrode in the form of a third grid known as a SUPPRESSOR grid is placed within the tetrode between the screen grid and the plate. The name for this five-electrode tube is PENTODE. The suppressor grid is usually connected to the cathode and consequently is negative with respect to the plate. This negative polarity retards the movement of secondary electrons from the plate toward the screen grid. It repels the secondary electrons and sends them back to the plate.

MULTI-UNIT TUBES

When electron tubes first came into general use in the early days of radio, triodes were used as detectors, audio-frequency amplifiers, and oscillators. One type of tube could not meet the requirements of all these applications to the best advantage. Present-day tubes are designed with widely varying characteristics so that it is possible to select a tube which will give an efficient performance in a particular application. Some tubes are constructed to combine in one envelope the functions which originally required two or more tubes.

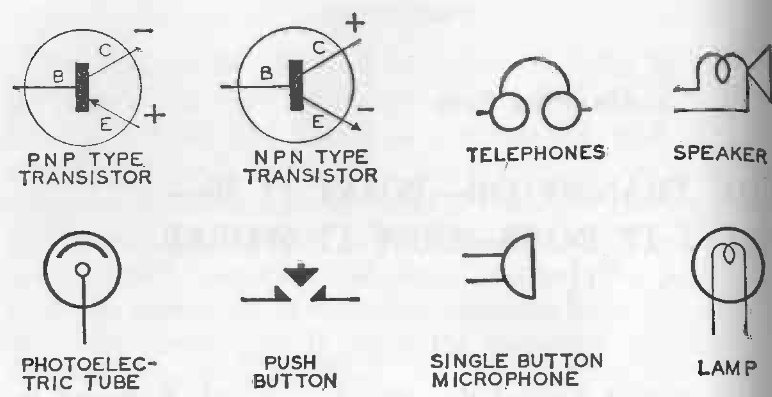
CHAPTER FIVE

THE TRANSISTOR—WHAT IT IS—WHAT IT DOES—HOW IT WORKS

A tiny device about the size of your little fingernail has revolutionized electronics during the past decade. It can do many of the things formerly possible only with electron tubes. This device is called a TRANSISTOR.

For many purposes a transistor is more efficient and more dependable than an electron tube. It not only simplifies many existing designs and constructions but inspires the construction of electronic equipment heretofore impossible. At first, transistors were used in the manufacture of small, economical hearing aids and portable radios the size of a package of cigarettes. They now see service in automatic telephone exchanges, digital computers, industrial control systems, and telemetering transmitters for satellites. Transistors enable artificial satellites, orbiting around the earth, to radio back information. These semiconductor devices are useful in the circuits of electronic equipment for the home, industry, and national defense.

Broadly speaking, a transistor can perform the same functions as a radio tube in many electronic circuits. It can be a valve, switching device, detector, relay, amplifier, and oscillator. In effect, the transistor is a precise, efficient, versatile, and often economical valve for controlling electrons in the circuits of electronic equipment. But there is a difference between electron tubes and transistors in how they perform their tasks. The electron tube controls electrons in a vacuum or a gas. The



SYMBOLS USED IN CIRCUIT DIAGRAMS

The symbols for PNP and NPN junction-type transistors are shown at the upper left.

transistor controls electrons in a solid—a carefully prepared crystal of a material called a SEMICONDUCTOR.

Electrons have little difficulty in passing through the materials called CONDUCTORS, such as the metals copper and silver. They cannot pass at all through glass, mica, polystyrene, and the many other materials in the group called INSULATORS and NONCONDUCTORS. The semiconductors lie between conductors and nonconductors in the nature of the pathway they provide for electrons. They offer much resistance to electrons but they do permit some to pass under certain conditions. In other words, semiconductors are neither good insulators nor good conductors. The name TRANSISTOR was derived from the fact that this device was first called "a transit resistor" by some of the scientists who helped to develop it. The word transistor was coined from TRANSit resistor.

The two semiconductor materials now being used in the manufacture of transistors are the elements germanium and silicon. Only tiny pellets or thin wafers of crystals of these mate-

rials are employed. Germanium is one of the rare basic elements and was once considered relatively useless. The chief American source of germanium has been the dust in the stacks of zinc smelters. It is also extracted from the ashes of coal mined in Kentucky, West Virginia, and England. Silicon is also a basic element but in contrast to germanium is very plentiful. It is obtained from sand by an electric furnace process. Sand is chiefly an oxide of silicon.

Transistors have no filament nor heater. Consequently there are no problems of burnout or of a source of heating current.

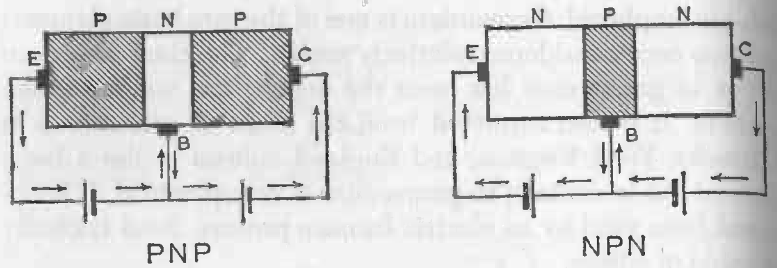
Transistors are manufactured in two distinctly different types. One is called the POINT CONTACT type. The other is called the JUNCTION type. It is the junction transistor which has played a steadily increasing part in every branch of electronics.

A point contact transistor consists of a miniature block of germanium crystal with two fine, pointed wires called the EMITTER and COLLECTOR making contact with its top surface. A third connection called the BASE is made to the body of the crystal. The point contact transistor has particular advantages over the junction type as a high-speed switch in electronic computers.

The junction-type transistor is built like a "sandwich." An inner layer of semiconductor material corresponding to the "meat" is enclosed between two outer layers of a different semiconductor material like the "bread" in a sandwich. Electrical connections are welded to the two outer layers and to the inner layer and the terminals of the wires identified as the EMITTER, BASE, and COLLECTOR.

The junction transistor is more stable and more effective as a low- and medium-frequency amplifier than the point contact type. The transistors specified for the circuits in this book are the junction type.

There is no satisfactory short and simple explanation of the manner in which transistors do their work. A knowledge of the theories of the basic structure of the elements is necessary to



PNP AND NPN JUNCTION TRANSISTORS

Junction transistors are "sandwiches" of two types of germanium. The PNP transistor has a thin wafer of N-type (negative) germanium in the center between two layers of P-type (positive) germanium. The P-type germanium is formed by diffusing impurities such as a small amount of the elements gallium or indium on either side of the N-type layer. The NPN transistor is a "sandwich" with a wafer of P-type germanium in the center between two layers of N-type germanium. The arrows indicate the direction of the electron flow in the external circuit. The letters P and N indicate respectively P-type and N-type germanium. The letters E, B, and C indicate respectively the emitter, base, and collector.

understand semiconductor physics and the theory of transistor operation.

A few of the most important principles involved in the operation of transistors are given here briefly, with the reminder that complete comprehension of the theory of transistor operation is not necessary in order to construct the transistor apparatus described in this book. Those who wish more information on this subject are referred to *The Transistor Manual*, 6th edition, published by the General Electric Co. and obtainable from dealers in electronic supplies for $2.00.

HOW A TRANSISTOR PERFORMS

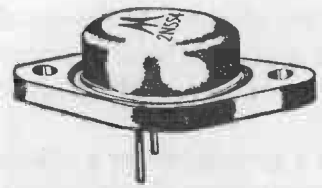
When an electromotive force (an electrical voltage) is applied to a conductor, for example a piece of copper, it causes a

movement of electrons in the metal. Free electrons in the metal move toward the positive end of the copper. This movement of electrons is the usual flow of electrons termed an electric current.

But when a semiconductor, such as a germanium or a silicon crystal, is substituted for copper, the application of voltage may produce a movement of both electrons and HOLES. A "hole" is formed when a group of atoms (a molecule) in the semiconductor loses an electron. The electron is then free to move about in the crystal. The molecule which lost an electron may pick up one from a nearby molecule, thus leaving a second hole and a POSITIVE charge. In this way holes may travel through the crystal, jumping from molecule to molecule and producing a current flow which behaves as if it were a movement of positively charged particles.

If the current flow in a semiconductor crystal is made up principally of a movement of electrons (negative) the crystal is called an N-TYPE semiconductor. On the other hand if the current flow in the crystal is primarily a movement of holes (positive) the crystal is called a P-TYPE semiconductor. A junction transistor is made up of a combination of these materials. Three pieces are used and the transistor is called an NPN or a PNP transistor, depending upon the manner in which the materials are sandwiched. In the manufacture of germanium and silicon transistors the production of either N-type or P-type material can be controlled by adding impurities to the semiconductor crystal when it is forming. The impurity may be a "donor," such as arsenic, which "donates" extra free electrons and forms N-type semiconductors, or an "acceptor" such as aluminum which "accepts" electrons from the crystal and produces free holes.

Power Transistors. Present-day transistors are able to handle only a very small amount of power—a few watts at the most. Power transistors which will handle a great deal of energy are under development and will probably be available in the future.



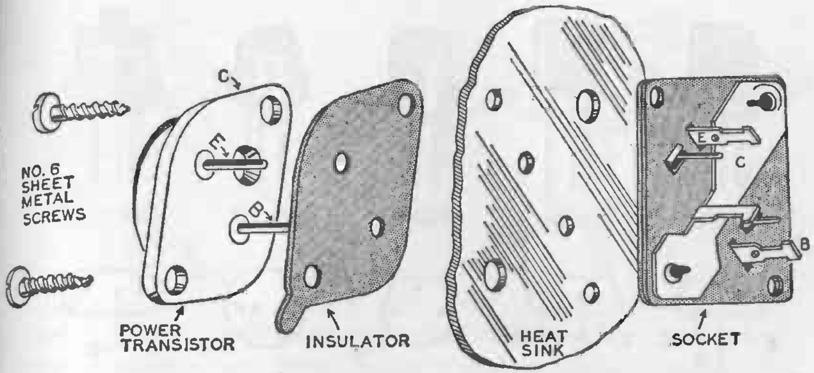
MOTOROLA 2N554 POWER TRANSISTOR
The RCA 2N307 power transistor is the same size and shape.

Small-power transistors are now on the market and are of special interest to the amateur experimenter for use in rectifiers and in the output stage of audio amplifiers.

Small-power transistors, such as Motorola 2N554 and RCA 2N307, are mounted on a diamond-shaped, die-cast metal base and covered with a metal cap. Two brass pins project from the bottom. These are the terminals of the BASE and EMITTER. The die-casting is the terminal of the collector. The identity of the two pins is indicated by the letters E and B marked on the die-casting.

In most instances means must be provided for dissipating the heat developed in a power transistor. This is generally accomplished by bolting the die-cast base of the transistor to a metal plate, metal cabinet, or metal chassis. The plate, cabinet, or chassis then becomes a HEAT SINK for radiating and dissipating the heat. At normal room temperature (70° to 80° F) about 5 square inches of heat sink surface are required to radiate the heat produced by each watt passing through the transistor. A transistor is quickly destroyed by overheating.

A mounting kit, as shown in one of the illustrations, simplifies mounting a small-power transistor of the types mentioned above. To use the kit, it is necessary to drill holes through the metal of the heat sink in accordance with the paper template which is supplied with the kit. The template has an adhesive back which will stick to the metal without slipping. Use a center punch to make a punch mark in the center of each hole indicated on the template. Use an ordinary twist drill to make the holes.

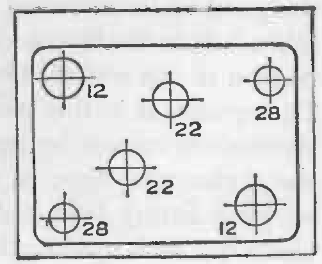


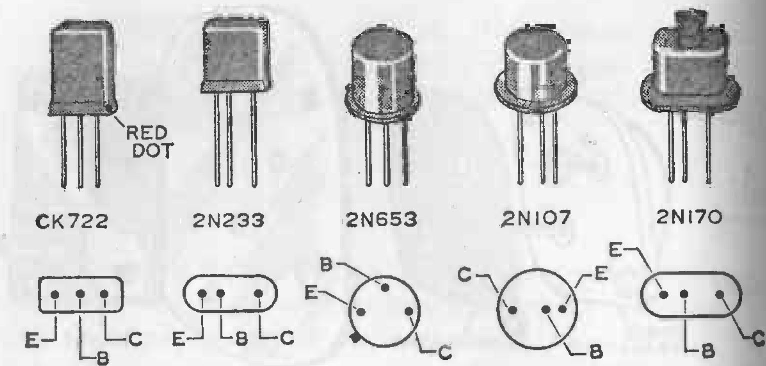
MOUNTING KIT FOR A POWER TRANSISTOR
This can be used for mounting the Motorola 2N554, the RCA 2N307, and some other power transistors on a heat sink or chassis.

SOCKETS AND MOUNTS FOR TRANSISTORS

Small transistors of the type of most interest to amateur experimenters, such as CK722, GE2N107, 2N135, and 2N136, are enclosed in a metal or plastic case. Three terminal wires protrude from the bottom. They are connected to the collector, base, and emitter. When purchasing a transistor it is necessary to get a diagram with it which will correctly identify the terminals. The terminal wires on some transistors are evenly spaced; on others two of the three leads are close together. The

FULL-SIZE MOUNTING TEMPLATE
The numerals indicate the size of drill to use for mounting the Motorola 2N554, RCA 2N307, etc., small-power resistor.

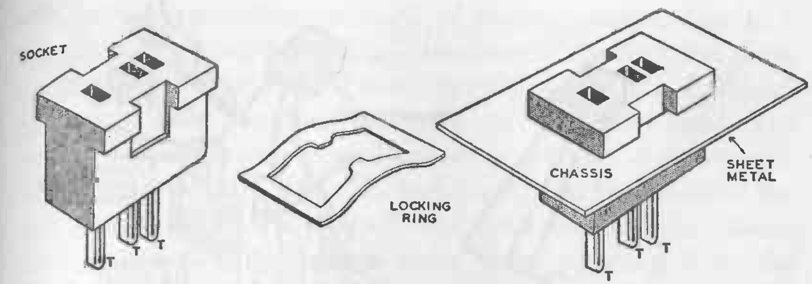




PNP AND NPN TRANSISTORS FOR HOBBYISTS, EXPERIMENTERS, ETC. The diagrams at the bottom are basing diagrams for identifying the collector, base, and emitter. The terminal wires of the transistors are shown cut off so that they can be pushed in a transistor socket. Hold the transistor upside down with terminal wires upward when comparing it with one of the diagrams.

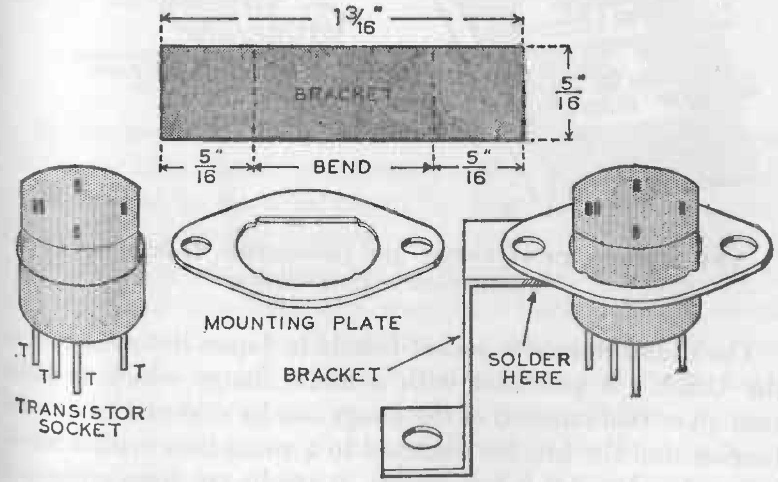
red or black dot printed on one side of some brands of transistor is used to identify the wires.

When transistors are connected by pushing the terminal wires into a transistor socket the wires should be evenly cut off so they are each ½ inch long. Do not twist or bend them back and forth or they may break. There are two types of transistor socket. One is rectangular, the other round. Both are designed to be mounted on a metal chassis by pushing them into a hole in the chassis of the same size and shape as the lower portion of the socket. They are held in place by a metal ring. The apparatus in this book is all of the "breadboard" type and the sockets cannot be mounted directly on the wood base. If the rectangular type of socket is used it should be set in a properly fitting hole in the center of a piece of sheet metal about one inch square. (See illustration.)



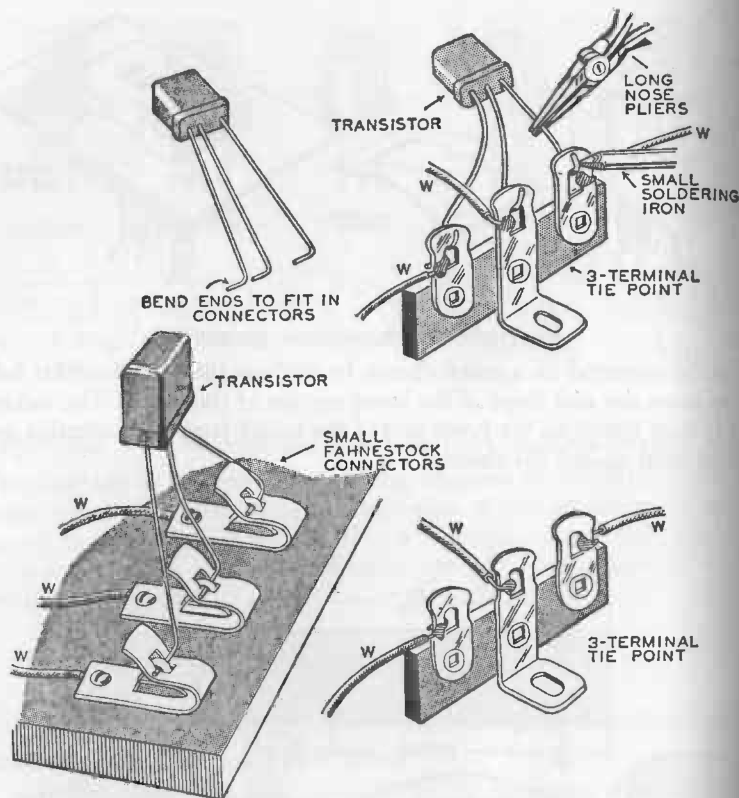
RECTANGULAR TRANSISTOR SOCKET

It can be mounted on a metal chassis by pushing into a rectangular hole of the same size and shape as the lower portion of the socket. The locking ring is then forced on the lower part of the socket from the underside and pushed tight against the chassis.



ROUND TRANSISTOR SOCKET

This type is provided with a metal flange or mounting plate which can be soldered to a homemade metal bracket and the bracket fastened to a wood base with a small wood screw.



TWO METHODS OF MOUNTING AND CONNECTING TRANSISTORS IN "BREADBOARD" CONSTRUCTION

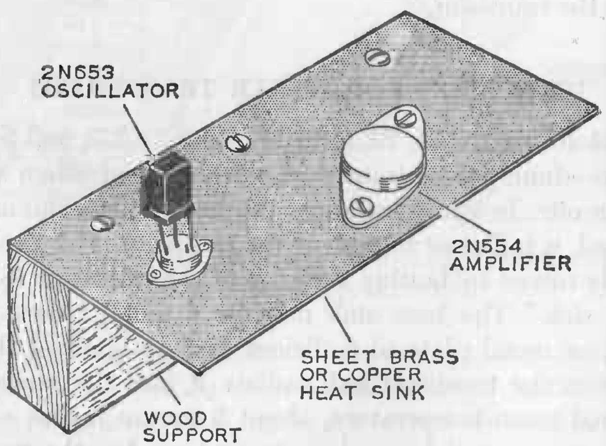
The round transistor socket (made in Japan but available in the U.S.A.) is provided with a metal flange which is large enough so that one end of the flange can be soldered to a metal bracket and the bracket fastened to a wood base with a small screw. The bracket is homemade. It can be cut from a piece of tin can or other thin sheet metal with a pair of small snips. The round sockets are made with both four and five terminals but only three terminals are used in building any of the transistor apparatus described later in this book.

There are two other methods of making connections to a transistor which can be used in "breadboard" construction. Both are illustrated. One method is to fasten three small Fahnestock connectors close together in a row on the wood base. The terminal wires in this instance are not shortened. A right-angle bend is made in each about ¼ inch back from the end and the bent portion inserted in a clip. The second method uses a 3-terminal tie point. Note that the three wires (marked W in the illustration) which connect the tie-point terminals to the other components are soldered to the terminals before the transistor is attached. This is important. A transistor is easily destroyed by heat and this procedure avoids the possibility that heat might creep up the transistor wires while the W wires are soldered in place. When a transistor lead is soldered to a terminal, hold the lead close to the terminal with a pair of long-nose pliers so that the heat from the soldering iron does not damage the transistor.

HEAT SINKS FOR POWER TRANSISTORS

The Motorola 2N554, RCA 2N307, CBS 2N255, and Sylvania 2N307 medium-power transistors develop heat when used in some circuits. In many instances the heat, unless immediately dissipated, is sufficient to destroy the transistor. This problem is generally solved by bolting the base of the transistor tightly to a "heat sink." The heat sink may be a metal chassis, metal cabinet, or metal plate of sufficient area to conduct the heat away from the transistor and radiate it into the atmosphere. At normal room temperature, about 5 square inches of metal surface are required for each watt dissipated in the transistor. Since the collector junction of the 2N554 power transistor is electrically connected to the transistor case, when more than one transistor is used in the same circuit it will be necessary to use separate heat sinks or to insulate the transistors from a common heat sink.

A transistor mounting kit (for diamond-shaped power transistors) which includes a socket is available from radio dealers. One of these kits will not only simplify connections to the transistor but also provide an insulating mica or teflon washer for placement between the transistor and the metal of a heat sink. An adhesive drilling template is included in the kit. This is attached to the heat sink at the point where the transistor is to be mounted and the indicated holes drilled. The insulating washer is placed on the underside of the transistor. The socket is placed on the underside of the heat sink or chassis. Two No. 6 sheet metal screws clamp the whole assembly together but do not make electrical contact with the heat sink. The holes in the heat sink through which the screws pass are large enough to clear the screws.



HEAT SINK

This sketch illustrates how the 2N554 transistor used as an amplifier in the electronic "organ" is mounted on a metal heat sink to radiate the heat which is developed. The 2N653 transistor used as an oscillator is also mounted on the heat sink as a matter of convenience but not of necessity because it does not develop sufficient heat to require cooling.

CHAPTER SIX

RADIO COMMUNICATIONS AND ELECTROMAGNETIC WAVES

An interest in radio and its basic principles is an excellent starting point for acquiring a general knowledge of electronics. This chapter is a brief explanation of the elementary principles of radio communications. This information is not necessary to build the radio apparatus described later, but it will make the construction of radio receivers, etc., more interesting and assist in understanding some of the explanations found farther along in this book.

It is highly probable that there is at least one radio-broadcast receiver in your home and that it is usually referred to as "the radio." Unless there is an amateur radio operator in the household, little thought is ever given to the manner in which this almost magical electronic equipment functions or to the fact that it is essentially only a small portion of a marvelous system of communication.

Radio telegraphy and telephony, broadcasting, television, radar, and the facsimile transmission of pictures and documents are systems of radio communication for sending information or intelligence THROUGH SPACE to be received instantly at a distant point. Radio apparatus provides the only practical means of communicating instantly with remote ships, airplanes, and moving vehicles. For example, an elaborate system of radio makes it possible for the U.S. Navy Department in Washington, D.C.

to communicate within a few minutes with any U.S. Naval vessel including nuclear submarines anywhere on earth. Radar enables a high-flying airplane to "see" prominent landmarks on the earth through a thick layer of clouds. With this same radio device, ships at sea can locate icebergs, other ships, coastline, and other objects not visible to eyes.

ELECTROMAGNETIC WAVES

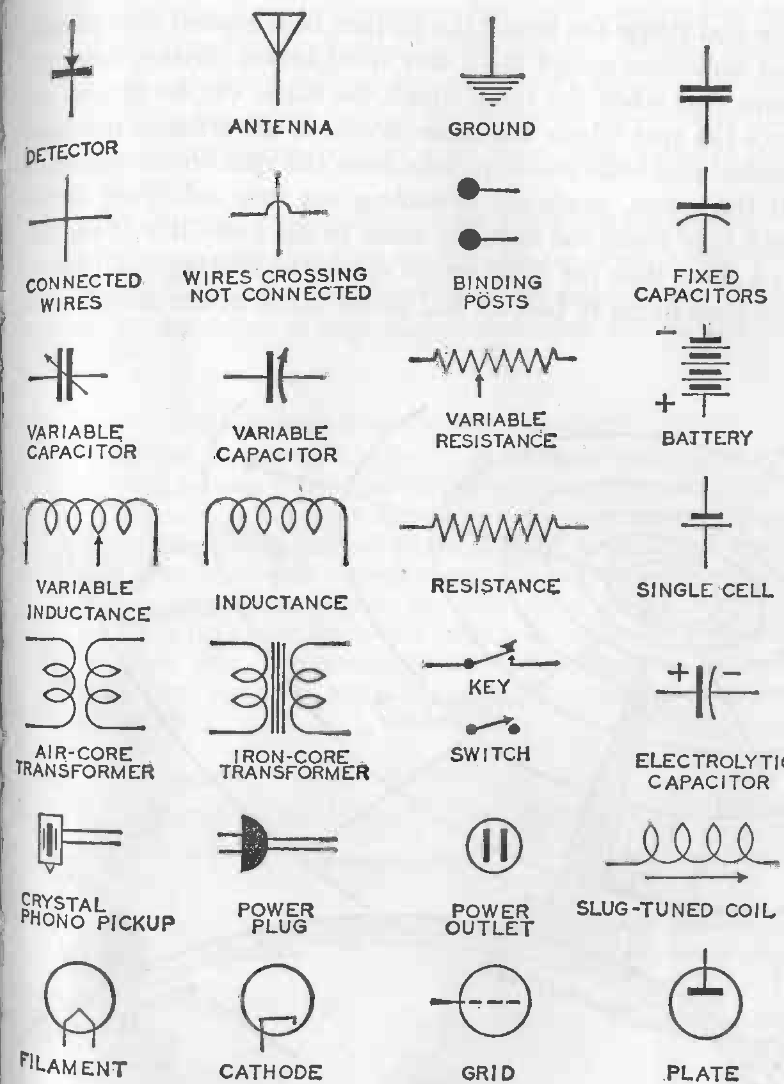
The ability to send information or intelligence through space to distant points depends chiefly on producing and controlling electromagnetic waves.

In 1887, Heinrich Hertz, a German physicist, demonstrated that electromagnetic energy could be sent out into space in the form of radio waves.

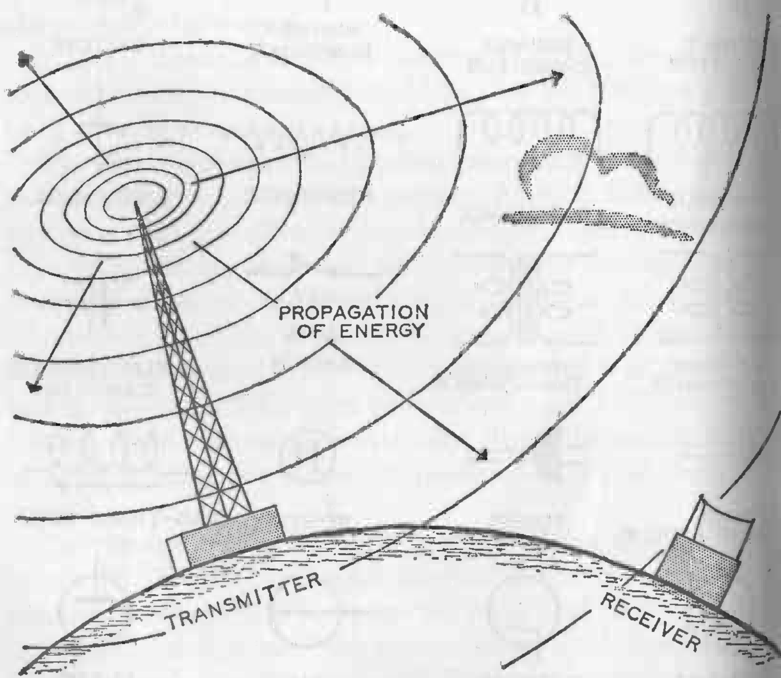
It has been explained that an electromagnetic field exists about any wire carrying an electric current. Another field called the radiation field also exists and under proper conditions becomes detached from the wire and travels outward through space in the form of waves which make radio communication possible. The waves which Hertz discovered how to produce were called Hertzian waves at first but are now known as electromagnetic and radio waves. Like light and radiant heat, radio waves are a form of radiant energy propagated through space at a speed of 186,272 miles per second or nearly 300,000,000 meters per second.

Electromagnetic waves and the movement of ripples or small waves in a pond have some characteristics in common. An analogy is often made between the motion of electromagnetic waves and the motion of the waves formed by dropping a stone on the smooth surface of a pond. The analogy is not an exact one but it serves a useful purpose by making a comparison with a well-known physical action.

Suppose you stand at the edge of a small pond and throw a stone into the water fifteen or twenty feet from the shore. Be-



SYMBOLS USED IN ELECTRONIC CIRCUIT DIAGRAMS fore you threw the stone, the surface of the pond was smooth and unbroken except for a few dead leaves floating near the shore. But when the stone struck the water ripples spread out from the spot where the stone struck. A disturbance has been created and little waves radiate from the spot where the stone hit the water, gradually spreading out into enlarging circles until they reach the opposite shore or die away if it is too far. In a short time the little waves reach the floating dead leaves and they begin to bob up and down. Some of the energy your



ELECTROMAGNETIC WAVES

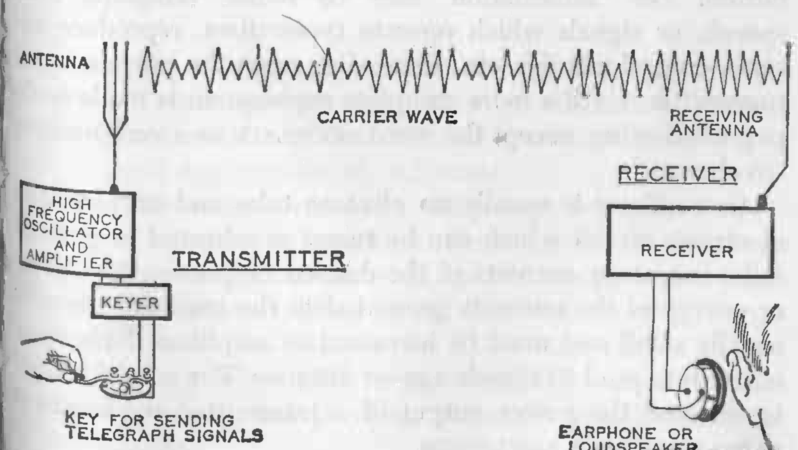
Unless a transmitting antenna is designed to shape the waves into a beam, electromagnetic waves spread out from the antenna in the form of expanding concentric circles.

arm and gravity gave to the stone has been imparted to the water and in turn to the leaves. Notice that the floating leaves are not carried along with the waves but move only up and down. The water is not moved sideways by the waves. The only effect of the waves is to raise or lower each movable particle in its path.

If a radio-frequency generator, such as a radio transmitter, is connected to an antenna, the energy sets up fields in the surrounding space and electromagnetic waves spread out from the antenna in the form of expanding concentric circles like the

THE PRINCIPLE OF RADIO TELEGRAPHY

A radiotelegraph transmitter consists of an oscillator and amplifier, a modulator, key, antenna system, and a source of power. The oscillator and amplifier produce high-frequency alternating currents which are fed into the antenna. The antenna radiates electromagnetic waves (called carrier waves) which travel outward through space. The key and keyer are used to impress the telegraph message on the carrier wave. They modulate or make changes in the carrier wave which correspond to the dots and dashes of the telegraph code. The antenna at the receiver intercepts the waves and the receiving apparatus makes the messages carried by the waves audible or visible.



waves in the pond. If the waves encounter a receiving antenna, some of their energy is given up to that device. Some of the energy produced by the transmitter is transferred through space to the receiver by wave motion in somewhat the same way as some of the energy of the stone thrown in the water was transferred through the water to the floating leaves.

The essential fact in this discussion is that in all forms of radio communication, energy is transmitted through space by means of wave motion.

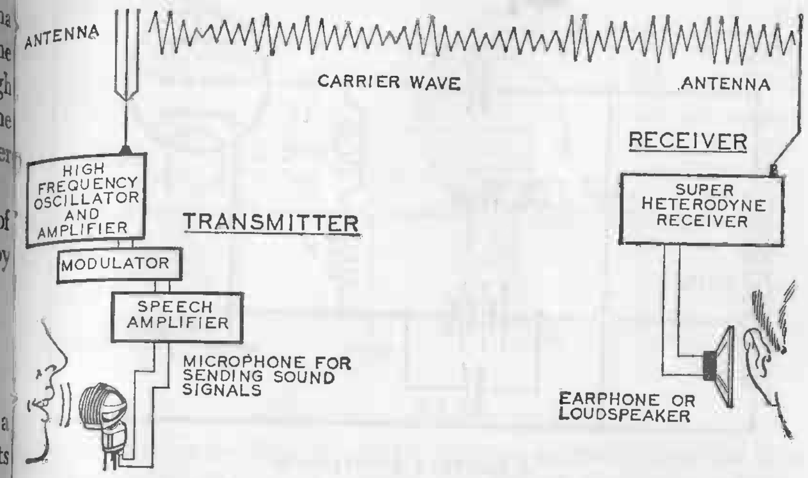
RADIO COMMUNICATIONS

A radio communications system consists essentially of a TRANSMITTER, a transmitting ANTENNA, and a RECEIVER and its ANTENNA. Everyone has seen a radio receiver for broadcast programs. Not everyone has seen a radio transmitter. The apparatus of a transmitter is divided into two groups, namely:

1. an OSCILLATOR which generates radio-frequency alternating currents and amplifies them.

2. the MODULATOR, an apparatus which modulates the radio-frequency currents with the information or signals to be transmitted. The "information" may be music, telegraph code, speech, or signals which operate typewriters, reproduce pictures, control missiles, etc., depending upon the purpose of the transmitter. Until a more complete explanation is made in the pages following, accept the word MODULATE as a verb meaning "to change."

An oscillator is usually an electron tube and an associated electronic circuit which can be tuned or adjusted to generate radio-frequency currents of the desired frequency. The power or energy of the currents generated in the oscillator circuit is usually small and must be increased or amplified if the transmitter is to send its signals a great distance. The amplifiers used to increase the power output of a transmitter are known as RADIO-FREQUENCY AMPLIFIERS.

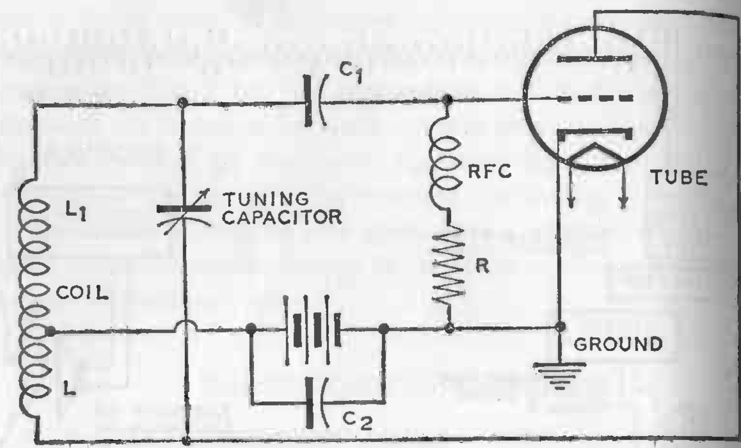


THE PRINCIPLE OF RADIOTELEPHONY AND BROADCASTING

The same type of oscillator used in radiotelegraphy is employed in radiotelephony and broadcasting but a modulator controlled by a microphone is substituted for the key and keyer. Speech and music picked up by the microphone modulate the carrier waves in accordance with sounds instead of the dots and dashes of the telegraph code. The antenna at the receiver intercepts the waves and the receiving apparatus makes audible the sounds impressed upon the carrier at the transmitter.

Incidentally, oscillators have numerous uses outside the field of radio. Switching, induction heating, diathermy, sorting, sampling, and counting materials and products are a few of the industrial applications of oscillators.

A transmission line carries the radio-frequency currents generated and amplified in the transmitter circuits to the transmitting antenna. The antenna radiates the energy in the radio-frequency currents out into space in the form of ELECTROMAGNETIC WAVES. These waves are of the same nature as light but are too long to be visible to our eyes. They travel outward in widening circles except when purposely sent forth in the form of a beam.

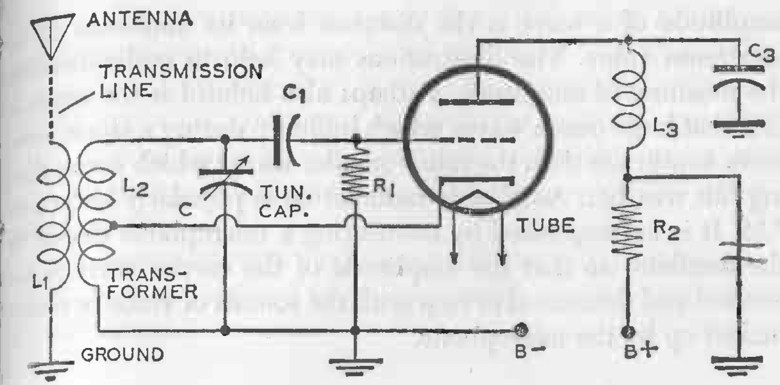


A HARTLEY OSCILLATOR

There are many different oscillators for generating high-frequency alternating currents. This diagram shows the circuit of a popular variable-frequency oscillator called the Hartley oscillator. It is in widespread use in transmitters and gives a fairly uniform output over a range of frequencies which can be adjusted from about 800 kilocycles to 100 megacycles. In addition to its use in transmitters, the Hartley oscillator is in common use in television and FM receivers. Some of the components in the circuit are plainly marked in the diagram. Refer to the symbols in the first illustration in this chapter and identify the unmarked ones.

A radio transmitter and antenna which sent forth steady, unvarying electromagnetic waves would not send any information or intelligence to radio receivers. The waves (called the CARRIER) must be modified or modulated in some manner in order to transmit intelligence.

The American Indians used to send important information considerable distances by signaling with the smoke from a fire located on a prominent hilltop. When a steady column of smoke rose from the fire, no information was conveyed to the distant observer. But when the smoke column was interrupted so that puffs of smoke were observed, the puffs conveyed a meaning



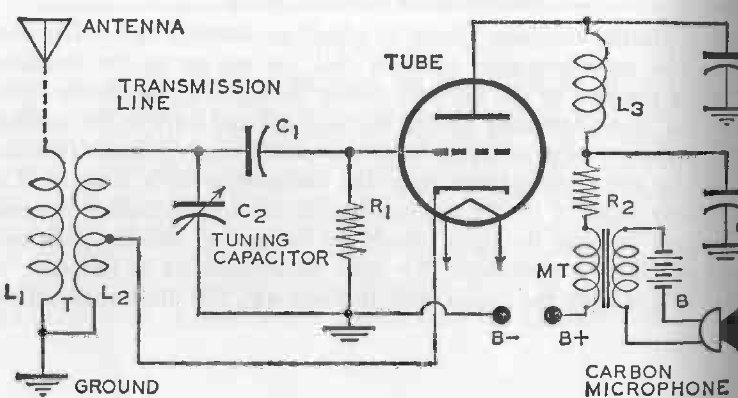
PRODUCING A CARRIER WAVE

This is a Hartley oscillator circuit to which an antenna circuit has been added. The radio-frequency currents that are set up in the oscillator circuit are coupled to the antenna circuit through the transformer coils L_1 and L_2. The alternating current flowing back and forth in the antenna produces electromagnetic waves known as carrier waves because they can be used to carry intelligence from the transmitter to a receiver. The carrier wave radiated by the antenna in this illustration cannot transmit information because its signal would be unvarying without additional apparatus called a modulator. To send information it is necessary to change or modulate the carrier wave in some way. See illustration following.

according to a prearranged code. Breaking a smoke column up into separate puffs could be called a method of modulating a smoke column.

There are several ways to modulate a carrier wave. One is to interrupt the wave so as to break it into signals corresponding to the dots and dashes of the telegraph code. This method is called KEYING. Radio telegraph transmitters are modulated by keying. When speech, music, or other sounds are to be transmitted, keying will not serve to modulate the carrier.

The method of modulation which is most widely used by broadcast stations is known as AMPLITUDE MODULATION. The amplitude of a wave is the distance from its minimum to its maximum value. The illustrations may help in understanding the meaning of amplitude. Perhaps also helpful is the obvious fact that large ocean waves which build up during a storm have more amplitude than the much smaller waves which occur during fair weather. Amplitude modulation is popularly known as AM. It is accomplished by connecting a microphone circuit to the oscillator so that the amplitude of the carrier wave is increased and decreased in step with the sounds of voice or music picked up by the microphone.

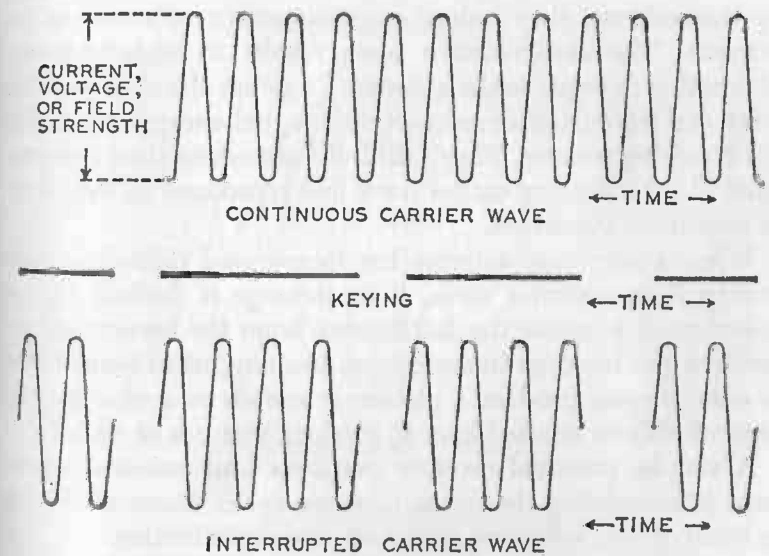


MAKING AN OSCILLATOR TRANSMIT INTELLIGENCE

If a microphone, transformer and battery are added to the plate circuit of the carrier-wave-producing oscillator shown in the preceding circuit diagram, the oscillator becomes a radio transmitter able to broadcast speech and music. Sounds which strike the diaphragm of the microphone cause the diaphragm to vibrate and vary the resistance offered to the battery current. The variations in resistance cause fluctuations in the current flowing in the primary of the transformer (MT) and corresponding A.C. voltage changes in the secondary. The voltage changes in the secondary cause variations in the plate voltage of the tube. Variations in the plate voltage produce variations in the amplitude of the carrier wave. Variations in the carrier wave are picked up by the receiving apparatus and transformed into corresponding sounds.

Many broadcasting stations, police, and other short-wave communications systems send forth FREQUENCY-MODULATED carrier waves. This method of modulation, popularly referred to as FM, varies the FREQUENCY of the carrier wave in accordance with voice or music signals. The amplitude of the carrier wave does not vary in this system; only the frequency of the carrier is modulated.

There is also a fourth method of modulation. It is called phase modulation and indirect frequency modulation. It is not used to a great extent.



PICTURES OF A CARRIER WAVE

When the variations in current or voltage of a radio-frequency alternating current, produced by an oscillator, are plotted on graph paper they form a wavy line like that at the top of the illustration. Plotting the field strength of the carrier wave produced by the radio-frequency currents produces a similar pattern. The broken line below the drawing of the carrier waves represents the dots, dashes, and spaces of telegraph signals. When a carrier wave is modulated by keying, it is broken into a pattern of dots and dashes as shown at the bottom of the illustration.

WHAT A RECEIVER IS AND HOW IT PERFORMS

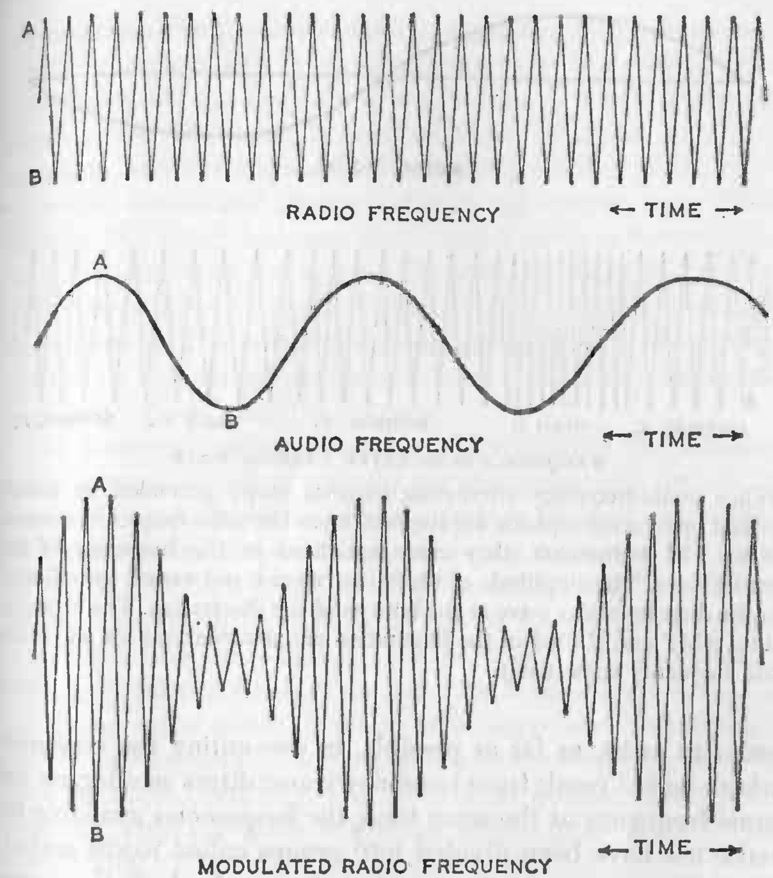
The components of a radio receiver are smaller and more compact than those of a transmitter. This is due chiefly to the fact that a receiver operates on much less power. A receiver completes the communication cycle which starts at the transmitter. A receiving antenna in the path of the waves radiated from a transmitter antenna intercepts the waves. A receiving antenna, even though it may be only a straight wire or rod, is in effect a circuit. Currents can be induced in it and currents can flow in it. Consequently when the electromagnetic lines of force which move along with the carrier wave are intercepted by the antenna, they induce an ELECTROMOTIVE FORCE in the antenna. The electromotive force results in high-frequency alternating currents in the antenna. Together the electromotive force and the currents represent intercepted energy required in the receiving process. They faithfully reproduce the characteristics of the incoming carrier wave and reproduce its frequency or amplitude variations.

When a receiving antenna has intercepted radio-frequency energy from a carrier wave, if its message is desired, the receiver must separate the intelligence from the carrier and reproduce the message in some form meaningful to human eyes or ears. It must produce a picture or sounds or a recording on tape which can be used later to produce pictures or sound.

A simple, practical receiver performs four essential operations in completing the communication cycle. These are known as interception, selection, detection, and reproduction.

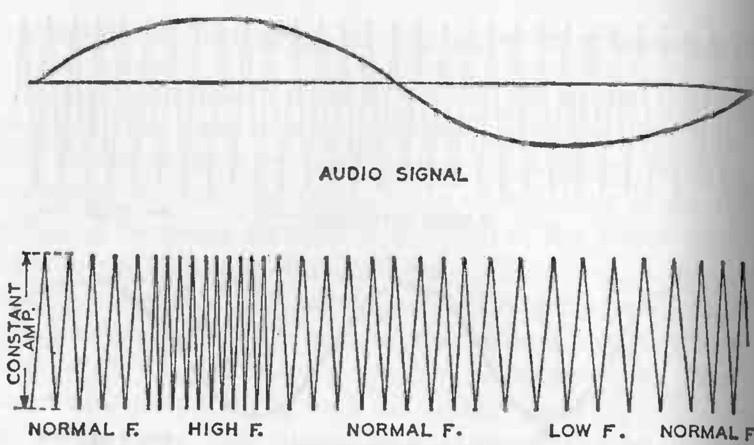
Interception has just been explained.

Selectivity. The amount of energy intercepted by an antenna is greatest when the antenna is tuned to the frequency of the intercepted carrier wave. Antenna tuning also increases a receiver's selectivity. Selectivity is the receiver's ability to intercept desired signals and reject all others. Space is a hodgepodge of thousands of messages being transmitted at all times. In



AN AMPLITUDE-MODULATED CARRIER WAVE

When audio-frequency alternating currents (center) generated by the sounds picked up by a microphone are imposed upon the radio-frequency currents (top) of an oscillator, the pattern of the resulting current and also of the carrier wave, when amplitude modulated, is as shown at the bottom. The amplitude (represented by the distance from A to B) is varied in accordance with the amplitude of the audio-frequency current.



FREQUENCY-MODULATED CARRIER WAVE

When audio-frequency alternating currents (top) generated by sounds picked up by a microphone are imposed upon the radio-frequency currents of an FM transmitter, they cause variations in the frequency of the carrier wave. The amplitude of the carrier wave is not varied, as indicated in the diagram of the wave at the bottom of the illustration. The abbreviations AMP and F used in the illustration are abbreviations for amplitude and frequency respectively.

order to assist, as far as possible, in preventing the confusion which would result from too many transmitters sending on the same frequency at the same time, the frequencies available for radio use have been divided into groups called BANDS and allocated for various purposes. It is necessary for both the operator and the transmitter to be licensed by the federal government.

A highly selective receiver must be able to pick up one frequency at a time and reject all others. A receiver must also have SENSITIVITY as well as selectivity. This quality is a measure of its ability to intercept weak signals and extract their message. Signals may originate from anywhere in the world from transmitters of widely varying power output. A highly sensitive receiver will pick them up whether weak or strong.

Detection. The process of separating the intelligence or message from a modulated radio-frequency signal is called DETECTION. Since it is the opposite of modulation it is also called DEMODULATION. Detection is accomplished with the help of a DETECTOR, actually a special form of small rectifier which has a valve-like action and changes alternating current into direct current. The usual detectors are a crystal DIODE, a two-element vacuum tube DIODE, or a three-element vacuum tube TRIODE.

The current output from a detector is a very weak, pulsating direct current. The pulses of current are at the radio-frequency rate but its strength surges up and down in step with the audio-frequency (modulation) amplitude.

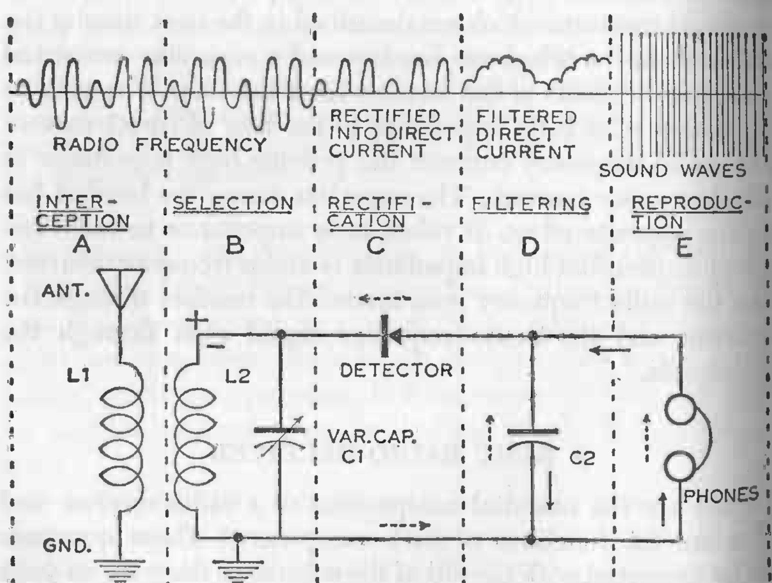
The detection process is completed by filtering the pulsating direct current. Filtering smooths out the pulses to a degree. In the simple receivers which are described in the next chapter the small coils in the telephone headset and a capacitor connected across the terminals of the headset form the filter. The coils in the headset offer little impedance to the flow of direct current or to audio-frequency currents but provide high impedance to radio-frequency currents. The capacitor across the headset has just the opposite effect. It offers little impedance to radio-frequency current but high impedance to audio-frequency current. Thus the radio frequency goes around the headset through the capacitor and the audio-frequency signal goes through the headphones.

A BASIC RADIO RECEIVER

What are the essential components of a radio receiver and what are the functions of each component? These questions can be answered with the aid of the schematic diagram on page 98. This diagram shows the conventional method of connecting the components of a simple radio receiver. It also gives a graphic representation of the intercepted signal as it passes through the receiver. The illustration is divided into five sections, marked A, B, C, D, and E, by vertical dotted lines. Each section is the portion of the circuit where one of the functions which have just been discussed is performed. For example, interception occurs in Section A, selection takes place in Section B, rectification in Section C, etc.

To completely analyze the action of the receiver it is necessary to repeat some of the previous explanations.

Section A—Interception. The antenna and ground are connected to the terminals of the primary coil L1 of a transformer. When a carrier wave cuts across the antenna a radio-frequency electromotive force is induced across the antenna and conse-



A BASIC RADIO RECEIVER.
The receiver circuit and the diagrams above it are divided into sections A, B, C, D, and E by dotted lines. The text explains what occurs in each section when a signal is received.

quently across the primary coil L1. The current flowing in primary coil L1 induces a current in the secondary coil L2 of the transformer.

Section B—Selection. The secondary coil L2 is part of a tuned resonant circuit consisting of L2 and the variable tuning capacitor C1. Although a small amount of signal selection occurs in the antenna system, the most effectual selection takes place in the tuned resonant circuit by adjusting the tuning capacitor C1.

The tuned resonant circuit presents maximum impedance to the frequency to which it is tuned and little impedance to frequencies off resonance. At resonant frequency, the voltage across the coil L2 and the voltage applied to the detector are maximum. At off-resonant frequencies only small voltages are developed across coil L2 and applied to the detector. The practical result is that the tuned circuit (the coil and capacitor form a circuit commonly called a TANK circuit) shunts the off-resonant frequencies to the ground and applies only the resonant frequency to the detector.

Section C—Rectification. Since the current in the tank is radio-frequency alternating current, the polarity at the terminals of the coil L2 is alternately positive and negative. When the top of the tank (connected directly to the detector) is positive, current flows through the detector, capacitor C2, and the phones in the direction shown by the dotted arrows. When the top of the tank is negative, the valve action of the detector prevents it from conducting, and the capacitor discharges current in the direction indicated by the solid black arrows. Thus the alternating current is rectified to a pulsating direct current.

Section D—Filtering. The small capacitor C2 connected across the phones charges during the short time when the detector conducts and partially discharges when the detector does not conduct. This charging and discharging process filters out almost all the radio-frequency component of the pulsating direct current. The filtered current rises and falls in a pattern which conforms to the modulation as shown by the wave form at the top of section D.

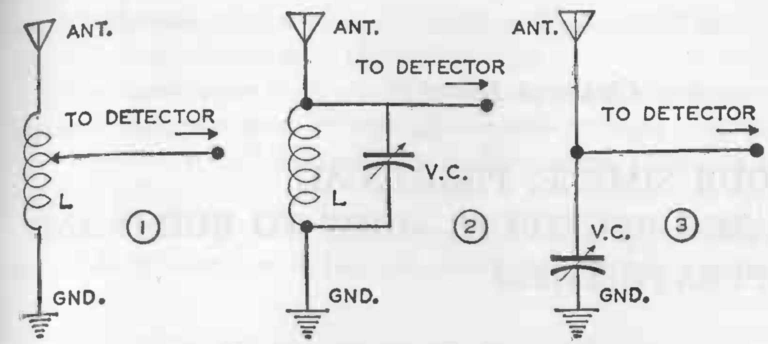
Section E—Reproduction. The headphones change the current pulses into vibrations of their diaphragms which cause the sounds that reveal the message.

ANTENNA TUNING

An antenna is in itself a tuned circuit which in itself provides some selectivity. An antenna possesses a certain amount of inductance, capacitance, and resistance and can be a resonant circuit the frequency of which can be changed by varying the inductance or capacitance. This can be done by placing a variable inductance or a variable capacitance in the antenna circuit as shown on page 101 or by changing the length of the antenna. When the antenna is a single wire or a mast the inductance and capacity vary directly with the antenna length. The longer an antenna, the lower its resonant frequency.

An antenna can be tuned in its construction by making its physical length one-quarter or a multiple of one-quarter of the wave length to be intercepted. At low frequencies, antennas are long; at high frequencies, antennas are short. In general, antenna length is of little importance in broadcast receivers but in the simple receivers considered in this book there are no RF amplifiers to provide signal amplification. The gain provided in a receiver by RF amplifiers surpasses the gain from antenna tuning. For that reason antenna length has an important effect on the sensitivity and selectivity of these receivers.

As stated before, the resonant frequency of an antenna can be changed by varying antenna capacitance, antenna inductance, or both. This can also be done by changes in physical dimensions of the antenna or by connecting a variable inductance or a variable capacitance in the antenna circuit. The addition or subtraction of inductance or capacitance has no effect on the physical length of an antenna but has considerable effect on



TUNING A RECEIVING ANTENNA

Lengthening the inductance coil in Fig. 1 would increase the electrical length of the antenna and decrease the frequency to which it would respond most efficiently. Shortening the inductance coil (L) would have the opposite effect.

Increasing or decreasing the capacity of the variable capacitors in the circuits in Figs. 2 and 3 will also change the electrical length of the circuits and the frequencies to which they would respond most efficiently. Increasing the capacity of the variable capacitor in Fig. 3 has the effect of shortening the antenna and making it respond to waves of higher frequency.

the ELECTRICAL length. The electrical length determines the resonant frequency of an antenna. When the inductance or capacitance are variable so that the electrical resonance is also adjustable, the electrical length of the antenna can be changed to accomplish exact tuning for a desired signal.

Antenna Coupling. Much greater selectivity can be obtained by using a transformer to couple the antenna to a separate tuned circuit which is directly connected to the antenna. The circuit is tuned by making either the capacitor or coil or both adjustable. The transformer isolates the tuned circuit from the resistance of the antenna, steps up the voltage, and increases both selectivity and sensitivity.

Chapter Seven

FOUR SIMPLE, PRACTICAL RADIO RECEIVERS—HOW TO BUILD AND OPERATE THEM

The component parts of commercially manufactured electronic apparatus are usually mounted on a steel or plastic frame called a CHASSIS. Many of the parts are mounted on the top surface of the chassis. The wiring is placed on the underside. A great variety of sizes and shapes of chassis bases and cabinets made of steel or aluminum are available from dealers in electronic supplies. This type of construction necessitates making holes of varying size and shape in sheet metal. Most young experimenters do not possess the special tools and the skill required to perform these operations. For that reason all plans in this book are for apparatus of the "breadboard" type. This is the simplest type of permanent construction. Tube sockets, capacitors, transformers, and other components are fastened to a wooden base with screws. A wooden base for radio apparatus, because of its appearance, is dubbed a "breadboard" by amateur experimenters.

The four receivers described in this chapter are sensitive, have considerable selectivity, and will produce strong signals in a pair of headphones when tuned to broadcasting stations within a 50-mile radius. With a suitable antenna it is possible to pick up stations at a greater distance. All four receivers are quite similar except that each detector is a different type. It is not necessary to construct any parts except the wood bases. The

components are purchased ready-made and assembled and connected in accordance with the instructions.

If you have never built any electronic apparatus it is recommended that you start by assembling one of these receivers. The experience will be useful in making more elaborate apparatus later.

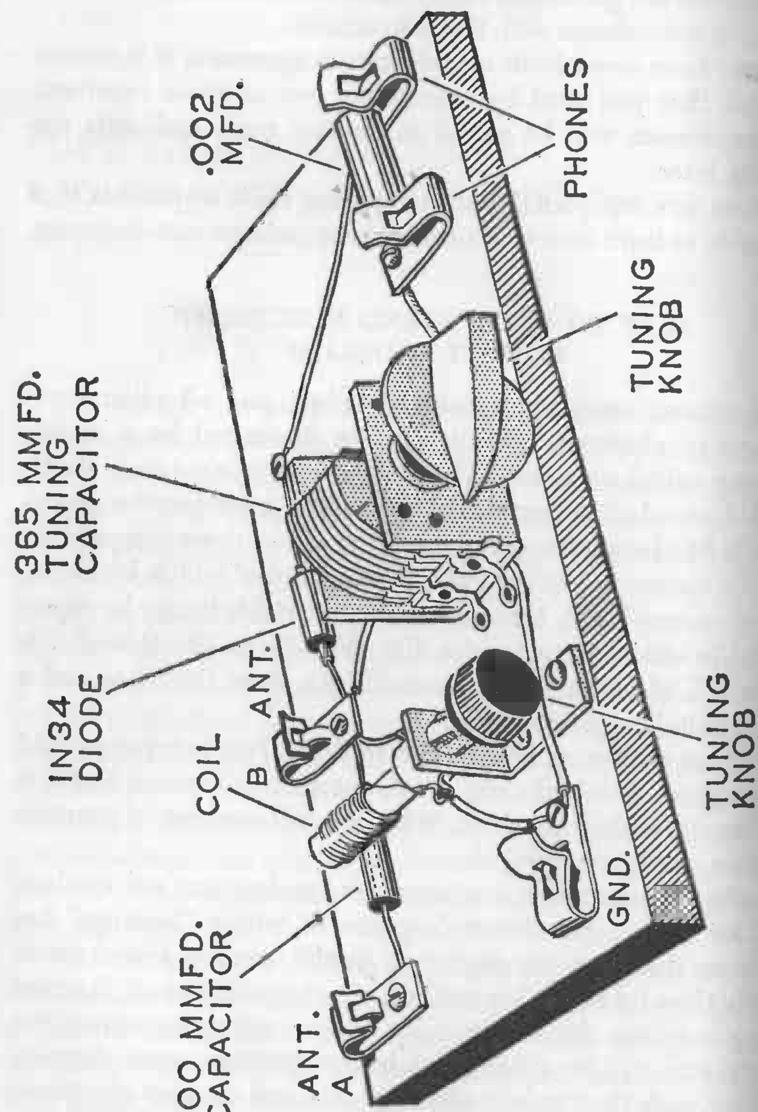
Before you try your hand at building radio apparatus it is advisable to learn how to read schematic radio circuit diagrams.

HOW TO UNDERSTAND ELECTRONIC CIRCUIT DIAGRAMS

Capacitors, resistors, transistors, tubes, and all other components of electronic circuits can be illustrated by a simple drawing called a SYMBOL. These are a sort of electronic shorthand. Instead of taking the time to make a perspective drawing of a fixed capacitor every time that one of these components is to be shown in a circuit diagram, a symbol which looks like this —|(— is employed. If the capacitor is variable it may be represented in either of two ways, like this —|(— or like this —/|(—. A single cell of battery is represented by a short thick line and a longer thin line parallel to it.

Pictures require skill and time to draw. Not everyone could draw a good sketch of a capacitor, antenna, or resistor. But it is easy to draw their symbols. With a small amount of practice you can soon draw symbols.

Radio experimenters, engineers, and technicians use symbols to draw SCHEMATIC circuit diagrams or wiring "hookups" because in that way an electronic circuit can be shown more clearly than by any other method. A schematic circuit diagram which indicates the size or value of the various capacitors, resistors, etc., is like a blueprint in construction work. Anyone familiar with the symbols can assemble and connect electronic apparatus without any other information than such a circuit diagram.



RADIO RECEIVER WITH CRYSTAL-DIODE DETECTOR FOR BROADCAST FREQUENCIES

Naturally, schematic diagrams may be a bit bewildering to some beginners in electronics. But it is essential to learn to "read" or understand these diagrams if you are interested in electronics and wish to make progress in the field. It is necessary to know how to read and draw schematic circuit diagrams in order to pass the government examination for an amateur radio operator's license. The symbols used in the circuit diagrams in this book are illustrated in Chapters Five and Six. Study them until they are familiar and you can draw them yourself.

There are two types of simple electronic diagrams often found in books for beginners. One type is called a BLOCK diagram and the other a PICTORIAL diagram.

HOW TO BUILD A RADIO RECEIVER WITH A CRYSTAL-DIODE DETECTOR

This is one of the simplest practical forms of radio receiver. It consists of a loopstick antenna coil, variable tuning capacitor, filter capacitor, and antenna capacitor mounted on a wood base and connected to an antenna and ground.

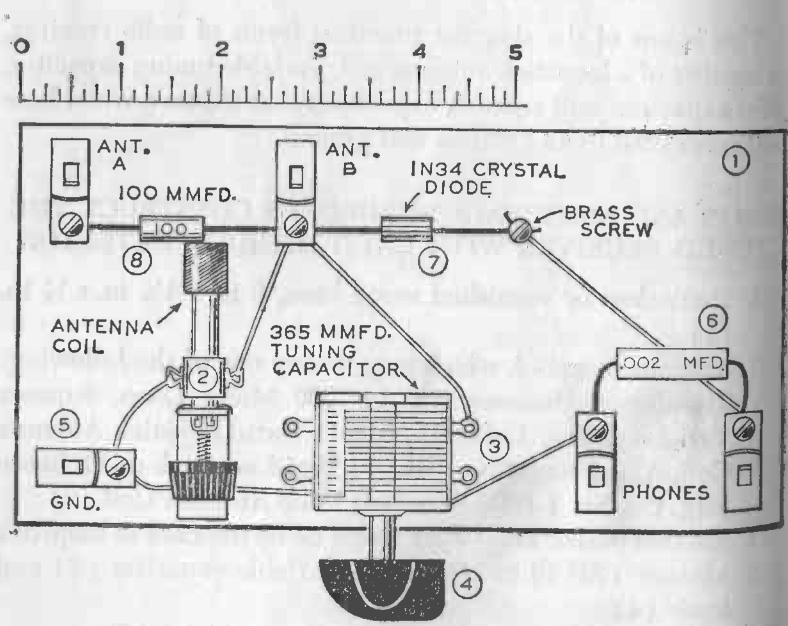
PARTS AND MATERIALS NEEDED TO CONSTRUCT THE TUNED RECEIVER WITH CRYSTAL-DIODE DETECTOR

- 1 Shellacked or varnished wood base, 8 in. x 4⅛ in. x ½ in. (1)
- 1 Antenna loopstick which may be any one of the following: Thordarson-Meissner No. 14-7000 Micro Loop, Superex Vari-Loopstick, Lafayette MS-11 Vari-Loopstick Antenna Coil, Allied Radio No. 51C034 Vari-Loopstick or Philmore Mfg. Co. No. 1-R841 Standard Loop Antenna Coil (2)
- 1 Molded plastic knob to fit screw on ferrite core in loopstick
- 1 Midget TRF 10 to 365 mmfd. variable capacitor (3) and knob (4)
- 5 Fahnestock spring contact slips 1 in. x ⅜ in. (5)

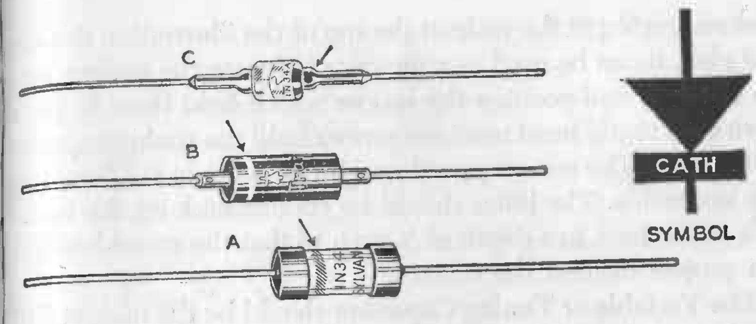
1 Sylvania 1N34 crystal diode or equivalent (7)
1 .002 mfd. paper capacitor (6)
1 100 mmfd. ceramic capacitor (8)
8 ⅜-in., No. 6 round head brass wood screws
2 ½-in. 6-32 round head machine screws to mount variable capacitor
Hookup wire, rosin-core solder

All of the components in the list above can be found in several catalogs of firms which sell electronic apparatus and components by mail.

A double headset consisting of a headband with two 1,000- to 1,500-ohm telephone receivers connected in series is needed to make the signals audible. A single headset can be used but will not be as satisfactory when tuning in weak signals as a double headset. A double headset is not expensive and can be



PLAN OF THE RECEIVER



CRYSTAL DIODES

Any one of these three general-purpose crystal diodes may be used as a detector. The arrows in the illustration point to the markings on the diodes which indicate the cathode end.

used in so many different ways that every electronic and radio experimenter should own one. An ordinary telephone receiver is wound with comparatively coarse wire and has a resistance of approximately 75 ohms. It is not as sensitive to very weak signals as a radiophone which is wound with sufficient turns of fine wire to have a resistance of 1,000 to 1,500 ohms.

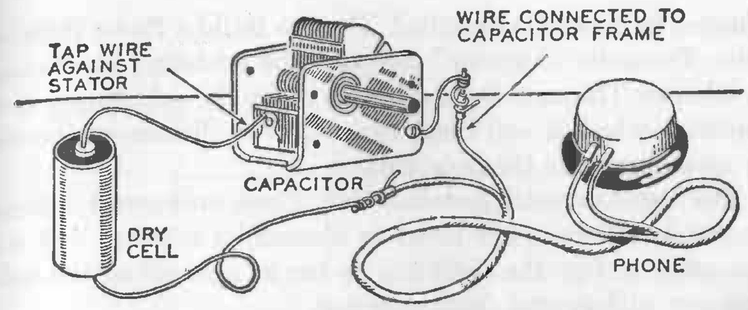
The Base. Start by making the wood base. This can be cut from any variety of seasoned and dry lumber from ½ to ¾ inch thick. Smooth all surfaces with fine sandpaper and apply two coats of white shellac or varnish. Allow the first coat to dry before applying the second. Shellac will dry more quickly than varnish. Apart from improving the appearance of the base, the purpose of the coatings is to seal the grain of the wood and keep moisture out. Damp wood is not an insulator and the base should be dry to prevent current leakage and consequent weakening of signals.

The receiver is ready to assemble as soon as the finish on the base is dry.

The perspective sketch of the completed receiver and the plan show how the components are arranged on the base. If you make a tracing of the scale at the top of the illustration showing the plan, it can be used as a measure to locate the various parts on the base and position the screws which hold them in place. Two 6-32 round head machine screws hold the tuning capacitor to the base. The screws pass through two holes in the base from the underside. The holes should be countersunk on the underside of the base to a depth of ⅛ inch so that the screw heads do not project beyond the surface.

The Variable or Tuning Capacitor should be the midget TRF single-gang, air dielectric type with intermeshing aluminum plates and a variable capacity ranging from 10 to 365 mmfds. It is mounted near the front edge of the base slightly to the right of the vari-loopstick antenna coil. The shaft of the capacitor should be fitted with a Bakelite knob so that the rotor can be turned without the hand coming into contact with the metal shaft. The screws which pass upward through holes in the base and thread into the bottom of the capacitor should not project more than ⅛ inch above the top surface of the base. If too long, they will project through the stator frame and touch some of the stator plates, thereby causing a short circuit. The screws should be only tight enough to hold the capacitor without straining it.

Test the Capacitor. The midget TRF variable capacitors on the market are not always very rugged. They must be handled carefully. To economize space and cost, the plates are placed very close together, too close in fact. They become misaligned sometimes, rub together, and cause a short circuit. When a capacitor is ordered by mail, handling and shipping often cause a short circuit between the stator and the rotor plates. It is advisable to test a capacitor before and after mounting it in place. To do this, connect a wire to one of the STATOR terminals. Connect the other end of the wire to a telephone receiver or headset (see illustration). Run a wire from the second terminal of the receiver or headset to the positive terminal of a dry cell. Attach a wire to the negative terminal of the dry cell. Tap the other end of the wire against the frame of the capacitor and at



TEST THE VARIABLE CAPACITOR

The text explains how to test a variable capacitor for short circuit.

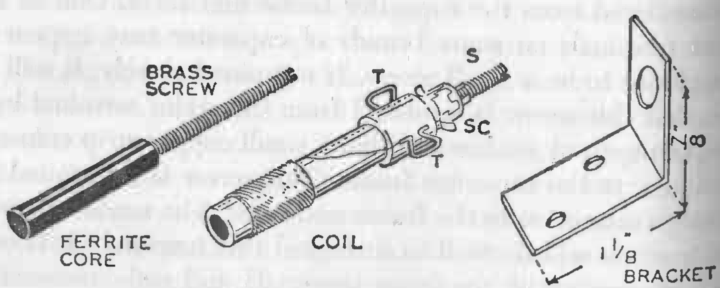
the same time listen in the phone or headset. If there is a distinct "click" each time that the wire touches the frame the capacitor is probably short circuited. Check to see if there is any dirt or foreign matter between the plates. Make the "click" test with the stator in several positions. If the capacitor is shorted the chance that you can fix it is small. Better throw it away and get a new one.

There are usually one or two small stator terminals on each side of the capacitor. They are connected to the stator plates but insulated from the capacitor frame and rotor. One of the stator terminals on some brands of capacitor may appear at first glance to be a small screw. If examined closely, it will be seen that this screw is insulated from the stator terminal by a thin, transparent washer and that a small copper strip connects the screw to the capacitor frame. This screw is a terminal for making connection to the frame and rotor. The novice at radio construction will do well to disregard this terminal (it is easy to short circuit with the stator terminal) and make connection to the rotor by placing a wire under the head of one of the screws which hold the capacitor to the base. The only way a good electrical connection can be made to a stator terminal is to solder a wire to it. See instructions for soldering later in this chapter under section entitled "How to Build a Radio Receiver with Transistor Detector." See also the soldering instructions in Chapter Thirteen. Be careful not to lay the soldering iron on anything which it will burn. Remember to disconnect the iron as soon as you are through using it.

The Vari-Loopstick Antenna Coil. There are several different loopstick antenna coils listed in electronics catalogs and it is necessary to buy the right one to use in assembling the radio receiver with crystal-diode detector.

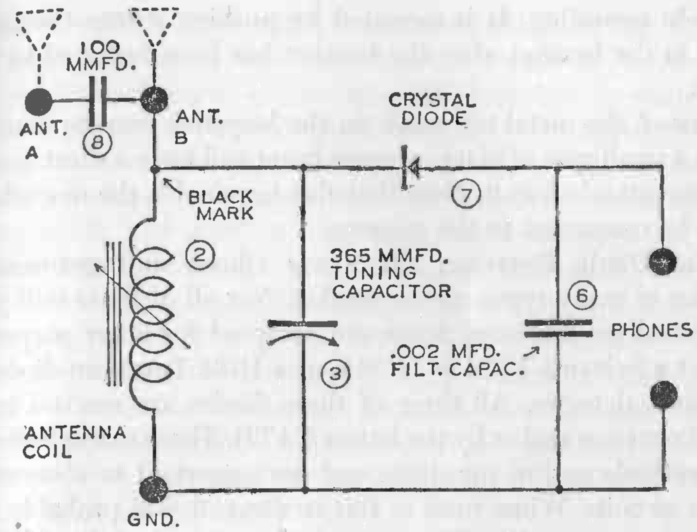
All the loopsticks specified in the list of parts and materials have been used in building models for this book. These loopsticks have a "Q" or inductance value of about 250 microhenries. By adjusting the ferrite core and tuning with a standard 365 mmfd. tuning capacitor any frequency over the entire broadcast band from 540 to 1600 kc can be tuned in on the receiver.

The correct loopstick to use in assembling the receiver with crystal-diode detector consists of an insulating tube about 2 inches long and 9/32 inch in outside diameter. A small coil of fabric-insulated wire is wound on one end of the tube. The ends



A VARI-LOOPSTICK ANTENNA COIL WITH MOUNTING BRACKET

T and T are terminals. S is the core-adjusting screw and SD identifies one of the spring clamps which holds the coil in place when it is pushed in the large hole in the bracket.



SCHEMATIC CIRCUIT DIAGRAM OF RECEIVER WITH CRYSTAL DIODE

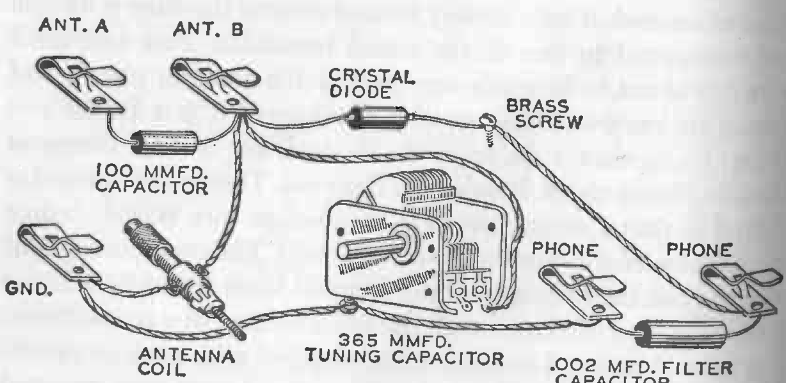
of the coil are connected to two metal terminals at the opposite end of the tube. There may be also a coil consisting of 12 to 14 turns of enameled wire loosely wound around the tube with one end connected to one of the metal terminals. This enameled wire coil is not to be made any part of the receiver circuit and should be removed. The core of the loopstick is a ferrite rod about 1½ inches x ¼ inch. A 3/32-inch or ⅛-inch diameter threaded brass rod is attached to the core. The end of the rod is slotted so that a screwdriver can be used to turn it and change the position of the core relative to the coil. The most convenient way to tune the loop is to attach a small knob to the end of the screw and turn the latter with the knob instead of a screwdriver.

A metal bracket 2 inches long is supplied with each loopstick. The bracket should be bent at right angles 1 inch from one end and fastened to the base with two ⅜-inch round head brass screws. The loopstick is fitted at one end with a single-hole, snap-in mounting. It is mounted by pushing it into the large hole in the bracket after the bracket has been fastened to the base.

One of the metal terminals on the loopstick may be marked with a small spot of black or green paint and have a short length of wire attached to it. Note that this terminal is the one which is to be connected to the antenna.

The Diode Detector. There are silicon and germanium diodes of many types on the market. Not all of these will perform well as detectors. Some are designed for other purposes. Select a Sylvania 1N34 or 1N34A, or a 1N34 Transiton diode to use as a detector. All three of these diodes are marked by a band near one end or by the letters CATH. These marks indicate the cathode end of the diode and are important to observe in some circuits. When used in this receiver, it will probably not make any noticeable difference which terminal of the diode is connected to the antenna. However, there may be a slight preference for connecting the cathode to the antenna.

Wiring or Connecting the Components. When the loopstick, variable capacitor, and the Fahnestock spring contact clips have



PICTORIAL CIRCUIT DIAGRAM OF RECEIVER WITH CRYSTAL DIODE

been fastened in their proper positions on the base, the receiver is ready to be wired. It is here that the novice may make mistakes. The schematic circuit diagram, pictorial diagram, and plan all show how the wiring is arranged. Use stranded thermoplastic insulated hookup wire. Three of the connections must be soldered, namely two connections to the antenna coil terminals from GND. and ANT. B clips and a wire from the ANT. B clip to a stator terminal on the capacitor. Remember that the terminal on the antenna coil identified by a black spot should be connected to the ANT. B clip. The bared ends of all other wires, except those which are soldered, can be clamped under a clip or screw head. Notice that one end of a wire clamped under a PHONE clip and a wire connected to the anode end of the crystal diode are connected together by clamping under a screw head on the base.

Use only rosin-core solder to make the soldered connections. Acid-core solder is taboo for electronic circuits.

There are two antenna clips. One is marked ANT. A and the other ANT. B. A small fixed capacitor (100 mmfd.) is connected across the antenna clips. The length of the antenna and the ground wire will determine whether the antenna should be connected to ANT. A clip or ANT. B clip.

When the wiring is completed the receiver is ready for trial. First, check all the connections to make certain they are tight and as in the diagrams.

Operation. Make the first test of the receiver where there is a good ground connection to a steampipe or water pipe available. The wire used as a ground connection should not be over 15 feet long.

If an outdoor antenna is not available, arrange a temporary indoor antenna by stretching about 50 feet of insulated wire indoors from room to room. Connect the antenna to one of the antenna clips. The clip marked ANT. A will probably produce the better signals with a long antenna and ANT. B better signals with a short antenna. Use the connection which produces the better signals.

Connect a 2,000- to 3,000-ohm radio headset to the phone clips. Place the phones in position and tune the loopstick by turning the threaded shaft which moves the ferrite core. Turn the variable capacitor at the same time. Listen carefully and as soon as a faint signal is heard adjust both the loopstick and the tuning capacitor until the signal is as loud as it is possible to make it.

For those who are interested, here is an explanation of how the receiver makes signals audible:

How the Crystal-Diode Receiver Performs its Function. When the antenna intercepts a carrier wave from a transmitter, radio-frequency alternating currents which faithfully reproduce the characteristics of the incoming carrier wave are produced in the antenna. The energy of the currents in the antenna is brought to maximum strength by adjusting the loopstick so that the antenna is tuned to the frequency of the intercepted carrier wave. The antenna coil and the variable capacitor form a tank circuit and the voltages and currents reaching the detector are greatest when the tuning capacitor is adjusted so that the tank circuit is also tuned to the frequency of the intercepted carrier wave.

Radio-frequency alternating currents cannot pass through the electromagnets in headphones and so they are rectified into pulsating direct current by the valve-like action of the crystal detector or diode. The diode is an electrical valve which conducts a current much better in one direction than in the other. Direct current will pass through the electromagnets in headphones. The pulsating direct current resulting from the rectifying action of the crystal diode is then filtered and smoothed somewhat so that the direct current component passes through the phones and the radio frequency passes through the filtering condenser. The direct current produces sounds in the headphones which convey the message to the ears of the listener.

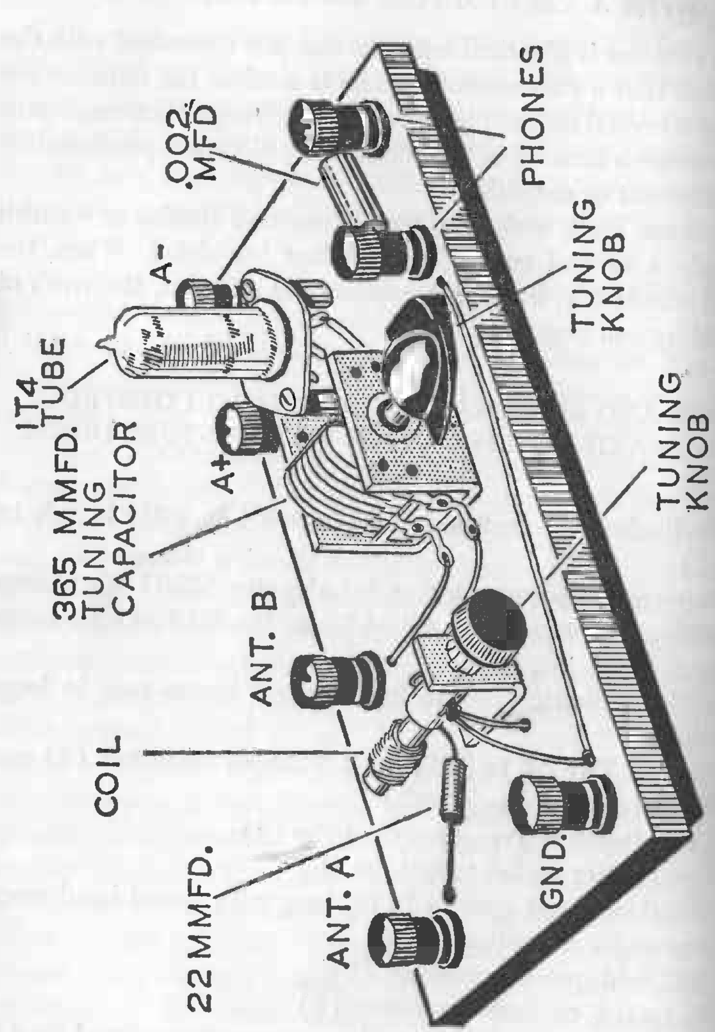
HOW TO BUILD A RADIO RECEIVER WITH A VACUUM-TUBE-DIODE DETECTOR

This receiver is identical with the one just described with the exception that a vacuum-tube diode is used as the detector instead of a crystal diode. The valve or rectifying action necessary in a detector is secured in this instance by electrons produced by a hot filament or cathode.

The Base. First, make the wood base and shellac or varnish it. Apply a second coat when the first has dried. When the second coat is dry, if the components are on hand, the work of assembling can begin.

PARTS AND MATERIALS REQUIRED TO CONSTRUCT THE TUNED RECEIVER WITH VACUUM-TUBE-DIODE DETECTOR

1 Shellacked or varnished wood base 8½ in. x 4⅛ in. x ⅜ in. (1)
1 Superex Vari-Loopstick or 1 Lafayette MS-11 Vari-Loopstick antenna coil, or 1 Allied Radio No. 51C034 Vari-Loopstick (2)
1 Molded plastic knob to fit screw on ferrite core in loopstick
1 Midget TRF 10 to 365 mmfd. variable capacitor (3) and knob (4)
1 1T4 Miniature type vacuum tube (5)
1 7-pin wafer socket to fit tube (6)
2 Metal or wood spacers ¾ in. long with round head wood screws for mounting socket
1 .002 mfd. paper capacitor (7)
1 22 mmfd. ceramic capacitor (8)
7 Binding posts or Fahnestock spring contact clips 1 in. x ⅜ in.
9 ⅜-in., No. 6 round head brass screws if Fahnestock clips are used. Only 2 are needed if binding posts are used.



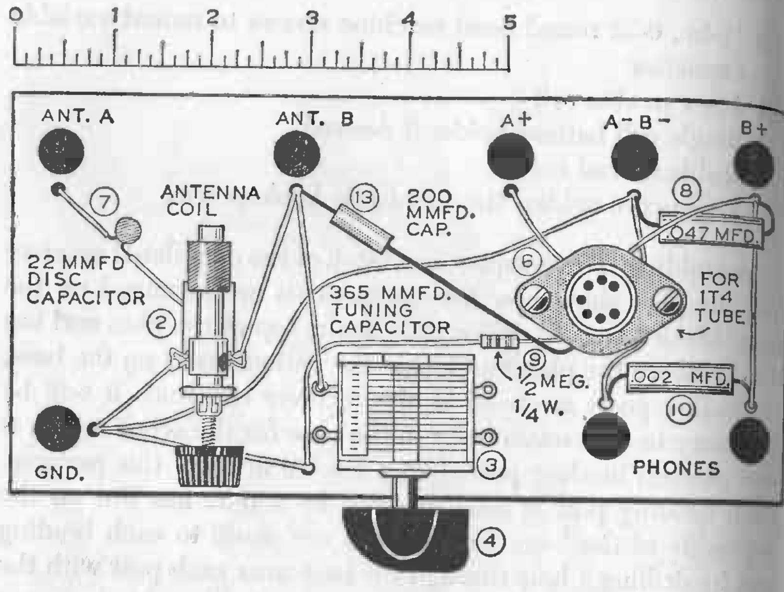
RADIO RECEIVER WITH VACUUM-TUBE-DIODE DETECTOR

2 ½-in., 6-32 round head machine screws to mount variable capacitor
1 1½-v penlite cell
1 Single cell battery holder if desired
4 Rubber head tacks
Rosin-core solder, thermoplastic hookup wire

Assembling. The perspective sketch of the completed receiver and the plan show how the components are arranged on the base. Make a tracing of the scale at the top of the plan and use it to measure the plan and locate the various parts on the base. If binding posts are used as the receiver terminals it will be necessary to drill seven holes in the base for the screw which is part of each binding post. Use a No. 29 drill for this purpose. Each binding post is held in place by a 6-32 hex nut on the underside of the base. Connections are made to each binding post by drilling a hole through the base near each post with the No. 29 drill. A wire which is to be connected to a binding post is pushed through the nearby hole from the top of the base and the bared end looped around the binding post screw on the underside of the base before the nut is tightened.

When Fahnestock clips are used as terminals, the bared ends of the connecting wires can be placed between the underside of the clips and the top surface of the base before the screws are tightened.

The bracket which holds the antenna coil should be bent at right angles midway between the ends and be fastened to the base with two screws before the coil is pushed into place in the large hole. The end of the threaded rod attached to the ferrite core is slotted so that it can be turned with a screwdriver. A much more convenient way of tuning the coil is to slip a small molded knob over the end of the rod and use the setscrew in the knob to fasten it in place. Note the 12 inches of wire connected to one of the terminals on the loopstick. Remove this wire and if the terminal to which it was attached is not



PLAN OF RADIO RECEIVER WITH VACUUM-TUBE-DIODE DETECTOR

already marked by a spot of black paint, mark the tube alongside the terminal with a spot of ink.

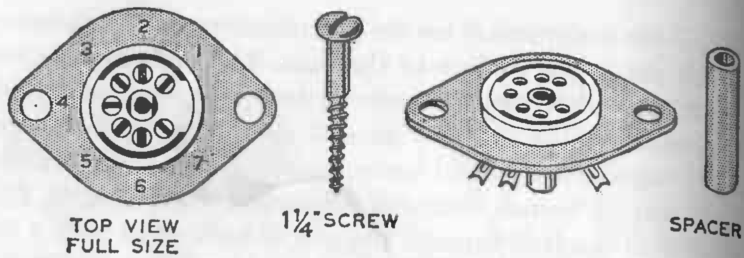
The variable tuning capacitor is the standard midget TRF single-gang air dielectric type with intermeshing aluminum plates and a variable capacity of 10 to 365 mmfds. The capacitor shaft should be fitted with a Bakelite knob. The capacitor should be mounted on the base near the front edge and held in place by two 6-32 round head screws which pass upward through holes in the base and thread into the bottom of the capacitor. The screws should not project more than ⅛ inch above the top surface of the base or they may project through the stator frame and touch one of the stator plates, thereby causing a short circuit. The screws should not be tightened hard. They should only be firm. If too tight they may pull the capacitor out of line and cause a short circuit.

The 7-pin wafer socket for the 1T4 miniature tube is mounted ¾ inch above the surface of the base. The ends rest on two cylindrical hollow metal spacers ¾ inch long. Spacers of this type are carried in stock by several electronic supply houses. If they cannot be obtained easily, make two wood spacers. Cut two pieces of ⅜-inch diameter hardwood dowel rod ¾ inch long and drill a hole through the axis of each piece with a No. 25 drill. Two 1¼-inch, No. 7 round head wood screws slipped through the holes at opposite ends of the socket and through the spacers fasten the socket in place on the base.

The 1T4 tube used in the receiver is not a diode. It is a pentode (5-electrode) tube designed as a radio-frequency or intermediate-frequency amplifier in lightweight, compact, portable, battery-operated receivers. But by using only two of the electrodes, namely the filament and the first grid, it will perform well as a diode detector. The filament operates on 1.5 volts or, in other words, on a single cell of flashlight battery. Connection to the dry cell can be made by soldering a flexible insulated wire to each terminal or by using a battery holder.

The four rubber head tacks in the material list are necessary only when binding post receiver terminals are used. A rubber head tack driven into each corner of the base on the underside will raise the nuts on the binding posts off table surfaces and avoid marring or scratching furniture.

Wiring. The receiver is ready to wire when all the components have been mounted on the base. Use stranded thermoplastic insulated hookup wire. Connect the terminal on the antenna coil which is marked by a spot of black paint to the ANT. B terminal and to the stator of the tuning capacitor. Connect one terminal of the 22 mmfd. capacitor to the stator of the tuning capacitor and the other terminal to the ANT. A terminal. Solder all connections to the antenna coil, capacitor stator, and socket. Connection is made to the capacitor stator by soldering a wire to one of the terminals on the side of the stator. Connection is made to the rotor of the capacitor by a wire placed



7-PIN WAFER SOCKET
The socket is mounted on the base with two spacers and screws.

under the head of one of the screws which hold the capacitor on the base.

Connect the A+ terminal to the No. 7 terminal on the socket and the A— terminal to the No. 1 terminal on the socket. One of the illustrations shows both top and bottom views of the tube connections and the top view of the socket. The No. 6 terminal on the socket should be connected to the ANT. B terminal. Note that 1, 6, and 7 are the only socket and tube terminals used. The tube connections are numbered in the diagrams so that the numbers of the terminal pins coincide with the numbers of the socket terminals. For example, pins numbers 1 and 7, which are the filament terminals on the tube, push into terminals 1 and 7 when the tube is put in the socket.

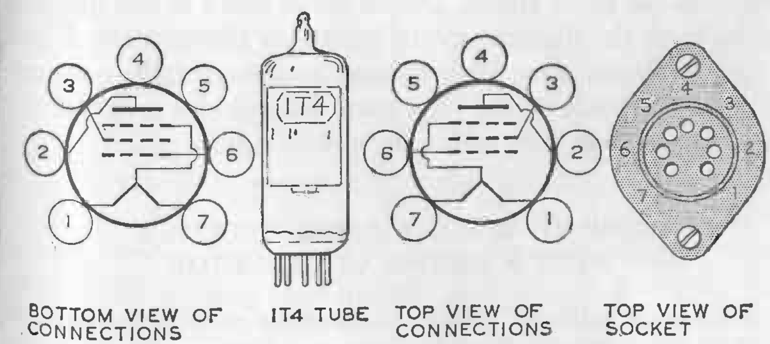
Operation. Connect a 1.5-v flashlight cell to the terminals A+ and A— using care to connect the negative of the cell to terminal A— and the positive of the cell to terminal A+. Connect a 2,000- to 3,000-ohm headset to the terminals marked PHONE. Connect a 25- to 50-foot antenna to ANT. B terminal. Connect terminal GND. to a good ground such as the nearest steampipe or water pipe. Push the 1T4 tube into its socket.

Place the phones on your head and tune the loopstick by turning the shaft which moves the ferrite core. Turn the variable capacitor slowly back and forth at the same time. As soon as a

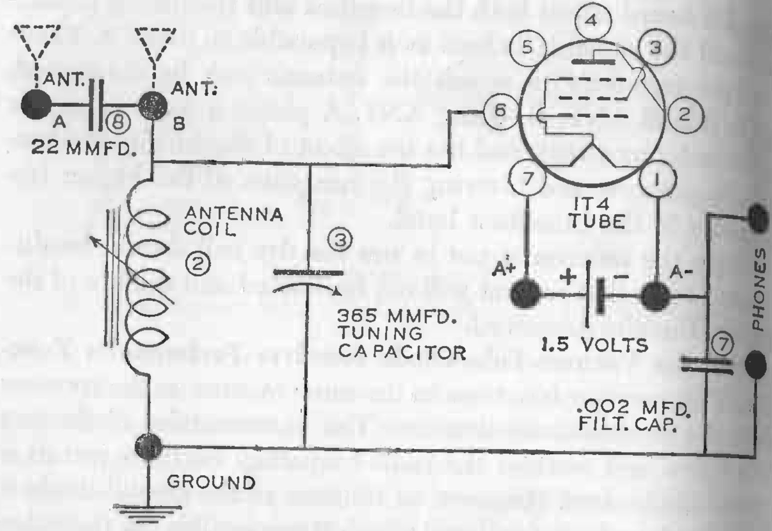
signal is heard adjust both the loopstick and the tuning capacitor until the signal is as loud as it is possible to make it. There are two terminals to which the antenna can be connected, ANT. A and ANT. B. Using ANT. A places a fixed capacitor in the antenna circuit and has the effect of electrically shortening the antenna and favoring the reception of the higher frequencies in the broadcast band.

When the receiver is not in use the dry cell should be disconnected so that current will not be wasted and the life of the battery thereby preserved.

How the Vacuum-Tube-Diode Receiver Performs its Function. This receiver functions in the same manner as the receiver with the crystal-diode detector. The vacuum-tube diode acts as a valve and rectifies the radio-frequency currents just as a crystal diode does. However, in the case of the crystal diode it is the semiconductor material which is responsible for the valve action of the detector, whereas in the vacuum-tube diode it is a stream of electrons thrown out of the hot filament which



1T4 ELECTRON TUBE
This is a pentode but when only the filament and grid are used it will perform as a diode.



SCHEMATIC CIRCUIT DIAGRAM OF RECEIVER WITH VACUUM-TUBE-DIODE DETECTOR

produces the valve action. The electrons move in one direction only—from the filament to the positively charged No. 1 grid.

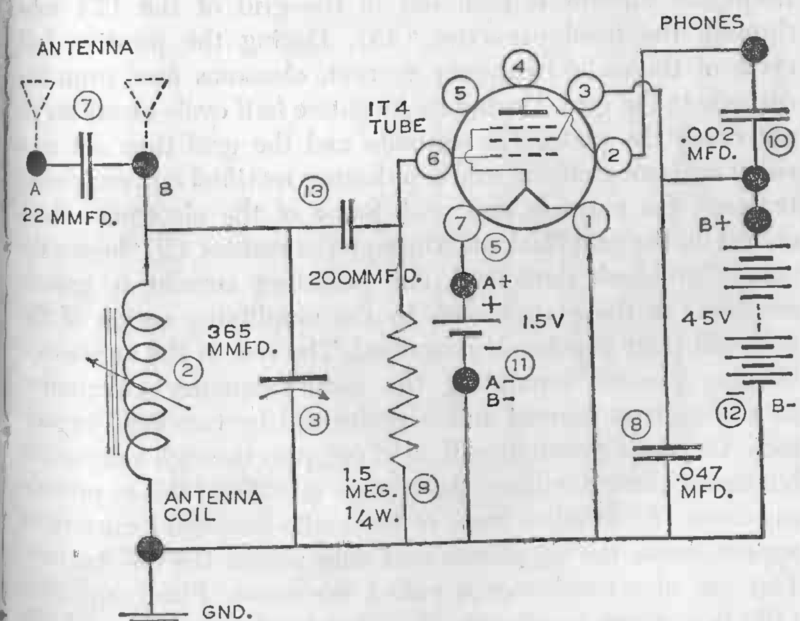
In a diode made expressly for use as a detector, the positively charged electrode would be a plate instead of a grid but in a 1T4 a grid serves very well as a substitute for a plate.

HOW TO BUILD A RADIO RECEIVER WITH A GRID-LEAK DETECTOR

A receiver with a "grid-leak" detector amplifies signals as well as detects them. It will receive weak stations much better than any of the two preceding receivers described in this chapter. The schematic diagram shows the 1T4 type tube connected as a pentode and operating as a grid-leak detector. An explana-

tion of how the pentode performs in this circuit requires a brief review of some facts about vacuum tubes.

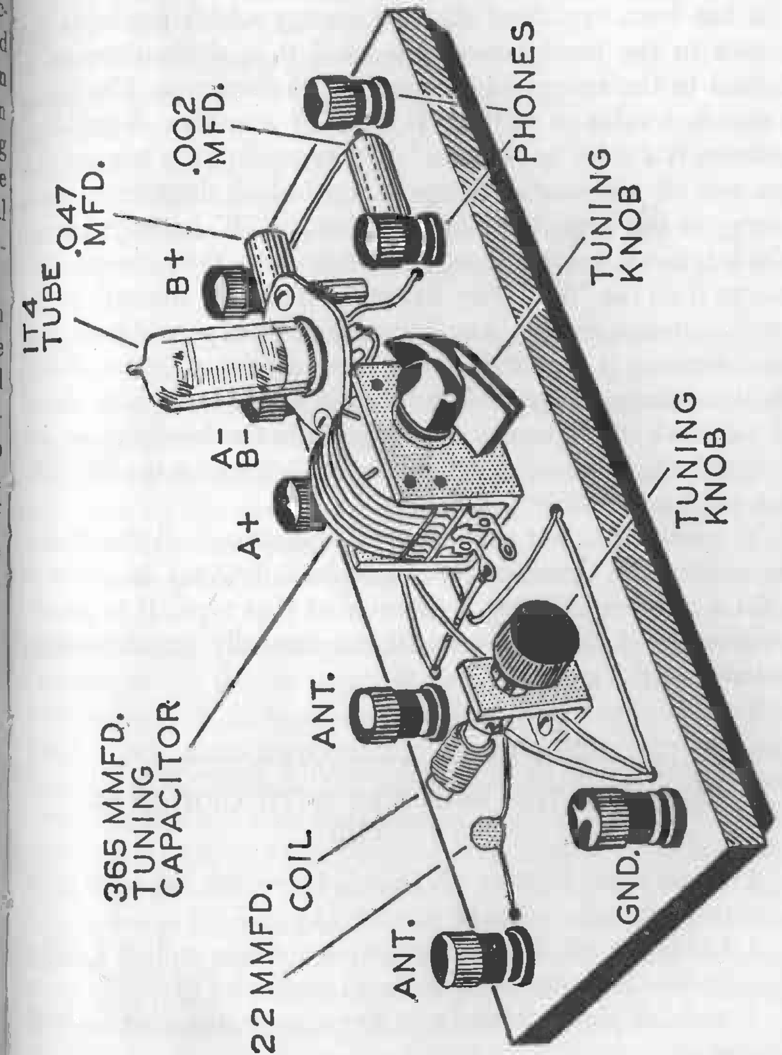
A DIODE tube has two elements, a cathode and a plate. The cathode is a producer of electrons which pass across the space between it and the plate when the plate is positive. When a third element called a grid, usually a spiral of fine wire surrounding the cathode, is placed between the cathode and plate, the tube becomes a TRIODE. Electrons produced by the cathode and traveling toward the positive plate must pass between the grid wires. Increasing the positive voltage on the plate increases the number of electrons reaching the plate. A positive voltage on the grid will also increase the number of electrons reaching the plate. But a negative voltage on the grid



CIRCUIT DIAGRAM OF RADIO RECEIVER WITH GRID-LEAK DETECTOR

DECREASES the number of electrons reaching the plate from the cathode. If the negative grid voltage is large enough no electrons will pass from the cathode to the plate. Since the grid is closer to the cathode than the plate a very small change in the voltage on the grid will cause a large change in the electron flow, or current, to the plate. This action is the amplifying action of the tube. Additional elements may be added to make a tube operate better than a triode. For example, two additional grids, making a PENTODE out of a triode, increase its amplifying power.

When the receiver with the pentode grid-leak detector is in operation the desired modulated radio-frequency currents are selected from the antenna by tuning the antenna coil (2) and the variable capacitor (3) just as in the crystal-diode, vacuum-tube-diode, and transistor detector receivers. The desired radio frequency current is then fed to the grid of the 1T4 tube through the fixed capacitor (13). During the positive half cycle of the radio-frequency current, electrons flow from the cathode to the grid. During the negative half cycle electrons do not reach the plate. The cathode and the grid thus act as a valve or diode detector and a pulsating rectified current passes between the cathode and grid. Some of the electrons which collect on the grid "leak off" through the resistor (9), hence the name "grid-leak detector." The pulsating current is greatly amplified in the plate circuit by the amplifying action of the grid and plate previously described. The rest of the action is a filtering process separating the radio-frequency component from the direct current and is performed by two fixed capacitors. Alternating current will, in effect, pass through a capacitor but direct current will not. Advantage is taken of this to provide capacitor (8) to allow most of the audio-frequency current to appear across the earphones and none across the "B" battery. This use of a condenser is called BYPASSING. Fixed capacitor (10) is a FILTER condenser which levels off the peaks and fills in the hollows or spaces between the pulses of direct current



RADIO RECEIVER WITH GRID-LEAK DETECTOR

so that the pulsating current varies at an audio rate similar to the modulating current at the transmitting station.

It has been explained that the energy which produces the sounds in the headphones connected to a diode detector is limited to the energy intercepted by the antenna. The diode is merely a valve or rectifier. It is not an amplifier. A grid-leak detector is a relay or "trigger." Just as pulling the trigger of a gun sets off a powerful charge so a grid-leak detector releases energy in the headphone circuit from the "B" battery, energy which is much greater than the energy from the antenna. The energy from the "B" battery has many times the strength of the feeble antenna energy. Another advantage of a grid-leak pentode detector is that it is much more sensitive than a diode. Weak carrier waves picked up by a diode receiver which would be too weak to produce audible signals in the headphones will "trigger" the pentode and with the assistance of the "B" battery produce audible signals.

Of course it is not necessary to understand all the theory concerning the operation of a grid-leak detector in order to build a receiver utilizing a detector of that type. It is merely necessary to follow the instructions carefully for assembling and wiring the receiver.

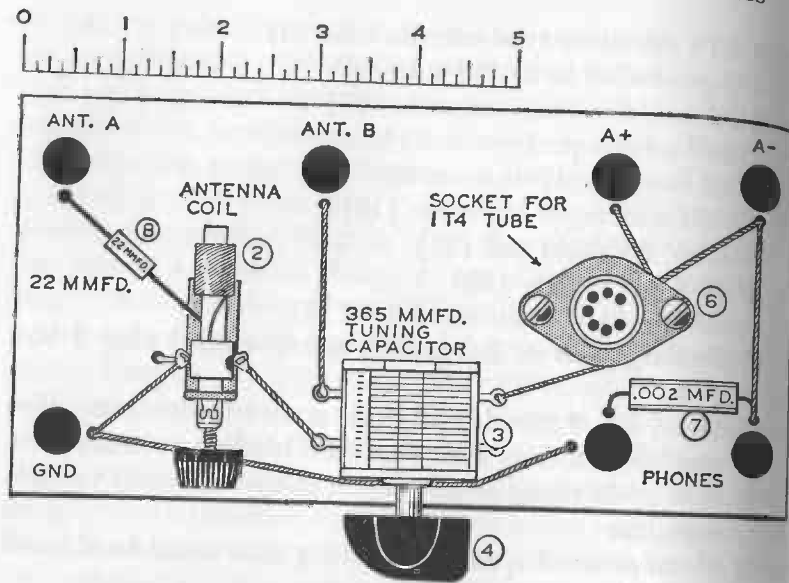
COMPONENTS AND MATERIALS NEEDED TO ASSEMBLE THE RECEIVER WITH GRID-LEAK DETECTOR

1 Wood base, 8½ in. x 4⅛ in. x ⅜ in., which has been given two coats of shellac or varnish (1)
1 Lafayette MS-11 Vari-Loopstick antenna coil or 1 Allied Radio Corp. No. 51C034 Vari-Loopstick (2)
1 Molded plastic knob to fit screw on ferrite core in loopstick
1 Midget TRF 10 to 365 mmfd. variable capacitor (3) and knob (4)

1 1T4 miniature type vacuum tube (5)
1 7-pin socket to fit 1T4 tube (6)
1 22 mmfd. ceramic capacitor (7)
1 .047 mfd. paper capacitor (8)
1 1.5 megohm, ¼-watt resistor (9)
1 .002 mfd. paper capacitor (10)
1 1.5-V flashlight cell (11)
1 45-V "B" battery (12)
1 200 mmfd. ceramic capacitor (13)
8 Binding posts or Fahnestock spring contact clips 1 in. x ⅜ in.
10 ⅜-in., No. 6 round head brass screws for fastening clips and bracket. Only 2 are needed if binding posts are used.
2 ½-in., 6-32 round head machine screws to mount variable capacitor
2 Metal or wood spacers ¾ in. long with round head wood screws for mounting socket
4 Rubber head tacks
Hookup wire, rosin-core solder

Assembling. The components can be assembled on the base as soon as the shellac or varnish coatings are dry. The sketch of the complete receiver and the plan show the location of the parts. Their exact position is easily determined by making a tracing of the scale at the top of the plan and using it as a measure. Make a hole through the base for each binding post with a No. 29 drill. Drill a second hole ½ inch away from each binding post hole. The second set of holes is for the wires which are to be connected to the binding posts. The wires are pushed through the holes from the top of the base and the bared ends wrapped around the binding post screws on the underside of the base before the nuts are tightened.

If Fahnestock clips are used instead of binding posts as receiver terminals, the second set of holes is omitted. When clips are put in position the holding screws are not tightened until



PLAN OF RADIO RECEIVER WITH GRID-LEAK DETECTOR

the bared ends of the connecting wires have been placed between the underside of the clips and the top surface of the base.

Bend the bracket for the antenna coil at right angles midway between the ends and fasten it to the base with two round head brass screws before the coil is pushed into place. The end of the antenna coil from which the threaded rod extends should be pushed into the large hole in the bracket until it locks in place and cannot be pulled out. The threaded shaft attached to the ferrite core is less than ⅛ inch in diameter but the standard $\frac{11}{16}$-plastic knob with ⅛-inch diameter hole and a headless set screw will fit the shaft satisfactorily. It is much easier to turn the shaft with a knob than with a screwdriver.

The variable tuning capacitor used in the receiver is the standard midget TRF single-gang, air-dielectric, 10 to 365 mmfd. capacitor used in the other receivers described in this chapter. Test the capacitor for a possible "short" between the stator and rotor after fastening it to the base. The two round

head 6-32 machine screws which pass upward through the base into threaded holes in the bottom of the capacitor should not be tightened hard or they may pull the capacitor out of line and cause a short circuit. They should be only snug or firm. Fit the rotor shaft with a plastic knob for convenience in turning the rotor.

The socket for the 7-pin 1T4 miniature tube is mounted on spacers so that it is raised ¾ inch above the surface of the base. The ends rest on two cylindrical hollow metal spacers ¾ inch long. Spacers of this size are carried in stock by some of the firms that sell electronic parts by mail. If they cannot be obtained readily, make spacers by cutting off two ¾-inch lengths of ¼-inch diameter copper tubing with a fine tooth hack saw, or make two wood spacers. Cut two pieces of ⅜-inch diameter hardwood dowel rod ¾ inch long. Bore a hole through the axis of each piece with a No. 25 drill. Two 1¼-inch, No. 7 round head wood screws slipped through the holes at opposite ends of the socket and through the spacers fasten the socket in place on the base. Before the socket is fastened to the base solder a 4-inch piece of hookup wire to socket terminals Nos. 1, 2, and 3. Also, solder one terminal of the 200 mmfd. ceramic condenser and one terminal of the 1.5 megohm resistor to No. 6 socket terminal.

The 1T4 miniature tube used in the receiver is a pentode (5-electrode) tube designed as a radio-frequency or intermediate-frequency amplifier in lightweight, compact, portable battery-operated receivers. But when connected in the manner shown in the schematic diagram it operates as a detector and amplifier. The filament of an 1T4 tube requires only a single dry cell (1.5 volts). The filament current is only 0.05 amperes and consequently the "A" battery will give long service. Connection to the dry cell can be made by soldering a piece of flexible hookup wire to each terminal or by using a battery holder. It will be necessary to solder two wires to the battery holder.

The rubber head tacks in the materials list are required only when binding post terminals are used. A rubber head tack driven into each corner on the underside of the base will raise the hex nuts above any surface upon which the receiver is placed and avoid scratching furniture.

Wiring. When all the components have been fastened in place use stranded thermoplastic insulated hookup wire to make the connections.

The short length of wire (12 to 14 inches) connected to ONE of the antenna coil terminals should be removed. If the terminal to which it was attached is not identified by a spot of black paint, mark the tube alongside the terminal with a spot of ink. This terminal of the antenna coil should be connected to the ANT. B binding post or clip. The other terminal of the antenna coil should be connected to the GROUND post.

The wires connected to the antenna coil terminals and to the stator of the tuning capacitor should be soldered in place with rosin-core solder. Connection can be made to the rotor of the capacitor by a wire placed under the head of one of the 6-32 screws which hold the capacitor on the base.

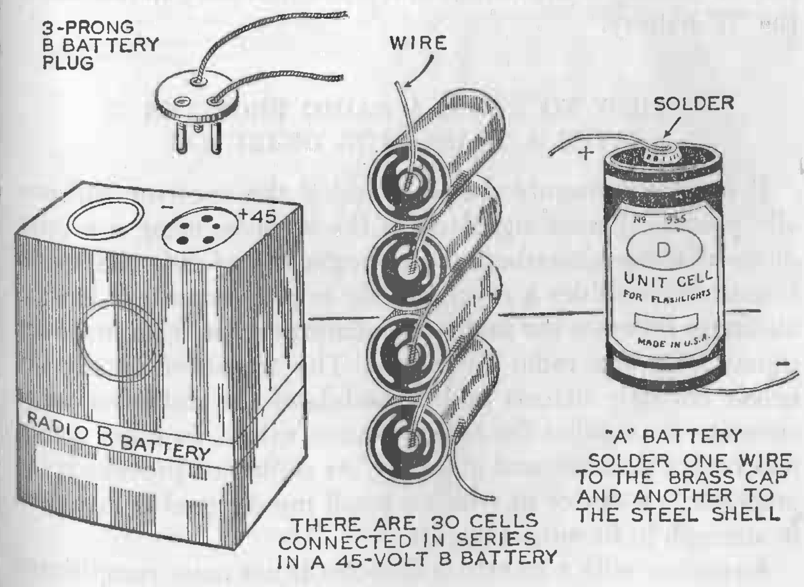
Connect the No. 3 socket terminal to one of the PHONE posts, to the B+ battery post, to one terminal of the .047 mfd. capacitor, and to one terminal of the .002 mfd. capacitor. No. 1 socket terminal should be connected to the other terminal of the .047 mfd. capacitor, to the B— battery post and to the GROUND post. No. 2 socket terminal is connected to one of the PHONE posts and to one terminal of the .002 mfd. condenser. No. 6 socket terminal is connected to one terminal of the 200 mmfd. capacitor and one terminal of the 1.5 megohm resistor. No. 7 socket terminal is connected to the A+ battery terminal. Use the schematic circuit diagram as a guide to complete the wiring.

Operation. Connect ANT. B post to a 50-foot antenna if you live in a metropolitan area and to a 100-foot antenna if you live in a rural area. Connect the post GND. to a good ground on a steampipe or, preferably, on a water pipe. The receiver should be located where it will not be necessary to make the wire to the

ground connection more than 15 or 20 feet long. Connect a 2,000- to 3,000-ohm headset to the PHONE posts. Connect a single cell of size D flashlight battery to the posts marked A+ and A—. Connect a 45-volt "B" battery to the posts marked B+ and B—. Pay particular attention to the polarity of these connections because they must be made correctly or the receiver will not operate.

The type of terminal on the "B" battery will determine the type of plug needed to make connection to it. Or it may require snap-on terminals instead of a plug. In that event, one female snap-on and one male snap-on will be needed. Solder a 6-inch piece of flexible wire to each snap-on terminal.

When all the necessary external connections to the receiver have been made, push the 1T4 tube into its socket and put on the headphones.



THE BATTERIES FOR THE GRID-LEAK DETECTOR

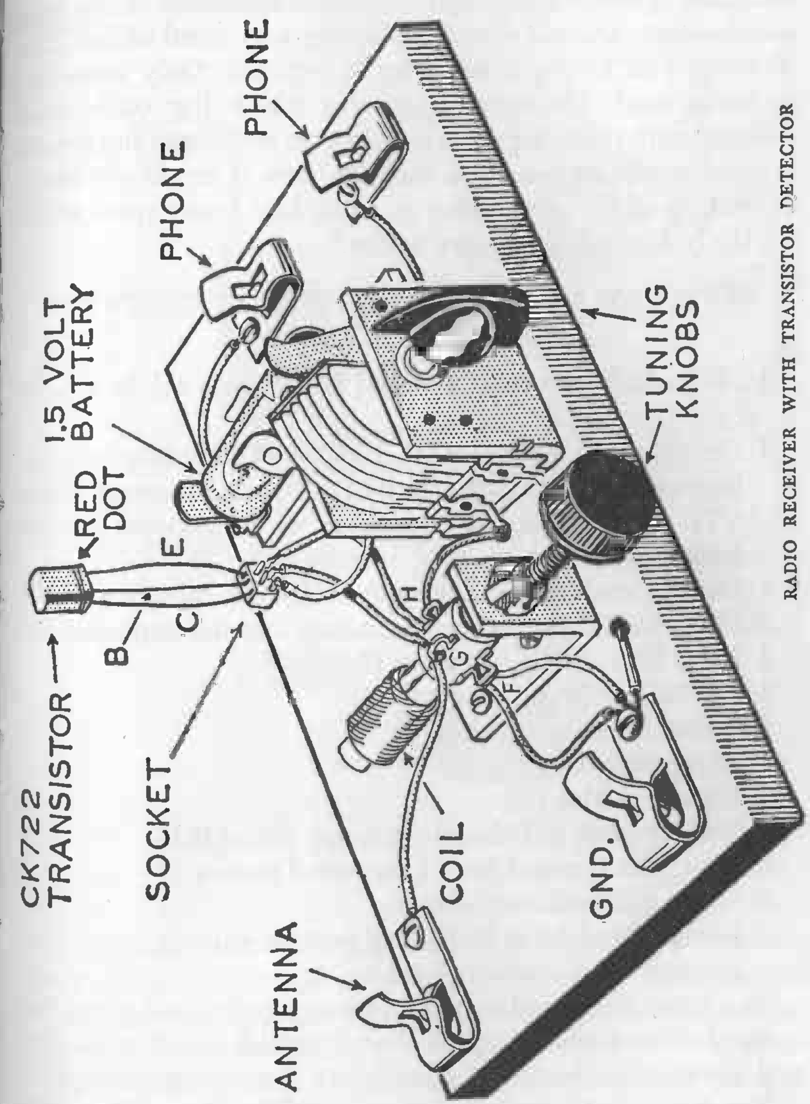
Adjust the loopstick by turning the knob which moves the ferrite core. Turn the variable capacitor slowly back and forth at the same time. As soon as a signal is heard in the phones (it may be very faint) adjust both the loopstick and the tuning capacitor until the signal is as loud as it is possible to make it. There are two antenna posts to which the antenna may be connected (ANT. A and ANT. B). Try both antenna posts. When a change is made from one to the other it is necessary to readjust the loopstick and the tuning capacitor. Radio stations may be heard when using ANT. A which may not be heard when using ANT. B and vice versa. Using ANT. A places the fixed capacitor in the antenna circuit and has the effect of shortening the electrical length of the antenna and favoring the reception of the higher frequencies in the broadcast band.

Disconnect the "A" battery when the receiver is not in use in order not to waste current and shorten the life of the cell. If the "A" battery is disconnected it is not necessary to disconnect the "B" battery.

HOW TO BUILD A RADIO RECEIVER WITH A TRANSISTOR DETECTOR

If correctly assembled and operated this receiver will usually produce louder signals than the receiver using a crystal-diode detector described at the beginning of this chapter. A transistor resembles a crystal diode in one respect: it has the ability to separate the audio-frequency portion of an incoming signal from the radio frequency. The transistor in this receiver not only detects and demodulates the radio-frequency currents; it amplifies the signal to some extent. In other words, it is both a detector and amplifier. As explained previously, an amplifier is a device in which a small input signal is increased in strength in its output circuit.

A receiver with a transistor detector is not more complicated than a receiver with a crystal-diode detector but it is more



RADIO RECEIVER WITH TRANSISTOR DETECTOR

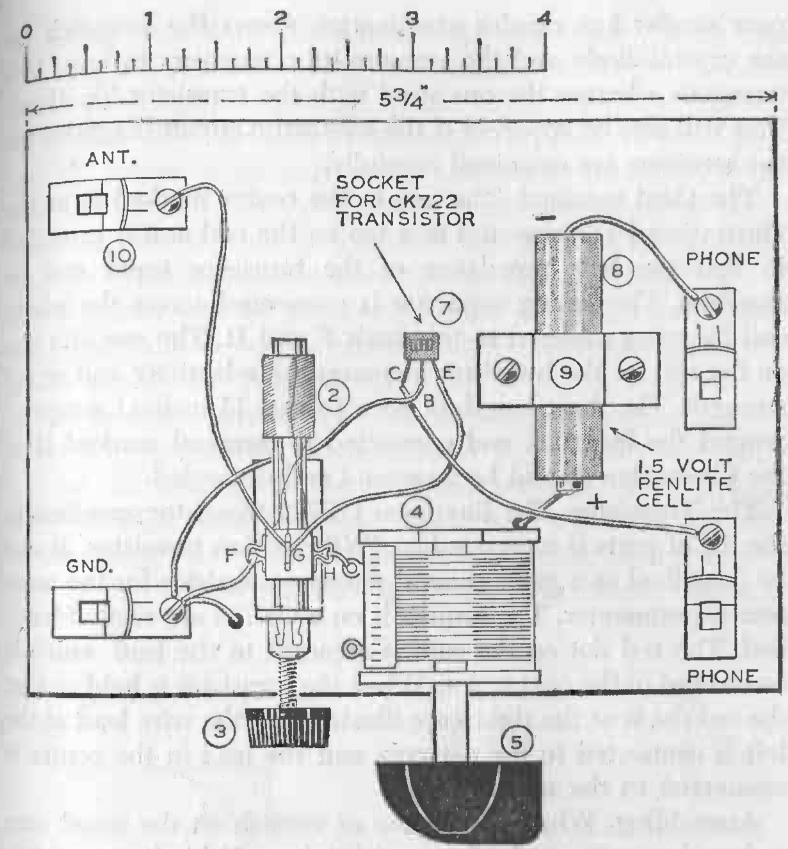
difficult to wire or hook up because there are three delicate soldering operations required to make connections to the transistor socket. A small electric soldering iron rated at less than 50 watts and having a small tip is required. Only rosin-core solder is used. Electronic apparatus which has connections soldered with soldering paste or acid-core solder will not remain in good operating condition long. If there is any doubt about the variety of the wire solder on hand, buy a new spool which is plainly labeled "rosin-core solder."

PARTS AND MATERIALS REQUIRED IN ORDER TO ASSEMBLE THE RECEIVER

- 1 Shellacked or varnished wood base 6 in. x 4½ in. x ⅜ in. (1)
- 1 Philmore catalog No. R841-T standard transistor loop antenna coil tapped for transistor circuits, or 1 Superex Model VTL 240 transistor vari-loopstick, or 1 Lafayette MS-299 transistor tapped variable antenna coil (2)
- 1 Molded knob and set screw to fit shaft of antenna coil (3)
- 1 Midget TRF 10 to 365 mmfd. rotary variable capacitor (4)
- 1 Knob for variable capacitor (5)
- 1 CK722 Raytheon transistor (6)
- 1 Socket for transistor (7)
- 1 1.5-v penlite cell (8)
- 1 Battery holder (9)
- 4 Binding posts or Fahnestock spring clips (10)
- 8 ⅜-in., No. 6 round head brass wood screws
- 2 ½-in., 6-32 machine screws
- 4 Rubber head tacks if binding posts are used
- Hookup wire, rosin-core solder

The Base. The wood must be thoroughly dry and given two coats of white shellac or quick-drying varnish on all surfaces to seal against the absorption of moisture during humid weather.

The Variable Capacitor. The same TRF 365 mmfd. midget variable capacitor used in assembling the receiver with a



PLAN OF RECEIVER WITH TRANSISTOR DETECTOR

crystal-diode detector is required. It is advisable to read the discussion of "The Variable or Tuning Capacitor" in the section on the receiver with a crystal-diode detector before mounting the capacitor on the base.

The Vari-Loopstick. The loopstick used in building the transistor receiver is not the same loopstick that is used for the other receivers described in this chapter. At first glance they appear similar but careful examination shows the loopstick for the crystal-diode and the vacuum-tube receivers to have two terminals whereas the one used with the transistor has three. This will also be apparent if the schematic circuit diagrams for the receivers are examined carefully.

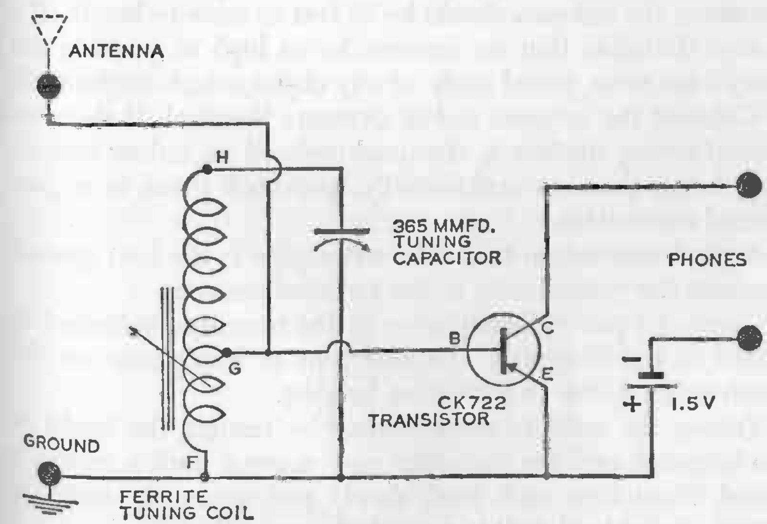
The third terminal (the one in the center marked G in the illustrations) is connected to a tap on the coil and is provided so that the low impedance of the transistor input can be matched. The tuning capacitor is connected across the whole coil by wires soldered to terminals F and H. The use of a tap on the coil for the transistor increases the selectivity and signal strength. The short length of wire (about 15 inches) wrapped around the loopstick and connected to terminal marked H in the illustration should be unwound and discarded.

The Transistor. The Raytheon CK722 transistor specified in the list of parts is a germanium PNP junction transistor. It can be described as a good general purpose transistor for the amateur experimenter. The terminals on a CK722 are easily identified. The red dot on the case is adjacent to the lead which is connected to the COLLECTOR. When the transistor is held so that the red dot is at the right (see illustration) the wire lead at the left is connected to the EMITTER and the lead in the center is connected to the BASE.

Assembling. When the shellac or varnish on the wood base is dry, the parts can be fastened in place. If binding post terminals are used, it will be necessary to drill a hole in the base for each post so that the screw on the bottom can be slipped through. It will also be necessary to bore an additional hole near each post for the connecting wires which pass through the base and under the nuts which hold the posts in place. If Fahnestock clips are used as terminals the holes are unnecessary. The clips can be fastened to the base with round head brass wood screws (⅜-inch No. 6). The plan and perspective sketch of the completed receiver show the proper location of all the parts.

Wiring. Use stranded hookup wire and make all the connections as direct and as short as possible. The wires connected to the vari-loopstick terminals should be soldered. The terminal on the coil (H) should be connected to the stator of the capacitor. The center or tap terminal (G) should be connected to the base terminal (B) on the transistor socket and to the ANTENNA post. Terminal (F) on the loopstick (see schematic circuit diagram) should be connected to the GROUND post. The rotor of the capacitor and the positive terminal of the 1.5-volt penlite cell should also be connected to GROUND. The negative terminal of the penlite cell is connected to one of the phone posts.

The EMITTER terminal (E) on the transistor socket is made positive by a connection to the ground. The COLLECTOR terminal (C) on the transistor socket is connected to the second phone post. It is the builder's choice whether to use a factory-made battery holder or to fasten the cell to the base with a strip of sheet metal as shown in the illustration. If the homemade strap



CIRCUIT DIAGRAM OF RECEIVER WITH TRANSISTOR DETECTOR is used it will be necessary to solder a wire to the bottom of the cell (negative) and a second wire to the brass terminal (positive) at the top of the cell.

Be sure that the dry cell and the transistor are wired in the circuit correctly. The receiver will not operate if the battery or transistor are reversed.

Before making any connections to a transistor socket, read the instructions which explain how to connect a transistor socket or to connect the transistor to a 3-lug terminal strip. The terminal strip is easier to connect but does not make the neat job possible with a standard transistor socket.

Using the Receiver. When all connections have been made, check them with the diagrams. Make sure they are tight and made correctly.

A good antenna is necessary for the operation of the receiver. If the receiver is used within 10 miles of a station, the antenna will not have to be as long or as high as otherwise. An antenna 50 feet long will probably provide good reception. For greater distances, the antenna should be 75 feet or more in length. It is always desirable that an antenna be as high as possible and away from trees, metal roofs, or any object which might touch it. Connect the antenna to the ANTENNA terminal. If there are several strong stations in the neighborhood an indoor antenna may bring them in satisfactorily, provided there is a good ground connection.

A good connection to a cold water pipe is the best ground. Connect the ground wire to the terminal GROUND.

Connect a pair of headphones to the terminals indicated by PHONE in the diagrams. The best type of headphone for this receiver is a 4,000- to 5,000-ohm headset.

Tuning the radio is accomplished by turning the knobs on the loopstick and the capacitor very SLOWLY until a station is heard. Then turn each knob slowly and separately until the signals are as loud as it is possible to make them.

The receiver is turned off when not in use by disconnecting

the headphones from either one or both of the PHONE terminals. This is done to preserve the dry cell. The current drain is very small and with care not to waste it the life of the cell will be practically equal to the normal usefulness of the cell if it were not used at all.

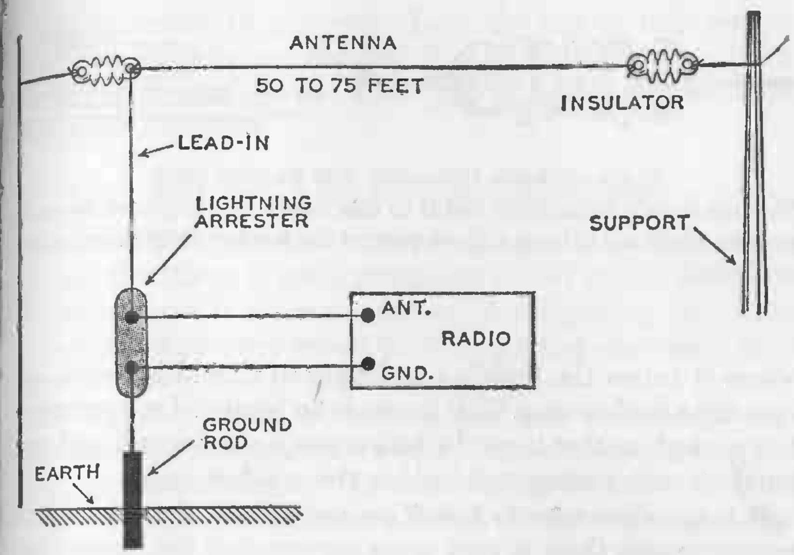
Chapter Eight

OUTDOOR ANTENNAS FOR THE RECEIVERS

An important part of any radio receiver is its antenna. None of the receivers described in the preceding chapter include radio-frequency amplifiers, and the best antenna for them in receiving broadcast programs is an outdoor antenna. This should consist of a single horizontal wire from 50 to 75 feet long, properly insulated and as high and clear of surrounding objects as possible. A height of at least 30 to 50 feet is desirable. All that is necessary as an antenna for some of the commercially built portable radio receivers equipped with radio-frequency amplification is a metal rod a few feet long, a flat coil of wire called a loop antenna, or a coil of wire wound around a ferrite rod known as a loopstick antenna.

The amount of energy which radio waves induce in a receiving antenna is infinitesimal—usually only a few millionths of a watt. For that reason it is important for the antenna wire to be carefully insulated from surrounding objects and erected where it will receive as much energy as possible. The more energy picked up and fed into a receiver, the louder will be the signals. Remember that although radio waves pass through some objects more or less freely, steel frame buildings, brick walls, overhead wires, and trees which are in leaf can effectually shield an antenna so that practically no waves reach it.

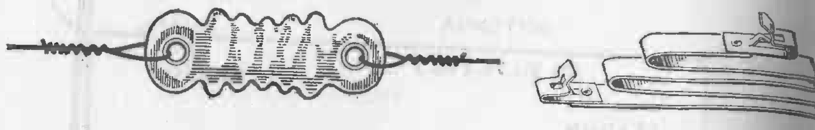
The wire connected to an outdoor antenna and leading to



COMPLETE ANTENNA SYSTEM FOR A BROADCAST RECEIVER

the receiver is called the LEAD-IN. Use No. 14 B.S. hard drawn copper wire for both antenna wire and lead-in. Or use the stranded copper or bronze antenna wire which is available at radio shops. If possible, the antenna and the lead-in should be one continuous piece of wire. If not in one piece the splices should be scraped bright and soldered. Place at least one 3-inch glass insulator at each end of the antenna to thoroughly insulate it from the wires which attach it to its supports. The best supports for an antenna are a building or a rigid pole. When a tree must be used as one of the supports, bear in mind that trees sway in the wind. Let the antenna wire hang quite slack so that motion of the tree will not strain or break the wire.

The lead-in wire should not be close to any object, including the building where the receiver is located, except at the point

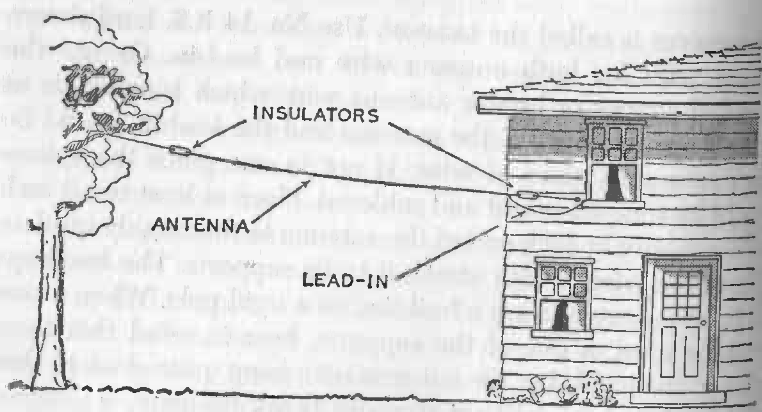


GLASS ANTENNA INSULATOR AND LEAD-IN STRIP

The lead-in strip is insulated and is so thin that it can be placed between a window sash and sill and will not prevent the window from being closed and locked.

where it enters the building and there it should be insulated by using a lead-in strip. This device is an insulated copper strip, thin enough so that it can be laid across a window sill and not interfere with closing and locking the window sash.

It is usually easier to install an antenna in the suburbs or country where there is yard space surrounding the house than it is to put up an antenna on the roof of an apartment house or city home. The antenna erected on an apartment house or city



AN ANTENNA IN THE SUBURBS

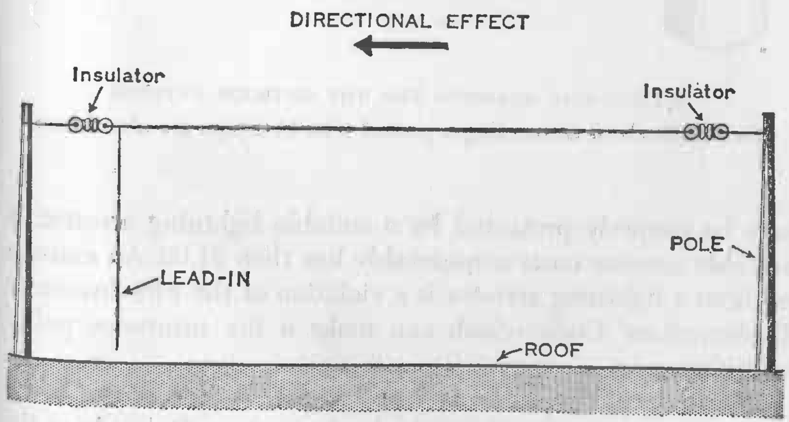
The antenna consists of a single wire stretched from house to a tree. The wire must have enough slack so that swaying of the tree will not strain it.

dwelling should be supported from the top of two wooden poles, 8 to 10 feet above the roof. If possible, the antenna should be located so that it is at right angles to neighboring antennas and telephone wires.

WHY USE A LIGHTNING ARRESTOR?

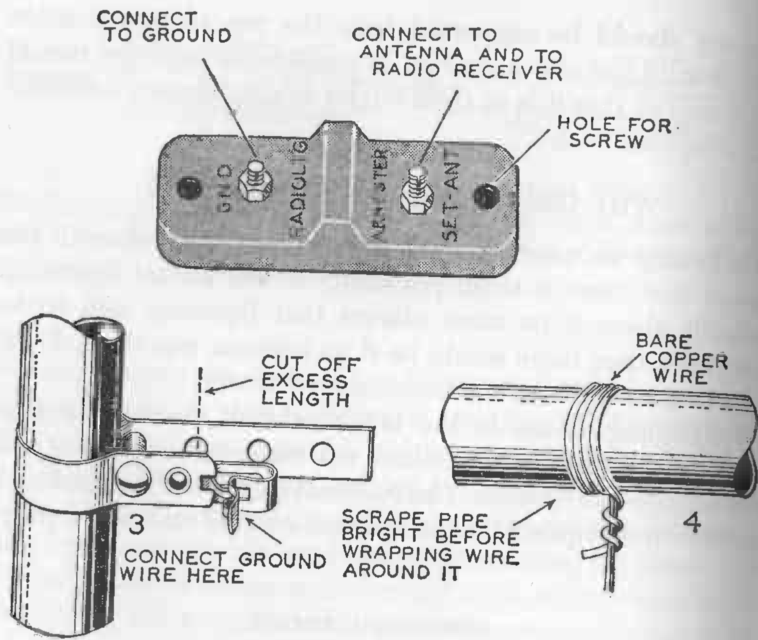
Ordinarily an amateur receiving antenna is so close to the ground that there is small possibility it will attract lightning. Probably there is no more chance that lightning will strike your home than there would be if no antenna was there. So, if there is an antenna on the house, do not worry.

If lightning strikes in the neighborhood, an antenna may pick up an induced charge which will cause some sparking and may damage the receiver. The National Board of Fire Insurance Underwriters requires that an antenna erected on insured prop-



AN ANTENNA IN THE CITY

Two short poles at opposite sides of the flat roof support the antenna wire. All antennas except a single perpendicular wire have a DIRECTIONAL effect and receive best in a direction opposite to that in which the free end points. The free end is the one opposite to that to which the lead-in is attached.



A LIGHTNING ARRESTOR FOR THE OUTDOOR ANTENNA
Two methods of connecting a ground wire to a pipe are also shown.

erty be properly protected by a suitable lightning arrestor. A suitable arrestor costs considerably less than $1.00. An antenna without a lightning arrestor is a violation of the Fire Insurance Underwriters' Code which can make a fire insurance policy worthless.

The arrestor should be fastened to the outside of the building close to the point where the lead-in enters. One side of the arrestor is connected to the lead-in, the other is connected to the ground. A ground rod for driving into the ground and connecting to the arrestor can be purchased at most radio shops. It is a copper-plated steel rod 4 to 6 feet long, fitted with a connecting clamp at the top.

THE GROUND OR EARTH CONNECTION

The receivers described in this book require a ground or earth connection as well as an antenna. The terminal marked GND. in the illustrations should be connected to a nearby water pipe. If there is no water pipe available within 25 feet make a ground connection to a steampipe or radiator. The pipe should be scraped clean and a ground clamp attached. A wire from the GND. terminal on the receiver is connected to the terminal on the clamp. A temporary connection to a pipe can be made by scraping a spot clean on the pipe and wrapping a bare copper wire around it tightly. This type of connection will probably become oxidized in a few weeks and have an objectional resistance. A permanent ground connection made with a clamp is more reliable.

Chapter Nine

AUDIO AMPLIFIERS YOU CAN BUILD

Amplifiers are a twentieth-century development which make possible long distance telephone, tape recorders, hi-fi phonographs, modern radio transmitters and receivers, radar, and television and are a necessary part of hundreds of other instruments and devices. The enormous growth of electrical engineering which has occurred in the last thirty years is due to a large extent to the introduction of amplifiers in the fields of electrical communications and automatic control equipment.

Fundamentally, amplifiers are used to increase currents, voltages, or power. A stronger current, greater voltage, or both may be obtained from the output of an amplifier than is fed into its input. For example, a signal of 1 milliampere fed into the input circuit may become 20 milliamperes at the output. Various circuit arrangements make possible various amounts of signal amplification.

A variety of devices perform as amplifiers and there are several methods of classifying them. One systematic arrangement is based upon whether or not any movable parts are employed in the basic operation of the amplifier. This classification divides amplifiers into the following groups:

1. Amplifiers which have movable parts
2. Amplifiers which have no movable parts

The first group, comprising amplifiers with movable parts, includes special dynamo-electric machines (Amplidyne, Rototrol,

and Regulex Exciter), galvanometer amplifiers, variable-induction devices, and variable liquid resistors.

Amplifiers with no moving parts include electronic amplifiers using vacuum tubes or semiconductors (transistors), magnetic amplifiers, and dielectric amplifiers.

Electronic amplifiers using vacuum tubes or transistors are the only types which the average amateur experimenter is equipped to construct and for that reason the only ones discussed here. Amplifiers are necessary in nearly all electronic equipment. The telephone, tape recorders, hearing aids, and other types of electronic devices employ amplifiers to raise the strength of extremely weak input signals so that they can be heard, recorded or seen.

Amplifiers designed for high-frequency circuits are called RADIO-FREQUENCY amplifiers. Those designed to amplify currents or voltages which produce sounds within audibility, or the range of the human ear, are AUDIO-FREQUENCY amplifiers. The amplifiers described in this chapter are all audio-frequency amplifiers.

ELECTRON TUBES VERSUS TRANSISTORS AS AMPLIFIERS

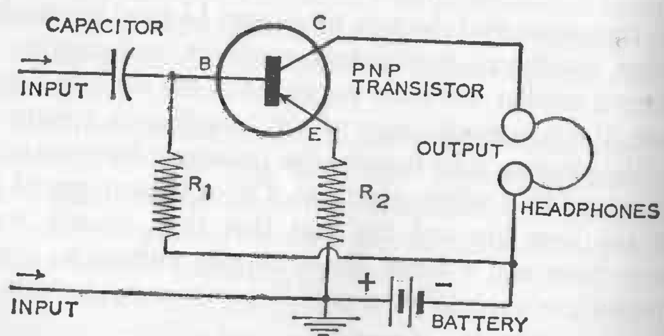
Both transistors and electron tubes may be used in circuits as amplifiers, oscillators, modulators, rectifiers, or detectors. The transistor is smaller and more rugged than the electron tube. In addition, the power efficiency of the transistor is greater than that of the electron tube because the transistor does not require heater power to produce electrons. Other advantages of transistors are long life and the fact that they do not require warm-up time and a large direct current voltage to operate. Transistors are especially adaptable to the miniaturization of electronic equipment.

Although electron tubes do not have all the desirable qualities of transistors they can surpass transistors in the amount of energy they will handle. Tubes are manufactured which will handle hundreds of times greater power than the largest transistor. The tremendous energy in the signals of a 50,000-watt radio broadcasting station cannot be attained with present-day transistor amplifiers. Electron tubes must be used as amplifiers when kilowatts are involved.

A DIRECT-COUPLED TRANSISTOR AUDIO AMPLIFIER

A resistor, capacitor, or transformer may be used to couple an amplifier directly to a signal source. Or, the amplifier may be direct-coupled. An amplifier may consist of several amplifiers or STAGES coupled together. Here also resistor, capacitor, transformer, or direct coupling may be used to connect each stage to the following stage.

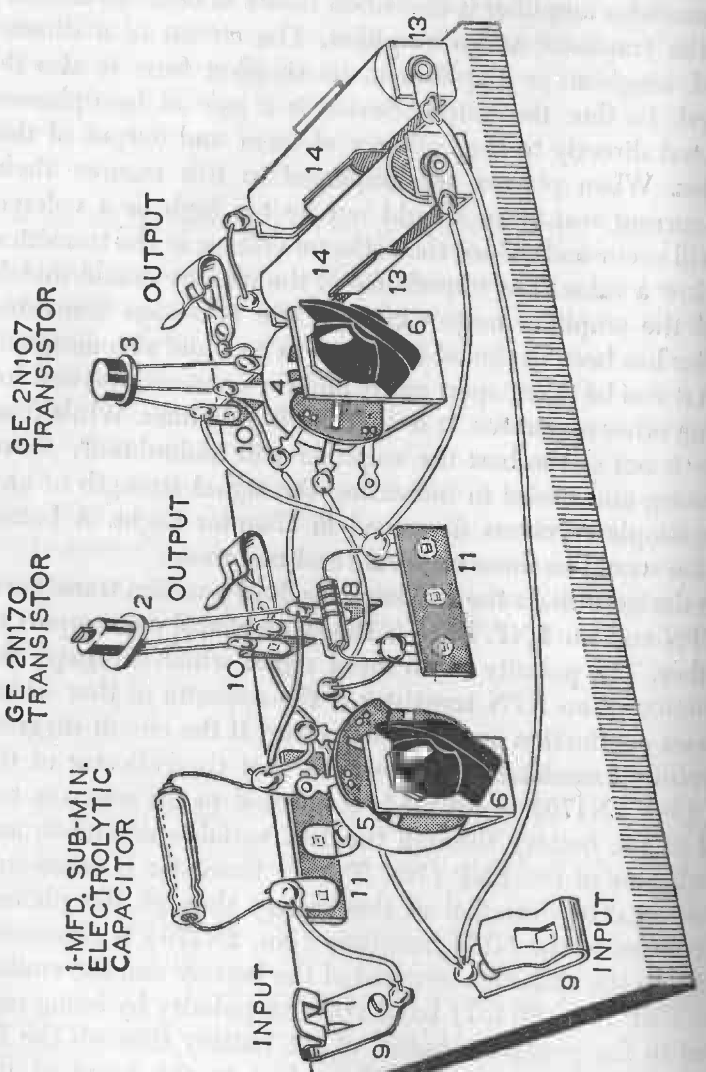
A few years ago it would have been necessary to use one or more electronic tubes in order to make an electronic amplifier. The transistor was invented in 1948. In a decade the production of transistors has reached many millions per year and the retail cost is below that of electron tubes which can be used for the same purpose.



THE CIRCUIT OF A SIMPLE SINGLE-STAGE TRANSISTOR AMPLIFIER

The construction of a simple direct-coupled, low-cost, two-stage transistor amplifier is described below in order to demonstrate the transistor as an amplifier. The circuit of a direct-coupled, single-stage amplifier in its simplest form is also illustrated. In this, the output device is a pair of headphones connected directly to the collector element and output of the amplifier. When phones are employed in this manner their direct-current resistance should not be too high or a voltage drop will occur and reduce the collector voltage at the transistor to too low a value. The impedance of the phones should match that of the amplifier output circuit. The two-stage transistor amplifier has been designed to be low in cost and also designed so that it can be taken apart easily and the components used for building other apparatus. It is not a "hi-fi" amplifier. While tone quality is not of the best the amplifier will undoubtedly prove interesting and useful in increasing the signal strength of any of the simple receivers described in Chapter Eight. A better amplifier would be more elaborate and cost more.

The design utilizes the two basic kinds of junction transistors; the NPN and the PNP. Each is the symmetrical counterpart of the other. The polarity of an input signal which increases the conduction of an NPN transistor is the opposite of that which increases conduction in a PNP transistor. If the circuit diagram is carefully examined it will be seen that the collector of the NPN (No. 2N170) transistor is connected to the POSITIVE terminal of the battery through the 10K variable resistance and the collector of the PNP (No. 2N107) transistor is connected to the NEGATIVE terminal of the battery through the phones. The emitter of the NPN transistor (No. 2N170) is connected directly to the NEGATIVE terminal of the battery and the emitter of the PNP (No. 2N107) has a POSITIVE polarity by being connected to the positive terminal of the battery through the 22-ohm resistor. A positive signal applied to the input of this amplifier appears in amplified form at the output.



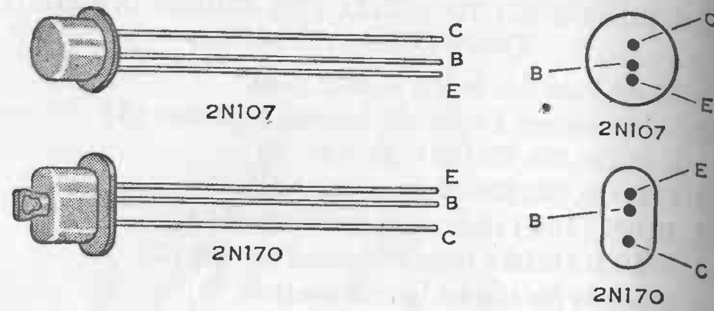
A DIRECT-COUPLED TRANSISTOR AMPLIFIER

PARTS NEEDED TO BUILD THE DIRECT-COUPLED TRANSISTOR AMPLIFIER

1 Wood base 7 ⅛ in. x 4 ⅛ in. x ⅜ in.
1 Subminiature 1 mfd. electrolytic capacitor (1)
1 G.E. Co. No. 2N170 transistor (2)
1 G.E. Co. No. 2N107 transistor (3)
1 10,000 (10K) ohm midgetrol control (4)
1 500,000 (500K) ohm midgetrol control (5)
2 Brackets for the midgetrol controls (6)
2 Knobs to fit the controls (7)
1 22-ohm, ½-watt resistor (8)
4 No. 3 Fahnestock spring contact clips or 4 binding posts (9)
2 3-terminal standard Bakelite tie points (10)
2 2-terminal standard Bakelite tie points (11)
4 Small solder lugs (12)
1 2-cell battery holder for size AA flashlight cells or 2 battery holders for single size AA flashlight cells (13)
2 Size AA flashlight cells (Eveready No. 915 or equivalent) (14)
16 ⅜-in., No. 4 round head wood screws
1 Pair 2,000-ohm headphones (15)
Hookup wire, rosin-core solder

The Transistors. Two General Electric Co. transistors are used in the amplifier. One is the type 2N107 alloy junction PNP transistor particularly suggested for students, experimenters, hobbyists, and hams. The other is the type 2N170 germanium NPN transistor intended for use in high-frequency circuits by amateurs, hobbyists, and experimenters.

The Capacitor. Any type of capacitor can be used in the input provided that it has a capacitance of 1 microfarad. The subminiature type is recommended because it is a design intended for use in transistor circuits. Since this type is an electrolytic capacitor, it is marked to indicate the positive and negative



NPN No. 2170 AND PNP No. 2N107 TRANSISTORS

terminals. Notice that the positive terminal is indicated in the circuit diagram and that the capacitor terminals should be connected as shown in that diagram.

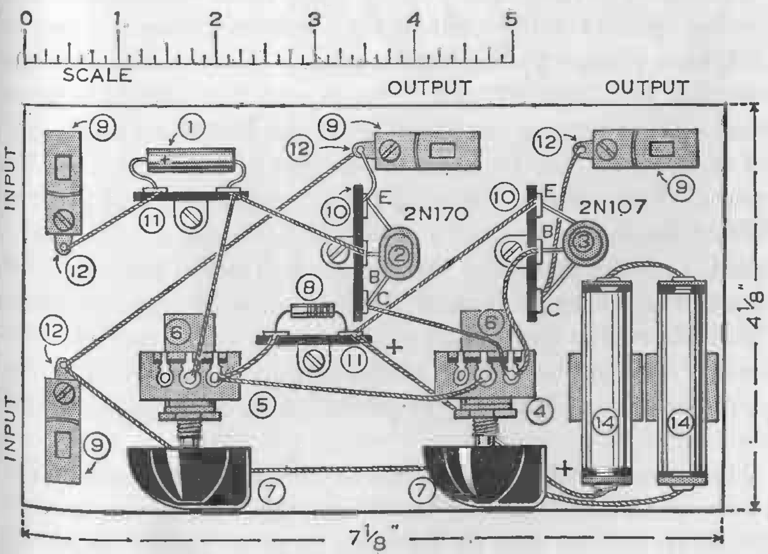
Telephone Headset. It is important to use only a 2,000-ohm (two 1,000-ohm receivers connected in series) headset as specified in the list of parts. This should be connected to the two output terminals of the amplifier marked PHONES. If a headset with a resistance of much less or much more resistance than 2,000 ohms is used, the bias voltage from the battery may be changed sufficiently to interfere with the proper operation of the amplifier.

Assembling. The wood base should be given one or two coats of white shellac or varnish and allowed to dry. The parts are mounted as shown in the plan. They are fastened in place with ⅜-inch, No. 4 round head brass screws.

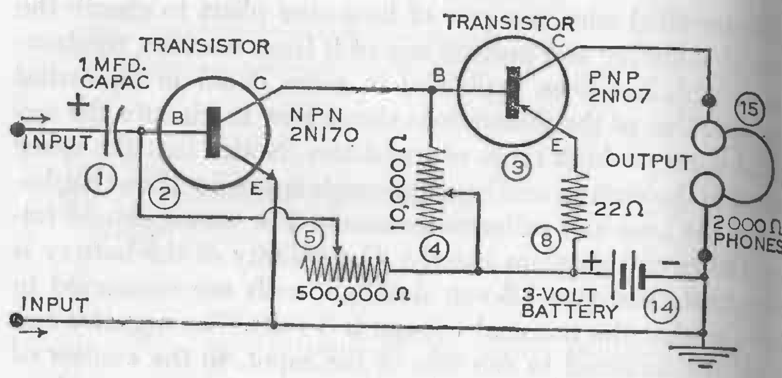
All connections should be soldered with rosin-core solder. If small solder lugs are placed under each Fahnestock clip it will prove easier to solder wires to the lugs than directly to the clips.

The illustrations show the transistor terminals soldered to two 3-terminal tie points. This construction is not obligatory. Transistor sockets or small Fahnestock clips may be used if desired. If the tie points are used, do not fail to hold each tran-

sistor terminal wire in a pair of long-nose pliers to absorb the heat of soldering and prevent any of it from reaching the transistor. This has been explained in more detail in an earlier chapter. One of the illustrations shows how to identify the terminal wires on both types of transistors. Notice that the space between the emitter and base terminals is smaller than that between the base and collector terminals. The wiring should follow the circuit diagram exactly. The polarity of the battery is important. The two 1.5-volt flashlight cells are connected in series so that the terminal voltage is 3 volts. The negative terminal is connected to one side of the input, to the emitter of the No. 2N170 transistor, and to one of the output terminals to which the headphones are connected. The positive terminal of the battery is connected to one terminal of each of the three re-



PLAN OF DIRECT-COUPLED TRANSISTOR AMPLIFIER



CIRCUIT DIAGRAM OF DIRECT-COUPLED TRANSISTOR AMPLIFIER

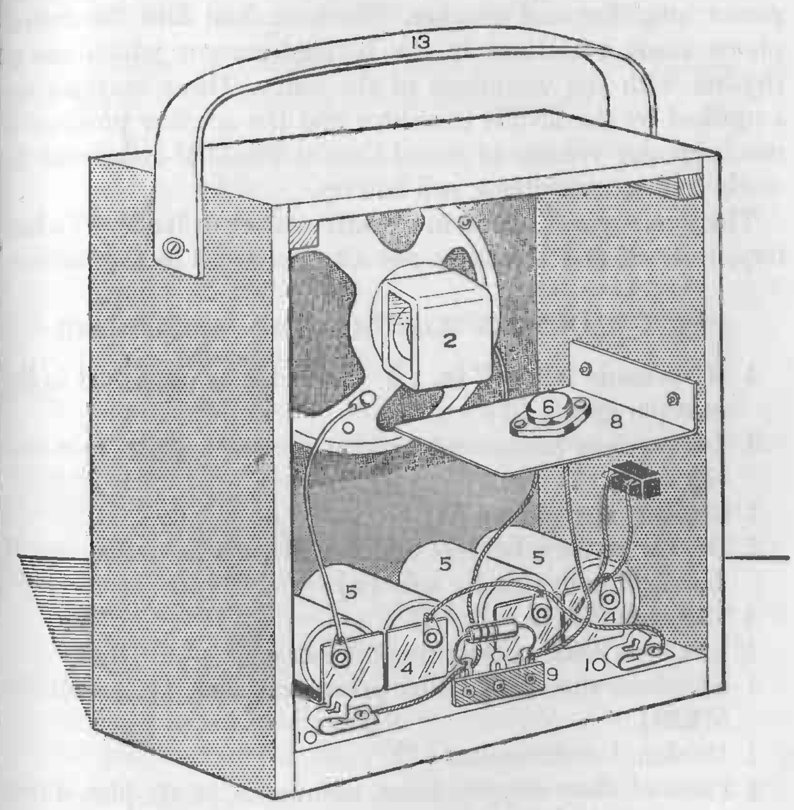
sistors so that a positive polarity feeds through them to the base of 2N170 and 2N107 and to the emitter of 2N107.

Operation. When the wiring has been completed and checked, place the dry cells in their holder. Connect a pair of 2,000-ohm phones to the output of one of the small receivers described in Chapter Eight. Tune in a station until it is heard clearly. Then remove the phones and connect them to the output of the amplifier. Connect the output of the receiver to the input of the amplifier. Listen in the phones and adjust the controls on the amplifier until you obtain the loudest and clearest signal. In some instances the sounds will be so loud that the phones cannot be kept close to the ears without discomfort. The difference in the volume of the signals at the output of the receiver and at the output of the amplifier demonstrates the great increase in signal energy produced through the use of the amplifier.

The current drain from the two dry cells used in the amplifier is very small and they will last a long time. However, it is advisable to remove one of the cells from its holder when the amplifier is not in use. This will break the circuit and conserve the battery.

A TRANSISTORIZED POWER MEGAPHONE OR BULL HORN

Although this small megaphone has an output of only ⅓ watt and is a toy in comparison with a standard 10-watt megaphone, it puts out a surprising volume of sound. The simplicity of the circuit is a desirable feature from the standpoint of the amateur



SKETCH OF THE ELECTRONIC MEGAPHONE

The back of the cabinet has been removed to show the arrangement of the components: (2) speaker; (4) battery holders; (5) dry cells; (6) 2N554 power transistor; (8) heat sink; (9) tie point; (10) Fahnestock clips. The black object beneath the heat sink is the ON-OFF switch.

experimenter. The megaphone is readily portable and will project the voice loud and clear to a distance of 100 to 300 feet. It has many uses both for fun and serious purposes: it can be used at picnics, on camping trips, and is a valuable aid in the conduct of swimming and boating activities.

The circuit and parts list reveal that the megaphone consists of a carbon microphone and battery connected to a small-power amplifier and speaker. Words spoken into the microphone cause variations in the battery current which are in rhythm with the vibrations of the voice. These currents are amplified by the 2N554 transistor and the speaker produces a much greater volume of sound than it would if connected directly to the microphone and battery.

The speaker is enclosed in a small cabinet or baffle. The battery, resistor, and transistor are also mounted in the cabinet.

PARTS REQUIRED TO BUILD THE MEGAPHONE

1 Homemade 9 in. x 7 in. x 4½ in. baffle as described in the next paragraph (1)
1 4-in. or 5-in. permanent magnet speaker with 3- to 4-ohm voice coil (2)
1 Carbon microphone (3)
2 Double battery holders which will each hold two size D flashlight cells side by side (4)
4 Size D flashlight cells (5)
1 Motorola 2N554 power transistor or equivalent (6)
1 Transistor mounting kit for power transistor (Motorola No. MK20)
1 10-ohm, 1-watt resistor (7)
1 Piece of sheet copper, brass, aluminum, or tin-plated iron 3 in. x 3¾ in. (8)
1 3-terminal tie point (9)
2 Binding posts or No. 3 Fahnestock spring contact clips (10)
7 ⅜-in., No. 4 round head wood screws for fastening battery holders, tie-point and Fahnestock clips

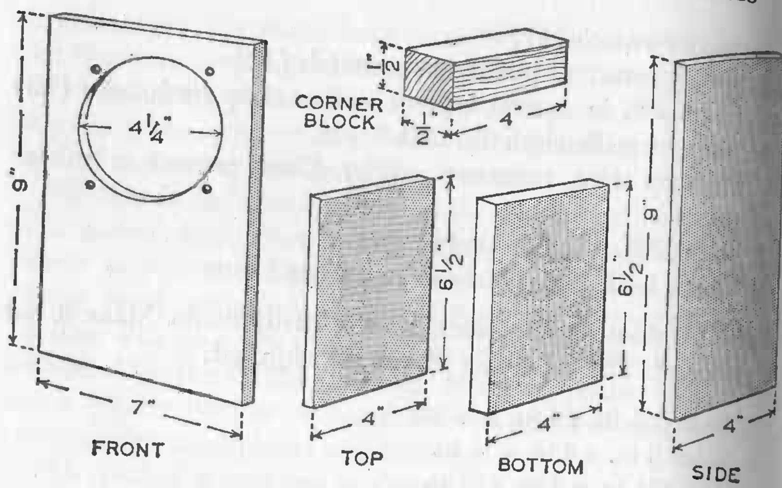
1 ON-OFF switch (11)
1 Spring return or push button switch (12)
1 12 in. x ¾ in. canvas tape or leather strap for handle (13)
1 Piece of grille cloth 6½ in. x 6½ in.
Hookup wire, rosin-core solder, Duco cement or rubber cement
8 ⅜-in., No. 4 R.H. wood screws
6 ½-in., 6-32 R.H. machine screws and nuts

The Cabinet or Enclosure. This is easily made. Make it out of plywood. The following pieces are required:

1 Base 6½ in. x 4 in. x ⅝ in.
2 Sides 9 in. x 4 in. x ¼ in.
1 Top 6½ in. x 4 in. x ¼ in.
1 Front 9 in. x 7 in. x ¼ in.
1 Back 9 in. x 7 in. x ¼ in.
2 Corner pieces 3¹⁵⁄₁₆ in. x ½ in. x ½ in.
Weldwood glue, ½-in. brads

The front has a circular opening 4¼ inches in diameter (if you use a 4-inch speaker). The center of the opening is 3 inches from the top. The circular opening is made by drilling a hole through which the saw blade can be passed and then cutting the wood away with a fret saw, jig saw, or sabre saw, whichever one of these tools is available.

The cabinet should be assembled as shown in one of the illustrations. Use glue in all the joints and fasten with small ½-inch brads. When the glue has dried the heads of the nails should be driven slightly below the surface of the wood with a small nail set and hammer. Fill the indentations with Plastic Wood and smooth with fine sandpaper. Give the cabinet one coat of white shellac and when it is dry, apply one coat of spar varnish. The grille cloth should be cemented to the inside surface of the front and close the circular opening. A carrying handle attached to the top will make the megaphone easily portable.

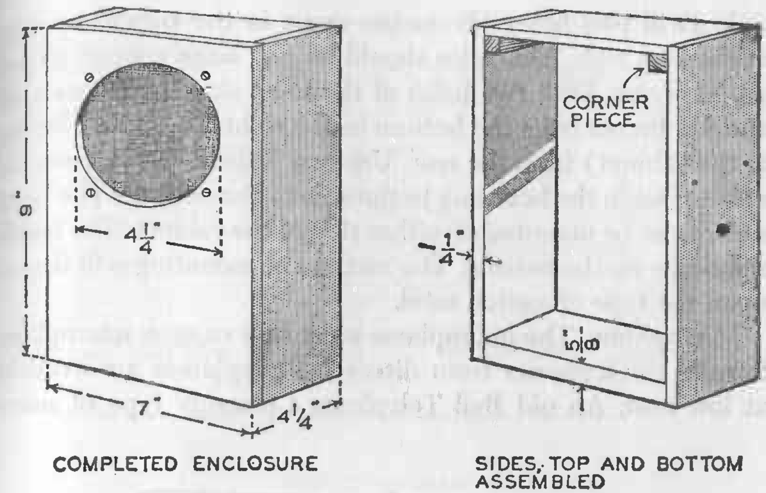


PARTS OF THE CABINET

The back of the cabinet is not illustrated. It is the same size as the front and has two small notches at the bottom through which the wires to the megaphone can pass.

Assembling. The speaker is mounted inside the cabinet with the front of the speaker against the rear surface of the front of the cabinet and aligned with the circular opening. The speaker is fastened in place with four ⅝-inch, 6-32 round head screws and hex nuts. The screws pass through the holes in the metal rim of the speaker and through four holes drilled in the cabinet around the edge of the circular opening. Put the screws through from the front so that the heads of the screws are on the outside of the cabinet and the nuts are against the back of the speaker rim.

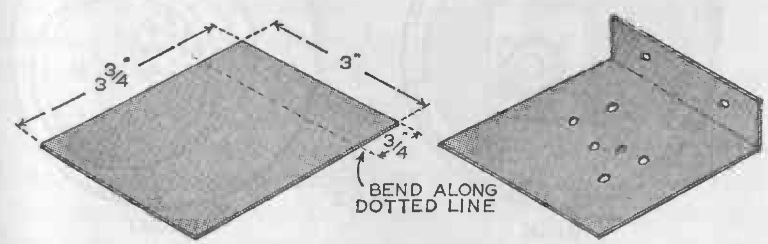
The two battery holders are fastened alongside each other on the base. Leave space at the rear edge of the base to mount the two binding posts or clips for the microphone terminals. The battery holders should be connected so that when the four cells are put in their place, they will be in series and deliver 6 volts at the terminals.



THE CABINET

The terminals of the 10-ohm, 1-watt resistor should be soldered to the outside terminals of the tie point.

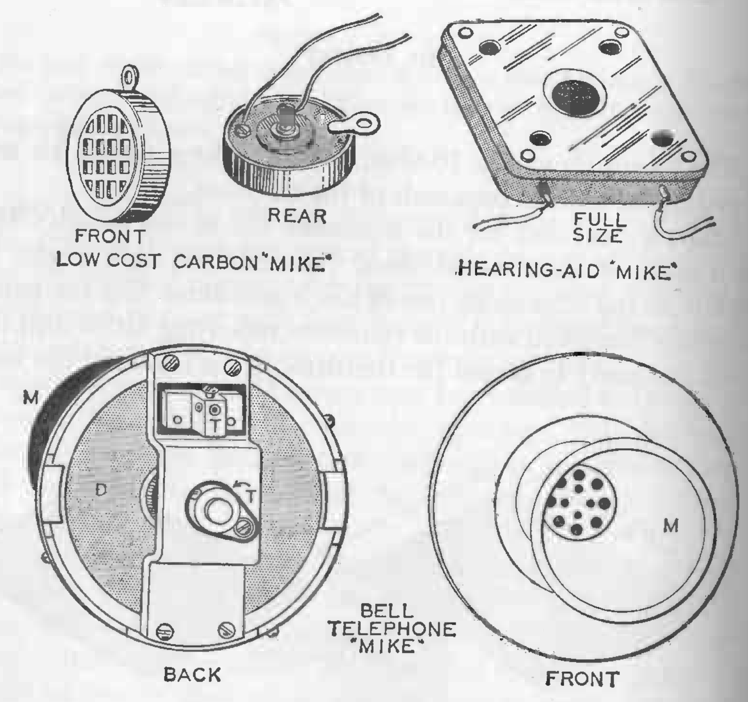
Make a heat sink for the transistor out of the 3-inch x 3¾-inch piece of sheet metal. Bend the metal at right angles ¾ inch from the edge along one of the 3-inch sides. Use the paper template furnished with the transistor mounting kit to drill the holes necessary to mount the transistor in the center of the heat



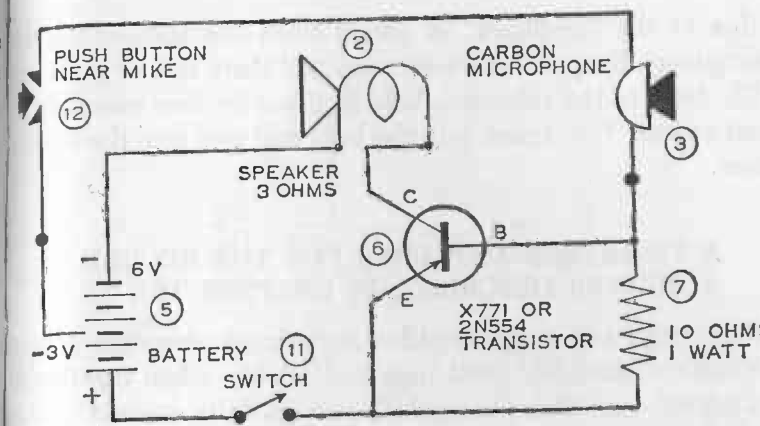
HEAT SINK FOR THE POWER TRANSISTOR

sink. Drill two holes 1¾ inches apart in the turned up edge of the heat sink. The holes should be just large enough to pass a 6-32 screw. Drill two holes of the same size 1¾ inches apart and 4½ inches from the bottom in the right-hand side (looking at the cabinet) from the rear. Use two ⅝-inch, 6-32 screws and nuts to fasten the heat sink to the side of the cabinet. The on-off switch can be mounted on either side of the cabinet. The handle should be on the outside. The method of mounting will depend upon the type of switch used.

Microphone. The microphone must be a CARBON microphone. Surplus microphones from discarded telephones are available at low cost. An old Bell Telephone Company type of micro-



CARBON MICROPHONES



CIRCUIT DIAGRAM

phone in good condition will give excellent results. One of the illustrations shows the front and the rear of a microphone of this type. One terminal is the case or frame and the other is the part marked T in the illustration. If a single-button carbon microphone with a "push-to-talk" switch of the type made for radio use can be secured, the push-button or spring-return switch in the list of parts will not be necessary.

Wiring. All connections should be soldered, using only rosin-core solder. Two wires connected to the binding posts or Fahnestock clips pass out through a small hole or a notch in the back. These wires should each be about 6 feet long and be connected to the microphone. A push-button or a spring-return switch should be connected in one of the microphone wires near the microphone. The switch on the side of the cabinet completely disconnects the battery when the megaphone is not in use. The push-button or spring-return switch is a battery saving device and must be pressed while speaking into the microphone. If the microphone is held at a distance of less than 3 feet from the cabinet the speaker may squeal and howl. This is due to the "feedback" of sound from the speaker to the microphone. Keep it 5 or 6 feet away and there will be no howl.

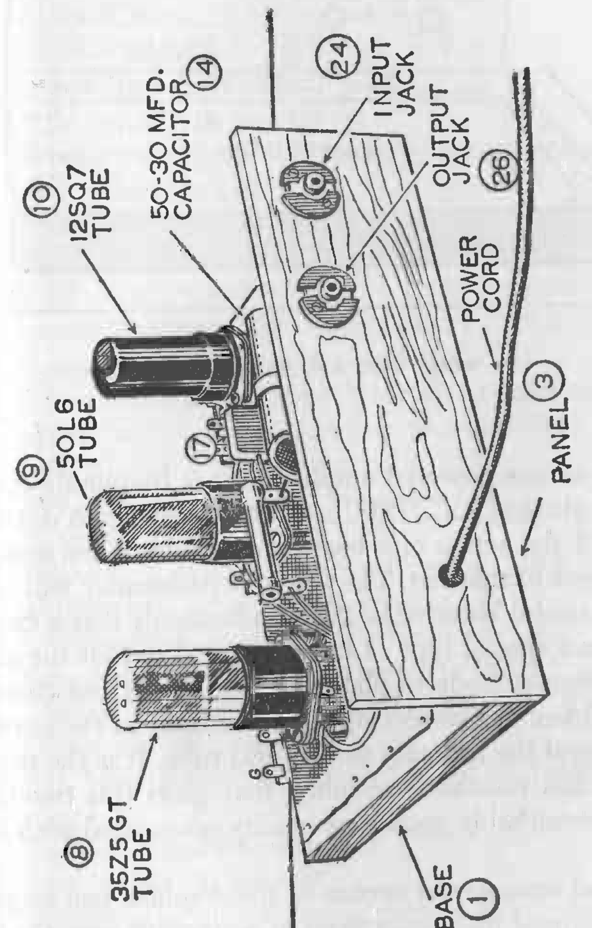
The back of the cabinet is held in place by four round head wood screws. Two screw into the base and two into the corner pieces.

A TWO-STAGE AMPLIFIER FOR THE RECORD PLAYER DESCRIBED IN CHAPTER TEN

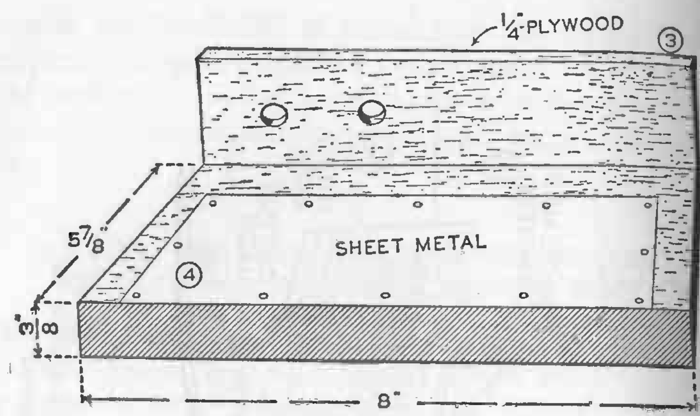
This simple two-stage amplifier reproduces phonograph records with remarkably good tone and fidelity when connected to a crystal-cartridge phonograph pickup. It is essentially the same amplifier described in Chapter Fourteen in *The Boys' Second Book of Radio and Electronics* but has been changed slightly so that it can be installed in the cabinet of the record player which is described in the next chapter. Hundreds of thousands of amplifiers using the same types of tubes and the same circuit have been manufactured and sold commercially for record players.

The amplifier is operated by 120-volt alternating current. Three tubes are used. One is a power supply rectifier, the other two are amplifiers. Resistors couple the two amplifier stages to each other and also couple a crystal pickup to the first stage. Tone and volume controls are provided. High-voltage plate circuit current is supplied by a 35Z5 half-wave rectifier tube and two electrolytic condensers. The amplifier tubes are a 12SQ7 and a 50L6. All three tubes fit standard octal sockets. The heaters of the three tubes are connected in series so that the amplifier may be operated by 120-volt A.C. without a resistor in series.

The 12SQ7 is a metal-envelope, multi-unit tube consisting of two diodes and a triode. The triode section only is utilized in the amplifier. The triode in a 12SQ7 has characteristics useful in resistance coupled amplifiers. The 50L6 is a beam-power pentode, a five-element, screen-grid tube designed for use in the



REAR VIEW OF THE TWO-STAGE AMPLIFIER DESIGNED TO BE INSTALLED IN THE RECORD PLAYER CABINET



WOOD BASE AND PANEL

output stage of low-powered amplifiers. It is frequently found in the output stage of A.C./D.C. broadcast receivers. A detailed explanation of the action of a beam-power tube is too complicated for a book of this sort. The young experimenter will have gained some useful knowledge if he understands that a beam-power tube is a special type of tube designed so that the electrons move from cathode to plate in dense sheets and thereby solve the problem of overcoming the distortions in the current characteristics of the ordinary screen-grid tube. It is the use of beam-power and resistance coupling that gives this two-tube amplifier its remarkably good tone quality when used with low power.

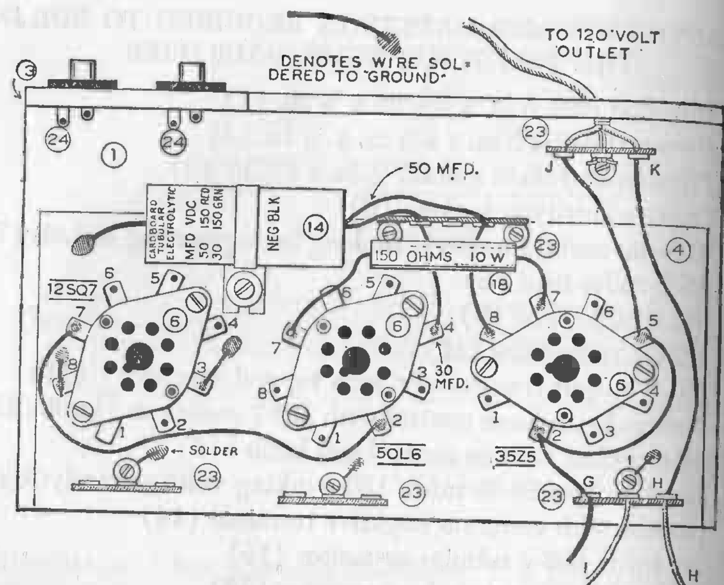
A completed commercial version of the amplifier can be purchased from several mail-order firms at reasonable cost. On the other hand, this is a piece of equipment which is not too difficult for the young experimenter to build at home.

The amplifier, minus the tone and volume control, is assembled on a wooden base.

COMPONENTS AND MATERIALS REQUIRED TO BUILD THE TWO-STAGE AUDIO AMPLIFIER

1 Plywood base 8 in. x 5⅞ in. x ⅜ in. (1)
1 Plywood panel 8 in. x 2¼ in. x ¼ in. (3)
1 Piece tinned sheet metal 7½ in. x 4½ in. (4)
3 Octal wafer-type sockets (6)
6 Tubular 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-working volts electrolytic capacitor with common negative terminal (14)
1 .02 mfd., 600-v tubular capacitor (15)
1 .004 mfd., 600-v 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)
5 3-terminal Bakelite tie points (23)
3 Phono pin plugs and jacks (24)
1 6-ft. length of rubber-covered lamp cord with attachment plug (25)
1 2-terminal Bakelite tie point
1 6-in. Jensen PM speaker
1 Double-pole, double-throw, rotary switch with knob
1 Ball-handle, single-throw, single-pole toggle switch

The last three items in the above list, namely the speaker and the two switches, are not required unless the record player described in Chapter Ten is constructed.

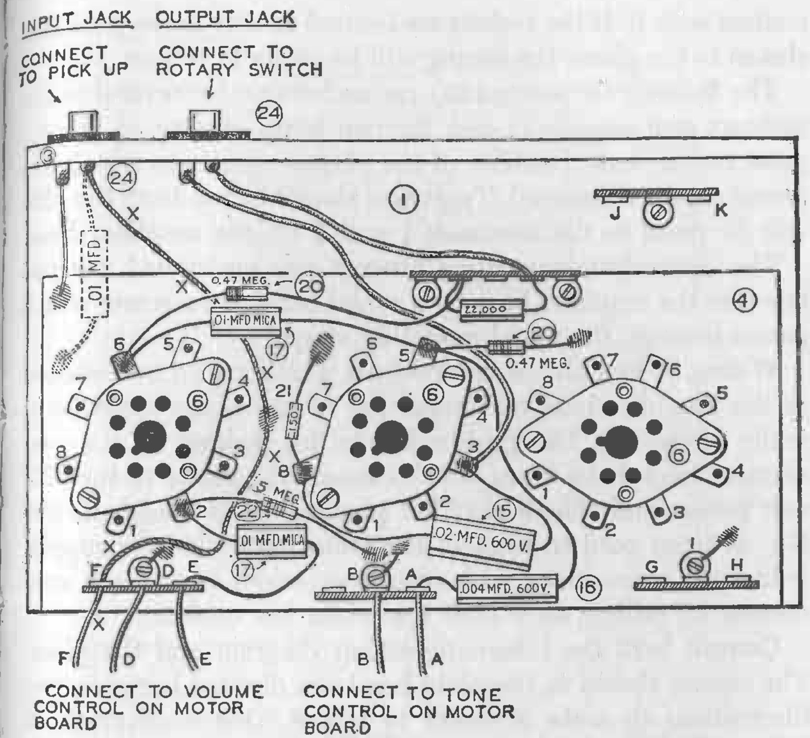


PLAN OF THE AMPLIFIER SHOWING THE ARRANGEMENT OF THE POWER WIRING

Components to which no wiring is connected in this sketch are not shown in order to avoid confusion with the wiring in the following illustration.

All the components in the above list except the wood pieces and sheet metal are standard parts which can be purchased from radio dealers who carry supplies for the serviceman and amateur.

Assembling. Make the wood base and panel according to the dimensions illustrated. When finished and sandpapered smooth give all surfaces two coats of shellac to make the wood moisture proof. The piece of sheet metal, which is used as a "ground" for the amplifier, can be cut from a clean, empty one-gallon can. One of the illustrations shows how the panel (3) should be attached to one edge of the base (1) and where the sheet metal (4) belongs on the base. The metal is fastened on the upper surface of the wood base with several short brads. One



PLAN OF THE AMPLIFIER SHOWING ARRANGEMENT OF REMAINDER OF THE WIRING (*Continued*)

In order to make the diagram less confusing, no wires are shown connected to the 35Z5 socket and terminals G, H, J, K. (See preceding illustration)

of the long edges of the metal sheet should be flush with the front edge of the base. The wood panel is fastened to the rear edge.

The location of the components on the base and panel can be determined from the illustrations. The wafer sockets (6) rest on ¾-inch tubular spacers so that the socket terminals are raised above the metal plate (4) and cannot make electrical contact with it. If the sockets are located exactly in the positions shown in the plans, the wiring will be easier to follow.

The Bakelite tie points (23) are anchorages for several of the resistors and capacitors and for two wires leading to the tie point on the base (inside) of the player cabinet to which the power cord is connected. Two wires should be run from the 120-volt tie point to the terminals J and K on the amplifier base.

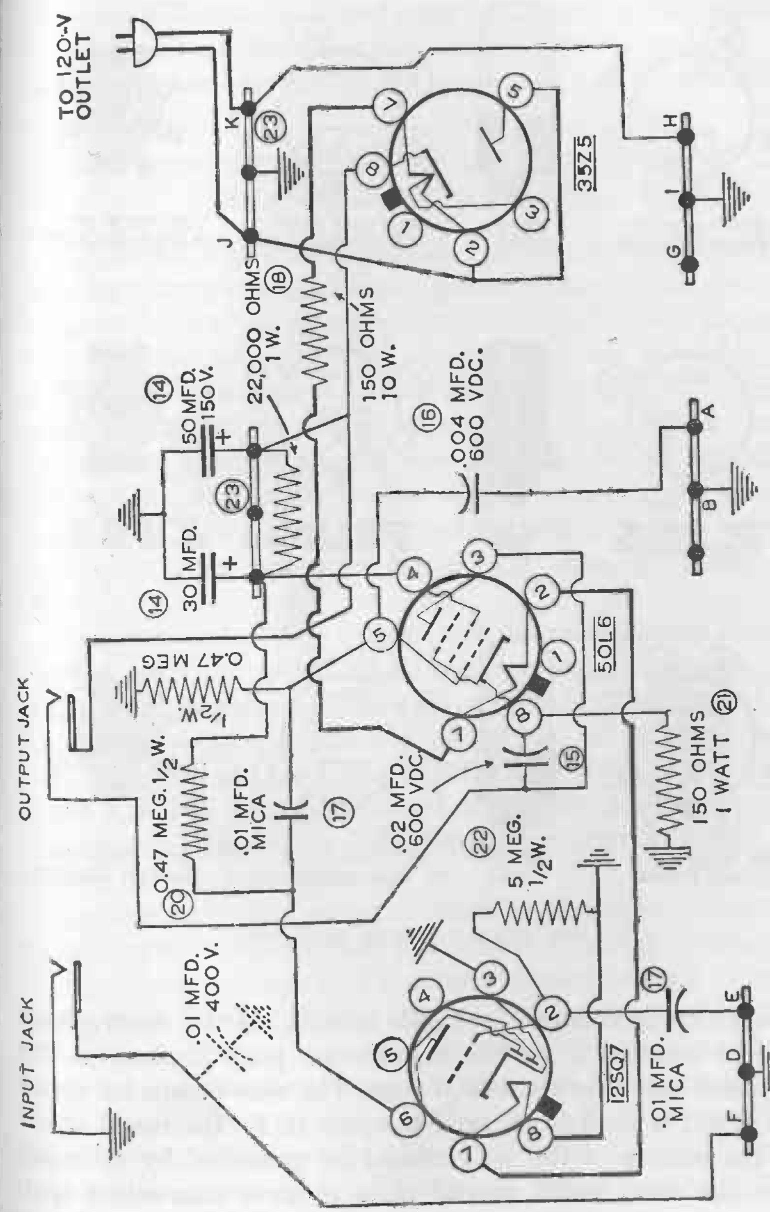
The electrolytic capacitors (two in one enclosure) are fastened to the amplifier base by a round head wood screw which passes through the metal mounting strap.

Wiring. When all the components which are to be fastened to the amplifier base and panel are in place, the amplifier is ready for wiring. Use pushback wire for making all the connections except the wires which connect the motor to the 120-volt power and where shielded phono wire is specified. Use No. 16 lamp cord to connect the motor to the power supply. Solder all connections with rosin-core solder. Test each connection by pulling on it after the solder has cooled.

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

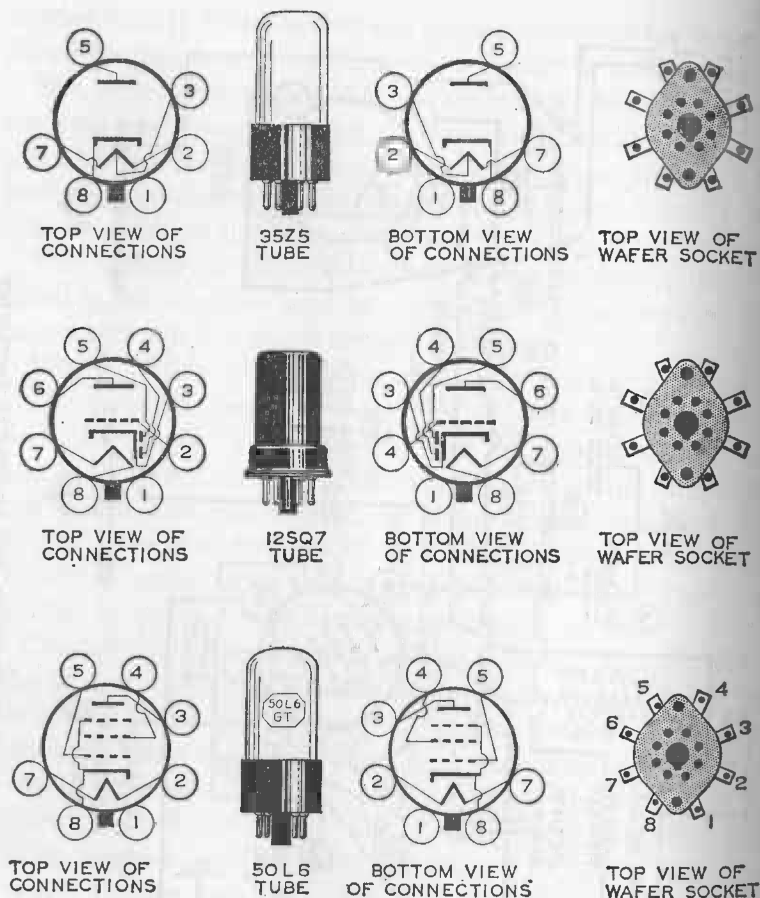
Each resistor and each capacitor connected in the circuits must be identified before it is soldered in place. The capacity or the resistance of some of these components may be printed on them. Others must be identified from the colors of their dots or bands. Make certain to connect the 50 mfd. section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

The outside terminal on the INPUT phono jack (see plan) should be "grounded" by a short wire soldered to the metal ground plate on the amplifier base. Use a piece of shielded



SCHEMATIC CIRCUIT DIAGRAM OF THE COMPLETE AMPLIFIER

The several ground connections shown are made to the metal plate on the wood base.



THE TUBES FOR THE AMPLIFIER

phono wire to connect the inside terminal of the INPUT phono jack to terminal F on the Bakelite tie point located on the amplifier base near the 12SQ7 tube. The wire conductor INSIDE the shield is used to connect the jack to F. The metal shield on the outside of the wire should be grounded by soldering it to the sheet metal ground plate at some convenient spot.

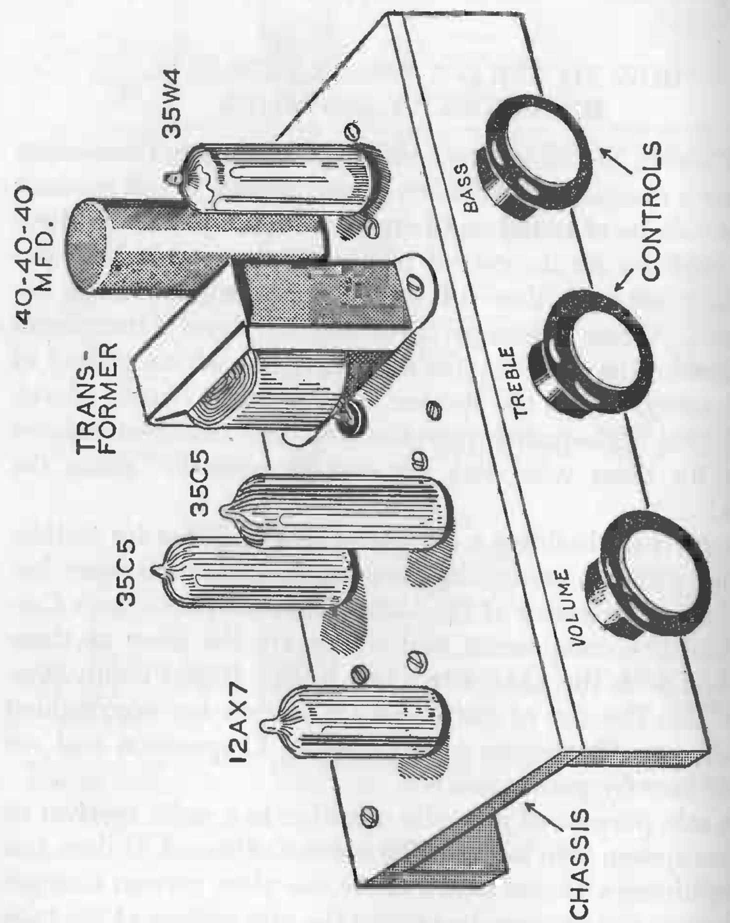
The amplifier can be wired most easily before it is installed in the player cabinet. For instructions how to connect the volume and tone control, power supply, etc., see Chapter Ten.

HOW TO BUILD A 5-WATT PUSH-PULL HIGH-FIDELITY AMPLIFIER

This 5-watt, high-fidelity amplifier can be used as the starting point for a complete high-fidelity phono system. It will produce greater volume of sound and better tone quality than the two-stage amplifier for the record player which has just been described. It has more than sufficient volume for the average living room. When connected to a record player (the player described in the next chapter may be used) with a pickup of good quality, and to the speaker described in Chapter Eleven it will give high-quality reproduction with sufficient volume except for those who wish for enough noise to "shake the rafters."

The parts for building a sample of this amplifier for testing, together with the circuit diagram and specifications were furnished by the courtesy of the Lafayette Radio Electronics Corporation. The components and circuit are the same as those furnished with the Lafayette Kt-92 5-watt High-Fidelity Amplifier Kit. The list of parts and the circuit are copyrighted by Lafayette Electronics Manufacturing Corporation and are printed here by permission.

The sole purpose of an audio amplifier in a radio receiver or a phono system is to increase the volume of sound. It does this by amplifying voltages which cause the plate current changes that actuate the speaker. Increasing the grid voltage of the tube or tubes in the output stage of an amplifier increases the volume of sound but may introduce distortion and lower the fidelity of the output. Two of the methods used to increase amplification without producing distortion are the use of pentode beam-power tubes and a push-pull circuit in the output stage. This



THE 5-WATT PUSH-PULL HIGH-FIDELITY AMPLIFIER

amplifier has both these features and in addition an inverse feedback circuit. A pentode power tube needs less grid voltage from the preceding amplifier stage. A push-pull circuit is still more efficient. It employs two tubes. A much higher output is possible without distortion with this circuit than with a straight single-tube amplifier as the output stage. Inverse feedback means that the circuit is arranged so that part of the output is fed back to one of the triodes in the 12AX7 tube in such a manner as to lower the output slightly but suppress noise and reduce distortion in the output.

The three controls provided are used to adjust the volume, treble, and bass of the output. There are several varieties of push-pull amplifier circuits. The two most common ones employ either transformer coupling or resistance coupling between stages. Resistance coupling is used in the amplifier under discussion.

Since this amplifier is more complex than the other equipment described so far in this book, it is suggested that the whole section under the heading "How to Build a 5-watt Push-Pull High-Fidelity Amplifier" be read carefully prior to assembling and wiring the instrument.

All of the parts and materials are supplied in the Lafayette Kt-92 Kit. If you have on hand some parts which can be used, you may prefer to buy the additional parts required individually rather than in kit form.

PARTS REQUIRED TO BUILD THE 5-WATT PUSH-PULL HIGH-FIDELITY AMPLIFIER

1 Chassis (See instructions in text which follows.)
1 Type 35W4 miniature electron tube (1)
2 Type 35C5 miniature electron tube (2)
1 Type 12AX7 miniature electron tube (3)
1 9-pin miniature molded tube socket (4)
3 7-pin miniature molded tube sockets (5)

1 5-watt push-pull universal output transformer with center-tapped primary and with 0-ohm, 3.2-ohm and 8-ohm secondary terminals (6)
1 500,000-ohm variable potentiometer with switch (7)
2 500,000-ohm variable potentiometers without switches (8)
1 Triple section 40-40-40 mfd., 150 working volts D.C. twist-prong
1 Electrolytic capacitor in aluminum can (9)
1 Sheet plastic mounting plate or wafer for above capacitor (10)
1 10 mfd. 25 WVDC electrolytic tubular capacitor (11)
1 0.1 mfd. molded tubular capacitor (12)
3 0.05 mfd. molded tubular capacitor (13)
1 0.005 mfd. molded tubular capacitor (14)
1 0.02 mfd. ceramic disk capacitor (15)
1 0.0005 mfd. ceramic disk capacitor (16)
2 470,000-ohm, ½-watt carbon resistor (17)
1 220,000-ohm, ½-watt carbon resistor (18)
2 100,000-ohm, ½-watt carbon resistor (19)
3 10,000-ohm, ½-watt carbon resistor (20)
1 47,000-ohm, ½-watt carbon resistor (21)
1 4,700-ohm, ½-watt carbon resistor (22)
1 2,200-ohm, ½-watt carbon resistor (23)
1 330-ohm, ½-watt carbon resistor (24)
2 100-ohm, 1-watt carbon resistor (25)
1 22-ohm, 1-watt carbon resistor (26)
3 Control knobs for variable potentiometers (27)
1 Phono jack (28)
1 5-lug tie point or solder lug terminal strip (29)
1 3-lug tie point or solder lug terminal strip (30)
1 2-screw terminal strip (31)
1 2-lug tie point or solder lug (32)
1 1-lug tie point or solder lug terminal strip (33)
2 ⅜-in., 6-32 RH machine screws
2 6-32 hexagonal nuts

19 ⅜-in., 4-40 RH machine screws
19 4-40 hexagonal nuts
1 Terminal lug (34)
3 to 4 feet of insulating tubing or "spaghetti" which will slip over terminal wires on resistors and capacitors
1 6-foot length double-conductor lamp cord and attachment plug. No. 22 solid insulated hookup wire. Shellac, rosin-core solder.

The Chassis. The components of a commercially-built amplifier are usually mounted on a steel or aluminum chassis. The transformers and tubes are placed on top of the chassis; the wiring is underneath. An 8-inch x 4-inch x 1½-inch steel chassis is furnished with the Kt-92 Lafayette Kit. All holes have been drilled at the factory.

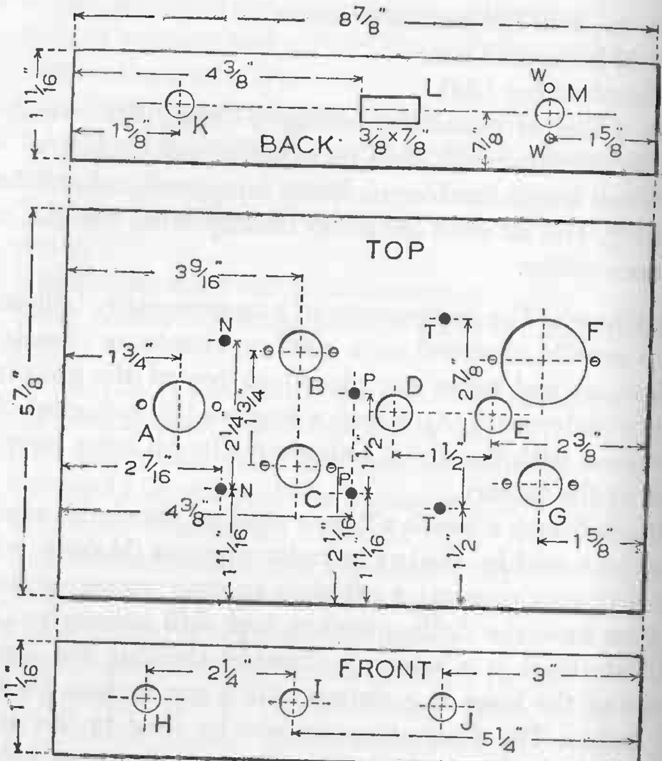
A blank 8-inch x 4-inch x 2-inch steel or aluminum chassis is a stock size sold by dealers in radio supplies. Making holes in a metal chassis presents a problem to most young experimenters. Few have the drills, punches, and skill necessary. One of the illustrations is a working drawing showing the size and location of the holes in a chassis with a top surface 8⅞ inches x 5⅞ inches. The illustration can also be used to "lay out" an 8-inch x 4-inch chassis. Make the distances between holes the same as those in the illustration.

A homemade wooden chassis can be used. This is a departure from the "breadboard" designs previously described and will acquaint the novice with the commercial chassis type of design.

Wood Chassis Construction. A wood chassis suitable for the amplifier can be built from ¼-inch plywood.

PARTS FOR WOOD CHASSIS

1 Top 8⅞ in. x 5⅞ in. x ¼ in.
1 Front 8⅞ in. x 1$^{11}/_{16}$ in. x ¼ in.
1 Back 8⅞ in. x 1$^{11}/_{16}$ in. x ¼ in.
1 Piece of thin sheet metal 8⅝ in. x 2⅝ in.



DETAILS OF THE THREE PIECES USED TO BUILD A WOOD CHASSIS

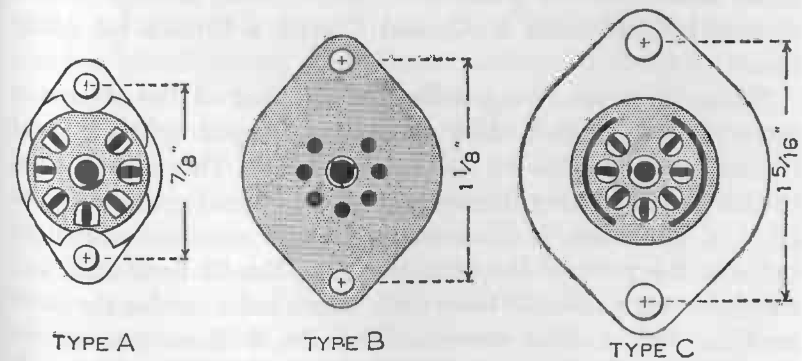
The size of the large holes in the chassis and the location of the two small mounting holes alongside each of the large holes will depend upon the type of tube socket used. There is a disadvantage in a wooden chassis. It is not practical to make a strong chassis of wood less than ¼ inch thick. When the common molded miniature 7-pin and 9-pin socket with ⅞-inch mounting centers (see type A in illustration) is mounted on ¼-inch thick wood, the terminals cannot be bent back on the underside without counterboring the wood. It would be very

difficult to solder wires to the socket terminals and keep them insulated from each other without first bending them back so that they are separated like the spokes of a wheel.

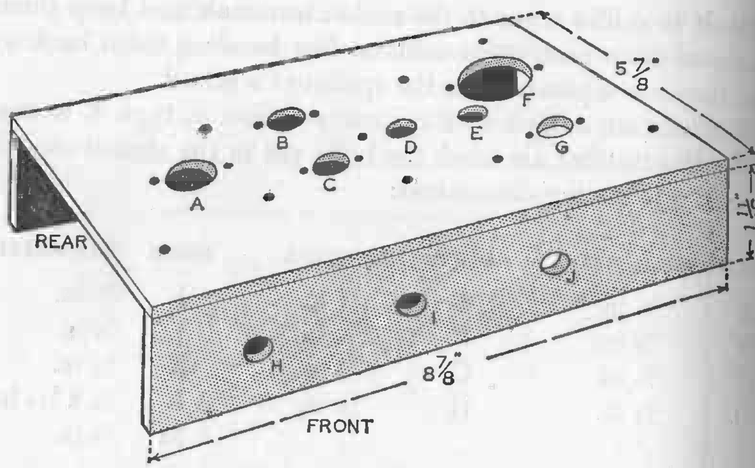
If miniature sockets of the variety shown as type A in one of the illustrations are used, the holes cut in the chassis should be of the following dimensions:

HOLE	DIAMETER	HOLE	DIAMETER	HOLE	DIAMETER
A	¾ in.	E	½ in.	I	⅜ in.
B	⅝ in.	F	1¼ in.	J	⅜ in.
C	⅝ in.	G	⅝ in.	K	⅜ in.
D	½ in.	H	⅜ in.	L	⅞ x 7/16 in.
				M	⅜ in.

Holes A, B, C, and G are holes for type A sockets. Locate the center of each socket hole and each pair of mounting center holes (7/16 inch from the center of each socket hole). Drill a pilot hole in the center of holes A, B, C, and G and the mounting holes with a No. 31 twist drill (Step One). Counterbore each mounting center hole with a ½-inch power-driven, wood-boring bit of the type shown in one of the illustrations (Step



THE THREE TYPES OF SOCKET AVAILABLE FOR MINIATURE TUBES



THE COMPLETED WOOD CHASSIS READY FOR THE COMPONENTS AND WIRING

Two) to a depth of ⅛ inch from the undersurface of the chassis top. Counterbore A, B, C, and G also to a depth of ⅛ inch from the undersurface of the chassis top (Step Three) using a 1-inch power, woodboring bit for the purpose. Then using the small center hole as guide drill hole A clear through with a ¾-inch bit and holes B, C, and G with a ⅝-inch bit (Step Four).

While holes are being drilled in any part of the chassis, a piece of wood ¾ inch thick should be clamped tightly against the surface where the bit will come through. This is to prevent the bit from breaking through the plywood and splintering the edge of the holes. It is necessary to drill nineteen mounting holes in the parts of the chassis with a No. 31 twist drill and two holes with a No. 28 twist drill. These holes are for the nineteen No. 4-40 machine screws and two No. 6-32 machine screws which hold parts on the chassis. These small holes can be made with a hand drill or small electric drill.

The 1¼-inch diameter hole for mounting the electrolytic condenser can be made with an expansion bit in an ordinary brace. The other large holes can be cut with ordinary wood augurs held in a brace provided that a piece of wood is clamped against the surface opposite the spot where the augur enters.

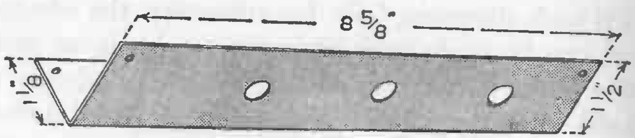
If wafer sockets with mounting holes $1\frac{5}{16}$ inches apart can be obtained, make holes A, B, C, and G $\frac{13}{16}$ inch in diameter.

Type A molded sockets should be mounted on the upper surface of the chassis with the terminals on the underside in the counterbored area. Wafer sockets are mounted on the undersurface of the top. The tubes are inserted in the wafer sockets by pushing them down into the sockets through the $\frac{13}{16}$-inch holes above.

If type C sockets are used they can be mounted on the upper surface of the top of the chassis and used without counterboring. The plastic body of this type of socket projects about ¼ inch below the mounting plate. Make holes A, B, C, and G ¾ inch in diameter with mounting holes on $1\frac{5}{16}$-inch centers.

Assembling the Chassis. When all the holes have been drilled the three pieces of the chassis should be fastened together to form a shallow inverted U. The joints are glued. The three pieces are held in position until the glue sets by several small diameter brads ½ inch long. These are driven along the edges of the top into the front and rear pieces. The best glue to make a strong joint between such narrow surfaces is an epoxy adhesive such as "Fix'n Patch." When this adhesive has set hard, smooth the outside surfaces of the chassis with fine sandpaper and apply two coats of shellac or varnish. Allow the first coat to dry before putting on the second. When the second coat is dry, the components can be assembled on the chassis.

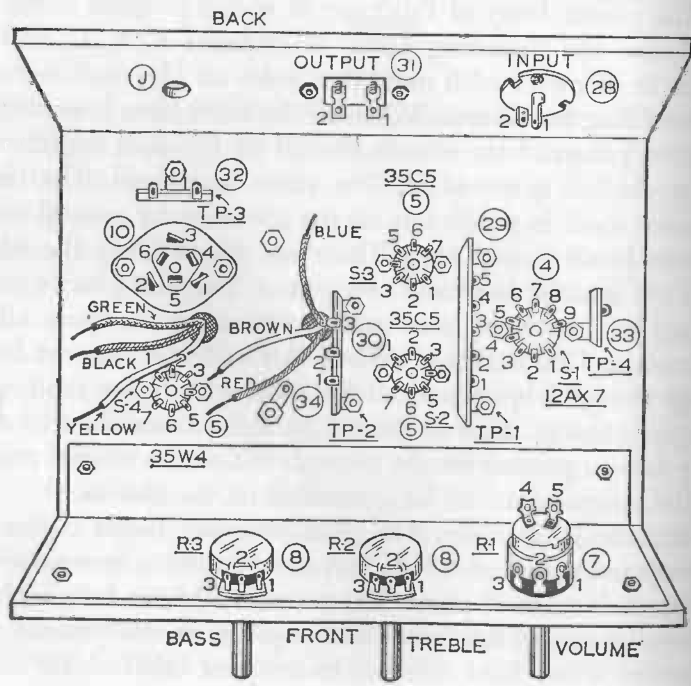
Mechanical Assembly. The piece of sheet metal in the list of components and materials serves as a chassis ground when the chassis is made of wood. The metal can be cut from a clean, rectangular one-gallon can. Cut the piece 8⅝ inches long and 2⅝ inches wide. Take care not to cut your hand on the sharp



THE "L"-SHAPED METAL PIECE WHICH FORMS THE CHASSIS GROUND ON THE WOOD CHASSIS

THE MECHANICAL ASSEMBLY OF THE 5-WATT AMPLIFIER VIEWED FROM UNDERNEATH THE CHASSIS

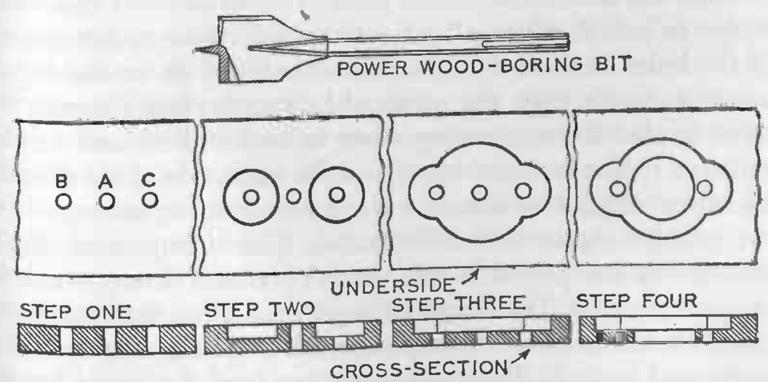
The abbreviations S-1, S-2, S-3, and S-4 indicate sockets. TP-1, TP-2, TP-3, and TP-4 are tie points. The numerals in circles correspond to the numbers of the components in the list of parts. The numbers without circles identify terminals.



edges of the metal. Bend it at right angles parallel to the long edges and 1½ inches back from one edge. Use four ⅜-inch, 4-40 round head machine screws and hex nuts to fasten the 8⅝-inch x 1½-inch face against the inside surface of the front panel and the 8⅝-inch x 1⅛-inch face against the underside of the top of the chassis. Drill three ⅜-inch diameter holes through the metal where they will align with the three holes of the same size in the front panel.

The frame of the output transformer and some parts of the amplifier circuit are connected to this "floating ground" through an 0.1 mfd. capacitor. One terminal of the capacitor is connected to the common negative of the 40-40-40 mfd. electrolytic capacitor. The other terminal of the 0.1 mfd. capacitor is connected to the solder lug under one of the hex nuts which hold the output transformer to the chassis. The solder lug under the nut is also connected to a wire which is soldered to the metal sheet.

The rest of the assembling and wiring instructions assume that type A molded sockets are used and with one exception apply both to a metal chassis and to a homemade wooden one.



THE UNDERSIDE OF THE HOLES FOR TYPE-A SOCKETS MUST BE COUNTERBORED TO MAKE SPACE FOR THE SOCKET TERMINALS

The exception is that type A sockets should be mounted on the top surface of a wooden chassis and on the underside of the top of a metal chassis.

All three controls have long shafts so that the amplifier can be installed in a cabinet and the shafts will be long enough to project through the wall of the cabinet. If the amplifier is not to be installed in a cabinet, cut the shaft of each control so that it projects only ⅜ inch beyond the threaded bushings. Clamp the end of the shaft in the jaws of a small vise and make the cut with a fine tooth hack saw. Be certain to clamp the shaft in the vise and not the body of the control.

Place the chassis on the table or bench with top down and the front panel turned toward you. Bend the small positioning lug on each control down flat against the front of the control. Mount the 500,000-ohm control with the attached on-off switch in the ⅜-inch hole J at the right-hand end of the front panel. Mount the other two controls in the holes H and I in the front panel. The controls should be inside the chassis. The bushings pass through the ⅜-inch holes in both the "ground" and the wood panel. Position the lugs as shown in the illustration and tighten the ⅜-inch nuts.

Turn the chassis over and place a 9-pin molded miniature socket in hole A. Place a 7-pin molded miniature socket in each of the holes B, C, and G. The sockets should be on the top of a wood chassis with the terminal lugs projecting through the holes so that the connecting wires to be installed later can be soldered to the terminal lugs from the underside of the chassis. Place each socket so that the No. 1 terminal lug on each is in the position shown in the illustration. This is important. If the sockets are not placed in the correct position it may result in incorrect wiring. The flange on each socket has two mounting holes. Fasten each socket in place with a ⅜-inch, 4-40 machine screw and hex nut. Place the mounting foot of a single lug tie point under one of the nuts which holds the 9-pin miniature socket in place as illustrated.

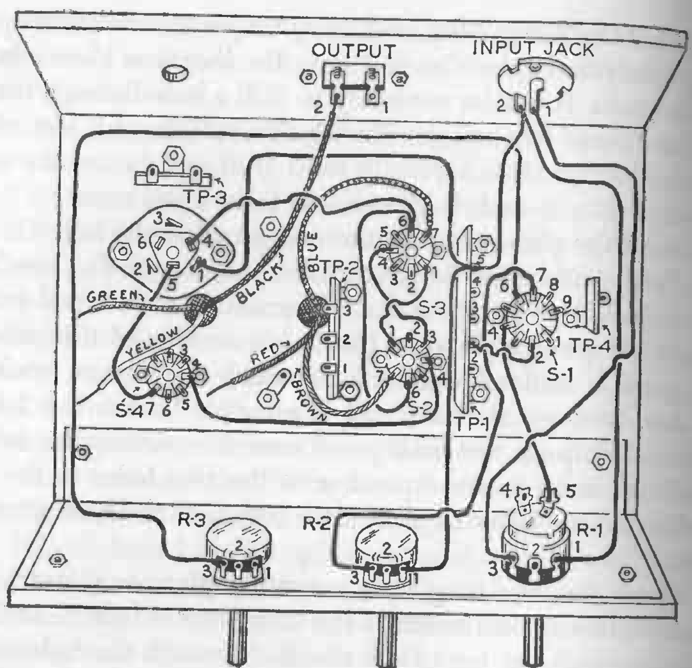
Mount the 2-lug, 3-lug, and 5-lug tie-point terminal strips on the underside of the chassis top in the locations shown in the illustrations. It will be necessary to drill a hole through the top of the chassis to correspond with the holes in the feet of the terminal strips. Use a No. 31 twist drill and fasten the strips in place with ⅜-inch, 4-40 machine screws and nuts.

Mount the phone jack on the rear panel in the hole H. Drill two holes with a No. 34 twist drill to align with the two holes in the jack. Use two ⅜-inch, 4-40 machine screws and nuts to fasten the jack in place on the inside surface of the panel. If the panel is made of metal it is necessary to place an insulating washer between the jack and the metal. Mount the 2-screw terminal strip on the back panel over the rectangular hole L. Drill two holes to correspond with the two holes in the strip and fasten the latter in place with two 4-40 machine screws or nuts.

Mount the insulating fiber mounting plate or wafer for the electrolytic can condenser on the underside of hole F. Drill two holes through the top of the chassis to match the holes in the wafer. Use two ⅜-inch, 4-40 machine screws and nuts to fasten the wafer in place. The 40-40-40 mfd. can condenser is installed by inserting the three prongs on the capacitor into the slots in the mounting wafer. The prongs are inserted from the top of the chassis so that the can stands upright on the chassis and the prongs project through the underside. Hold the can firmly against the wafer and twist the prongs slightly with a pair of pliers so that the can is held firmly against the wafer.

The prongs are also used as the common negative terminal of all three capacitors in the can. The three separate positive terminals are the three solder lugs which project through the triangular hole in the center of the mounting wafer.

The push-pull output transformer should be mounted on the top of the chassis between the holes D and E. Drill two holes in the top of the chassis with a No. 28 twist drill to match the two holes in the feet on the transformer. Use two ⅜-inch, 6-32

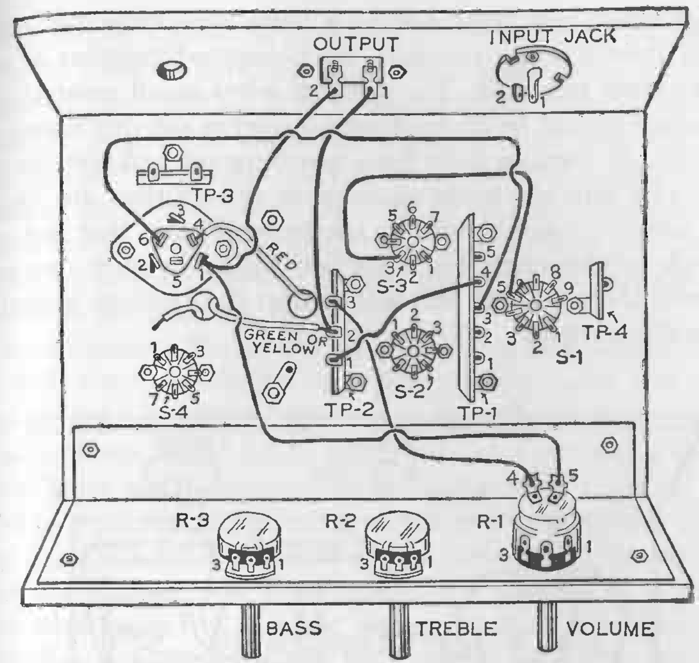


THE FIRST PART OF THE WIRING

Consult the two illustrations which follow. If more than one wire is to be connected to a terminal do not solder the connections to such terminal until all wires are attached to it.

round head brass screws and nuts to secure the transformer to the top of the chassis. Place a solder lug under the 6-32 nut nearest to the front panel of the chassis. Push the blue, red, and brown transformer terminal wires down through hole D so that the ends of the wires are beneath the underside of the chassis top. Push the yellow, green, and black transformer terminal wires down through hole E.

Wiring. All wiring is done on the underside of the chassis. All connections must be soldered. Connections made to terminals where more than one wire is to be attached are not

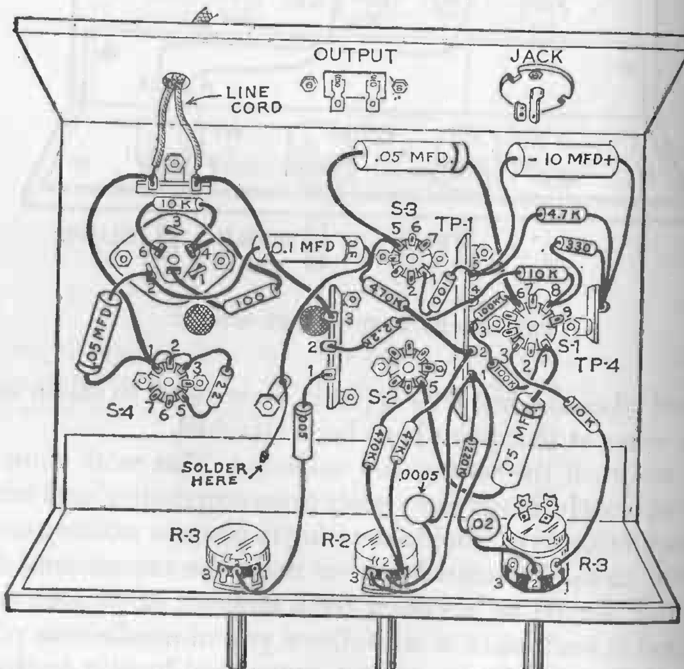


THE SECOND PART OF THE WIRING

soldered when the first wire is put in place. Wait to solder until all the wires at that point have been attached.

Do not rush the wiring and soldering. This work must be done accurately. Haste may result in an inoperative unit which will require hours of trouble-shooting to place in working order. Use No. 22 solid insulated wire to make the connections. The insulation should be removed for a distance of ¼ inch from each end of each piece of wire. Use a pair of needle-nose pliers to insert the end of a wire in a terminal and bend it so that it is securely in place. Use diagonal-nose cutting pliers to snip off surplus wire.

The wiring in the pictorial diagrams has been divided into two groups to avoid confusion. Place the wires in much the same position as in these diagrams. Some wires cross each other in the drawings but no wires are connected together at any place except terminals. The terminal wires on all resistors and capacitors should be covered with insulated sleeving known as spaghetti to insulate them from nearby wires and metallic objects. The terminal wires on some of the resistors are longer than necessary and should be shortened. Notice that one end of each tubular capacitor is marked with a band at one end. Connect the capacitor terminal nearest the band as indicated in the illustrations.



THE RESISTORS AND THE CAPACITORS ARE CONNECTED LAST

The terminal wires on these components should be covered with spaghetti and made as short as possible. Notice black bands near one end of each capacitor and place that end of each capacitor as shown above.

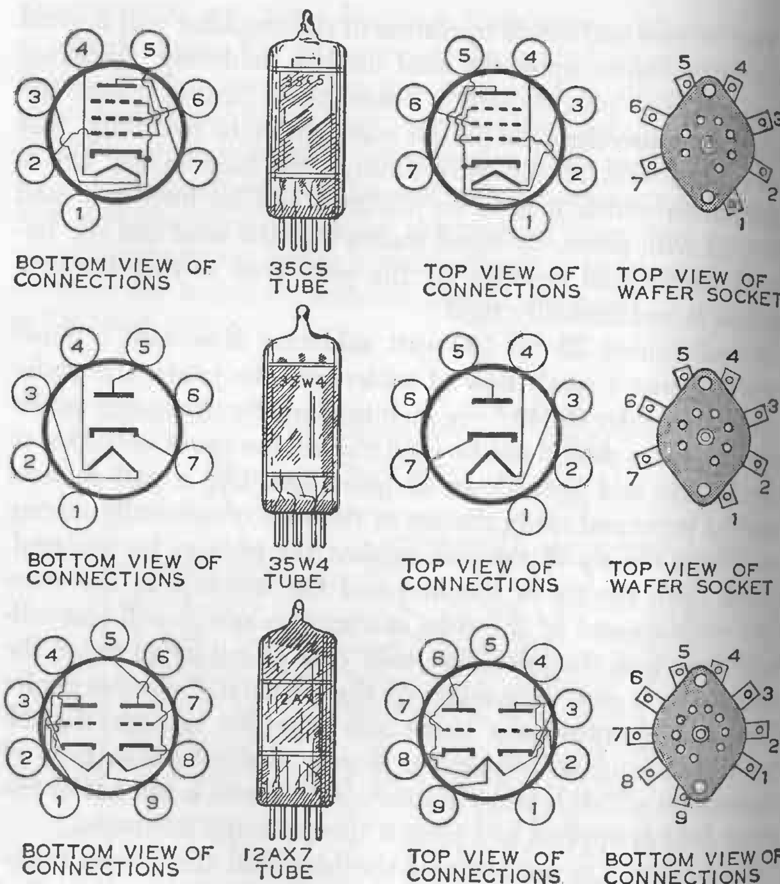
The success and stable operation of the amplifier will depend in great measure upon the skill used in soldering. Soldering alone will not provide strong connections. Strong, clean mechanical connections should be made prior to soldering. The end of the wire should pass through the hole in the lug or terminal to which it is to be soldered and be bent over and crimped with pliers. Crimped means that the wire and the terminal are pressed together by the plier jaws so that the connection is mechanically rigid.

A well-tinned 35- to 100-watt soldering iron with a chisel tip will insure a ready flow of solder into the joints. Use rosin-core radio solder 60/40,* 1/16 inch in diameter. Acid-core solder or paste fluxes should not be used since these cause corrosion of metal parts and breakdown of insulation. Use a pad of steel wool to wipe and clean the tip of the iron occasionally during use. Place the tip of the iron against the joint to be soldered. Touch both the tip of the iron and the terminal at the same time with an end of the wire solder. The solder will immediately flow into the joint. Use only enough solder to cover the wire where it makes contact with the terminal. Excessive solder may cause short circuits. If the iron is not hot enough, the solder in the joint will appear dull gray and pitted—a type of connection which is unsatisfactory. If the iron is too hot or too much heat is applied to a joint it may damage insulation.

No Solder. Do not connect the blue and the brown transformer leads permanently by soldering until the tests described in one of the following paragraphs have been made. These tests should be carried out only after all other connections have been inspected and checked and the tubes have been placed in their sockets.

Inspection. When the wiring has been completed, inspect all connections (except the transformer leads) to see that they are all well soldered. Look for possible short circuits between

* 60 parts lead, 40 parts tin.



THE TUBES FOR THE 5-WATT AMPLIFIER

socket terminals and between components which might be caused by excess or splashed solder or by the ends of wires touching where they should not. Reheat any suspicious-looking connections with a hot soldering iron; clean them up and re-solder.

The Transformer Secondary. The yellow, green, and black wires on the transformer are secondary terminals. They provide the correct impedance to operate a speaker with either a 3-ohm or a 6- to 8-ohm voice coil. The black wire should be cut off three inches from the hole where it comes through the chassis. Strip ¼-inch insulation from the end of the wire and connect it to lug No. 2 of the 2-screw output terminal strip. Do not solder it until a wire from lug No. 1 on the 40-40-40 mfd. capacitor has also been connected to lug No. 2 on the output terminal. If the amplifier is to be connected to a 3-ohm or 3.2-ohm speaker connect the green wire to No. 2 lug on tie point 2 (TP-2). Connect a wire also to lug No. 2 on TP-2. Connect the other end of the wire to lug No. 1 on the 2-screw output terminal strip. Cover the end of the yellow wire with tape so that it cannot make an electrical contact with any part of the amplifier. If the amplifier is to be used with a 6- to 8-ohm speaker connect the yellow wire to lug No. 2 on TP2 and to the No. 1 lug on the 2-screw terminal output strip. Cover the end of the unused green wire with tape. The unused secondary wire is not disposed of by cutting it short because it may be desirable to change the speaker at some time to one of different impedance.

Insert Tubes in Their Respective Sockets Carefully. The contact pins on miniature tubes are slender wires which are bent out of position easily. Be certain to line up the positioning space of the pins with the positioning space on the socket before pushing a tube in. Hold the tube so that it is vertical to the plane of the socket and push it into place carefully. Tube No. 12AX7 should be put in socket S-1, tube No. 35W4 into socket S-4, and the two 35C5 tubes into sockets S-2 and S-3.

Caution. Part of the amplifier circuit is connected to one side of the 120-volt A.C. line and precautions should be taken to see that this portion of the circuit is at low or ground potential before connecting the amplifier to a record player, radio, or other pieces of equipment which may be grounded. The plug on the power cord of the amplifier should be inserted in the power outlet so that no voltage or difference of potential is indicated between lug No. 1 on the 40-40-40 mfd. capacitor and ground (wall socket plate screw). Use a neon lamp tester to check this. If the lamp glows, the line plug should be reversed in the wall socket.

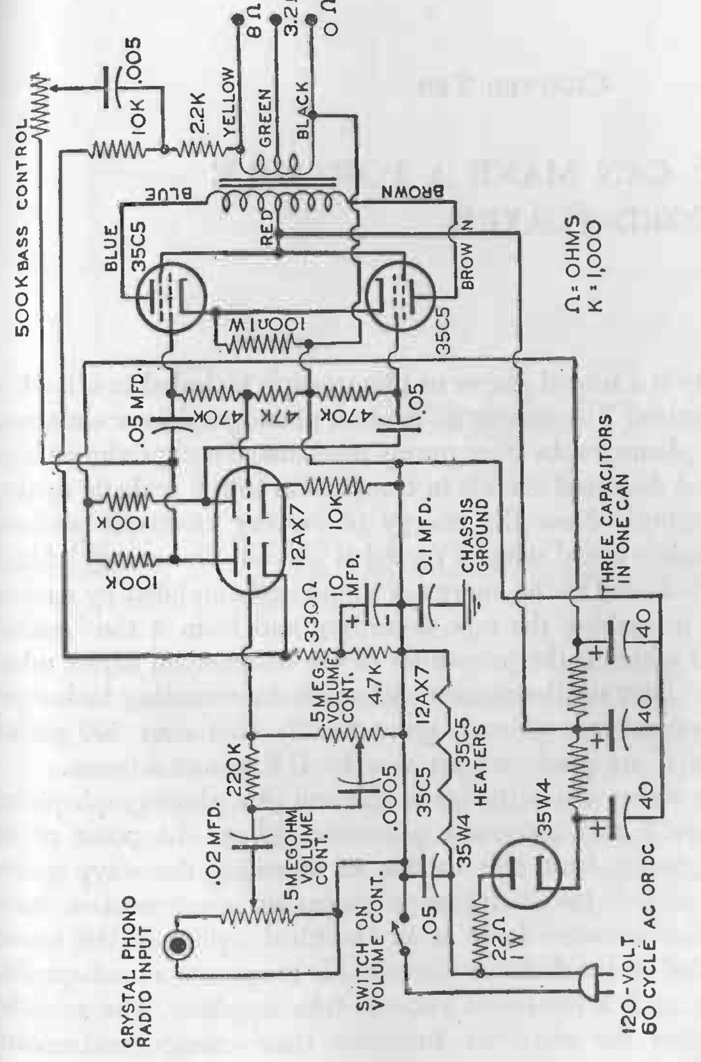
Test. When the power plug has been correctly positioned in the wall socket, connect the input (jack) and output (2-screw terminal plate) to the associated equipment (record player, radio, speaker, etc.).

1. Turn the amplifier on and set the volume control at a normal listening level. Notice the relative loudness and tone quality carefully.

2. Remove the amplifier power cord plug from the wall receptacle so as to turn the power off. Do not turn the power off by using the switch on the volume control because this will alter the adjustment of the control.

3. Reverse the blue and brown transformer wires connected to the No. 7 terminals on sockets S-2 and S-3. Replace the power plug in the wall receptacle and note carefully the level of sound from the speaker. Solder the blue and brown transformer wires in the position which produces the LOWEST level of sound. Although this position produces the lowest level of sound it is the CORRECT position. It provides negative feedback in the circuit and reduces noise and distortion in the output.

When the amplifier has been completed, if it produces an unpleasant loud rumbling sound this is probably due to oscillation at audio frequency caused by a reversed winding in the transformer, a mistake made in the manufacturing process. This can be remedied by connecting the black wire to the No. 2 lug on TP-2 instead of to the No. 2 lug on the output. The yellow or green wire, depending upon the impedance of the voice coil in the speaker, should then be connected to the No. 2 lug on the output.



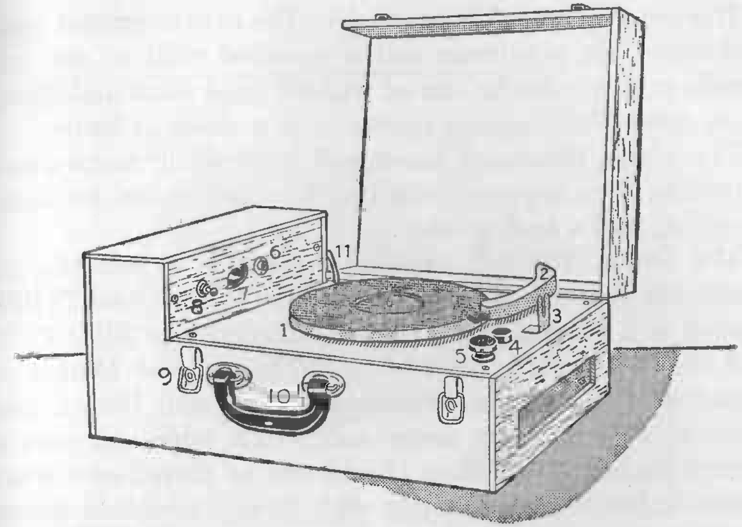
SCHEMATIC CIRCUIT DIAGRAM OF THE 5-WATT AMPLIFIER

CHAPTER TEN

YOU CAN MAKE A PORTABLE RECORD PLAYER

Why is a record player or phonograph included in a book on electronics? The answer is: modern phonographs are electronic. Early phonographs were purely mechanical and produced high-pitched distorted sounds in comparison to the realistic modern phonograph. Now the energy of moving electrons produces the sounds heard when a record is played. The energy of electrons is added to the energy of sound and amplified by vacuum tubes in making the tape recording and from it the "master" record which is the progenitor of the commercial copies which appear later on the market. Advances in recording techniques produce records of such great fidelity that over 300 million "platters" are produced per year by U.S. manufacturers.

The stylus and cartridge at the end of a phonograph pickup arm are a tiny electrical generator. When the point of the stylus moves from side to side in following the wavy groove on a record, the cartridge produces an electromotive force. The electromotive force is an electrical replica of the sounds recorded on the disk but is too feeble to operate a loud-speaker. Therefore it is fed into a vacuum-tube amplifier. The amplifier multiplies the electrons, increases their energy, and creates enough power at the output to operate a speaker. The vibrations of the speaker diaphragm produce sound waves.



PORTABLE RECORD PLAYER OR PHONOGRAPH

The numerals identify some of the parts as follows: (1) turntable; (2) pickup arm; (3) pickup armrest; (4) tone control knob; (5) volume control knob; (6) jack; (7) rotary switch; (8) on-off switch; (9) cabinet catch; (10) carrying handle; (11) power cord.

Assembling and installing a high-fidelity sound system for playing modern records has become a widespread hobby. Several catalogs list a great variety of phonograph motors, record players, cartridges, amplifiers, speakers, etc., which will produce highly faithful facsimiles of the sounds which made an original recording. A glance at the prices of these components will convince most youthful experimenters that the cost places them out of their reach.

This chapter discusses the assembly of a homemade, compact, common-sense portable record player. It does not play stereo records and is not completely hi-fi. But it does have first-class tone of a quality which should satisfy the average person.

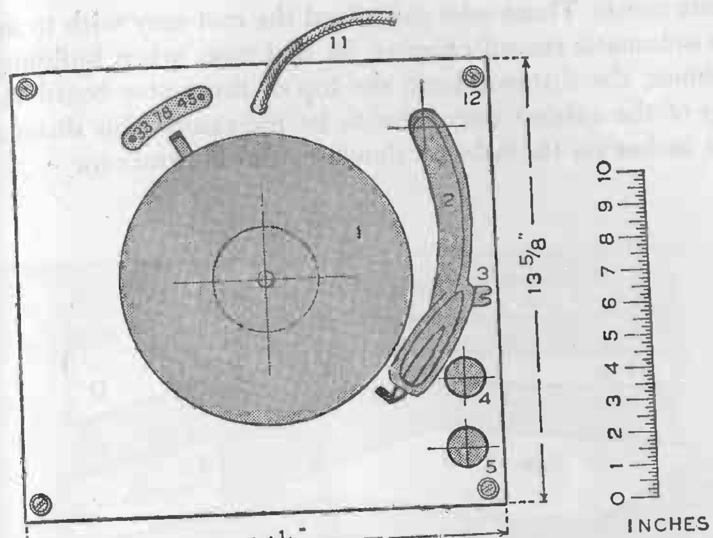
It is not a "built-in." It is portable. The case or cabinet opens and closes like a suitcase and is provided with an easy-grip handle so that it can be carried without great effort and stowed in an automobile luggage carrier or in a closet at home.

The player illustrated consists of a revolving motor-driven turntable, a pickup arm with cartridge and stylus, an audio-amplifier, and a loud-speaker.

The Motor. The first decision to make is in selecting the motor. Do you wish to build a player for 33⅓, 45, and 78 RPM records or a 4-speed player which will reproduce 33⅓, 45, 78, and the new "talking book" 16⅔ RPM records? Motors are available with a 4-pole, shaded-pole motor and 10-inch turntable or with a 2-pole motor and 9-inch table. All sizes of records up to and including 12-inch can be played on a 9-inch turntable but the 4-pole motor with 10-inch turntable is more desirable if you can afford it. It costs a little more than twice as much as a 2-pole, 9-inch turntable motor. Both types of motor are designed to operate on 110-to-120 volt, 60 cycle A.C. The turntable is rim driven by friction from a variable speed rubber-covered wheel. Placing the speed selector lever in "off" position automatically disengages the friction drive and turns off the motor. When you buy a motor check the package to be sure that a mounting template is included and at no extra charge. The template is a full-size printed pattern which shows the size and shape of the holes which must be cut in the motor board to accommodate the motor.

The Pickup Arm and Cartridge. The pickup arm and cartridge which you use in building your record player should be the three-speed or "turnover" type. A turnover cartridge is a dual-stylus cartridge. One stylus is about .003 inch in diameter and used when playing 78 RPM records. The other, much smaller (.001 inch in diameter) is for 33⅓ and 45 RPM microgroove records.

The cartridge in the pickup arm should be a crystal- or a ceramic-type cartridge and not the magnetic type. A mag-



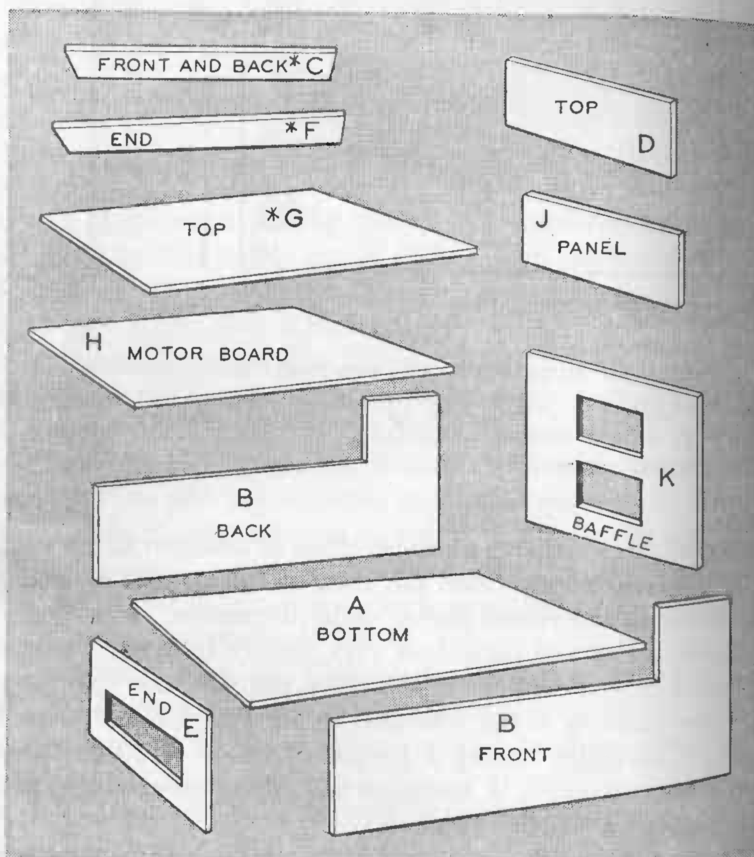
PLAN OF MOTORBOARD AND THE PARTS MOUNTED ON IT

(1) turntable; (2) pickup arm; (3) pickup armrest; (4) tone control knob; (5) volume control knob; (11) power cord; (12) screw to hold motorboard in cabinet.

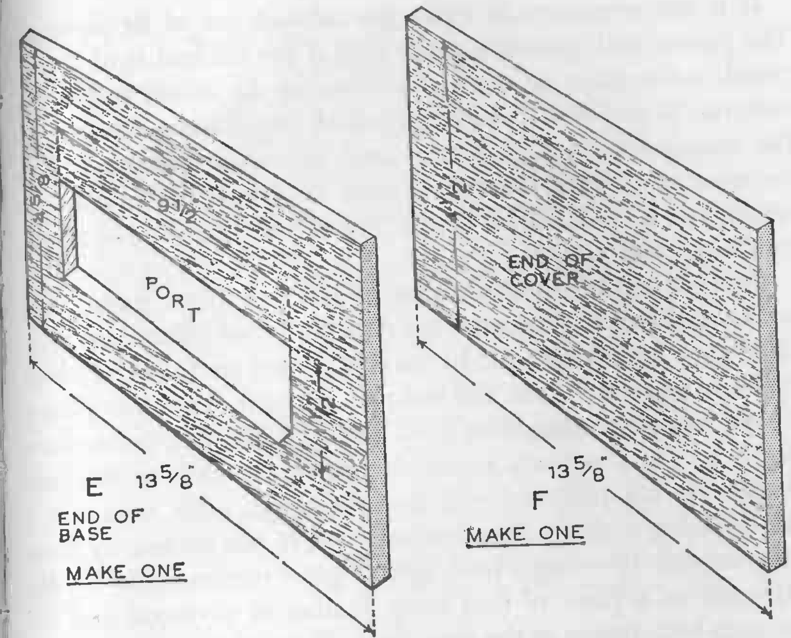
netic cartridge requires a pre-amplifier in addition to the usual amplifier and no provision has been made for this additional apparatus in the record player under discussion.

Pickup arms and cartridges vary greatly in price. The cost depends largely upon the frequency range. Since the player you are building is not intended to be a high-fidelity instrument, a cartridge having a frequency range of 30 to 11,000 cps is recommended. A cartridge with more range would be a waste of money in this instance.

So far it has been assumed that the player will be equipped with a single-play motor. This means manually stopping the motor when a record is finished, replacing it with another record, placing the stylus in starting position, etc., if you wish more music. Those who can afford the cost may wish to install an automatic record changer. In that case, when building the cabinet, the distance from the top of the motor board to the top of the cabinet may have to be increased. This distance is 3⅝ inches on the cabinet shown in the illustrations.



PARTS OF PLAYER CABINET
The letters identify the same pieces in the dimensioned working drawings which follow.



PLAYER CABINET PARTS (*Continued*)

The Cabinet. This is a woodworking project which requires no more proficiency with tools than is required to build a neat box. The only skill necessary is that required to saw straight and to accurate size.

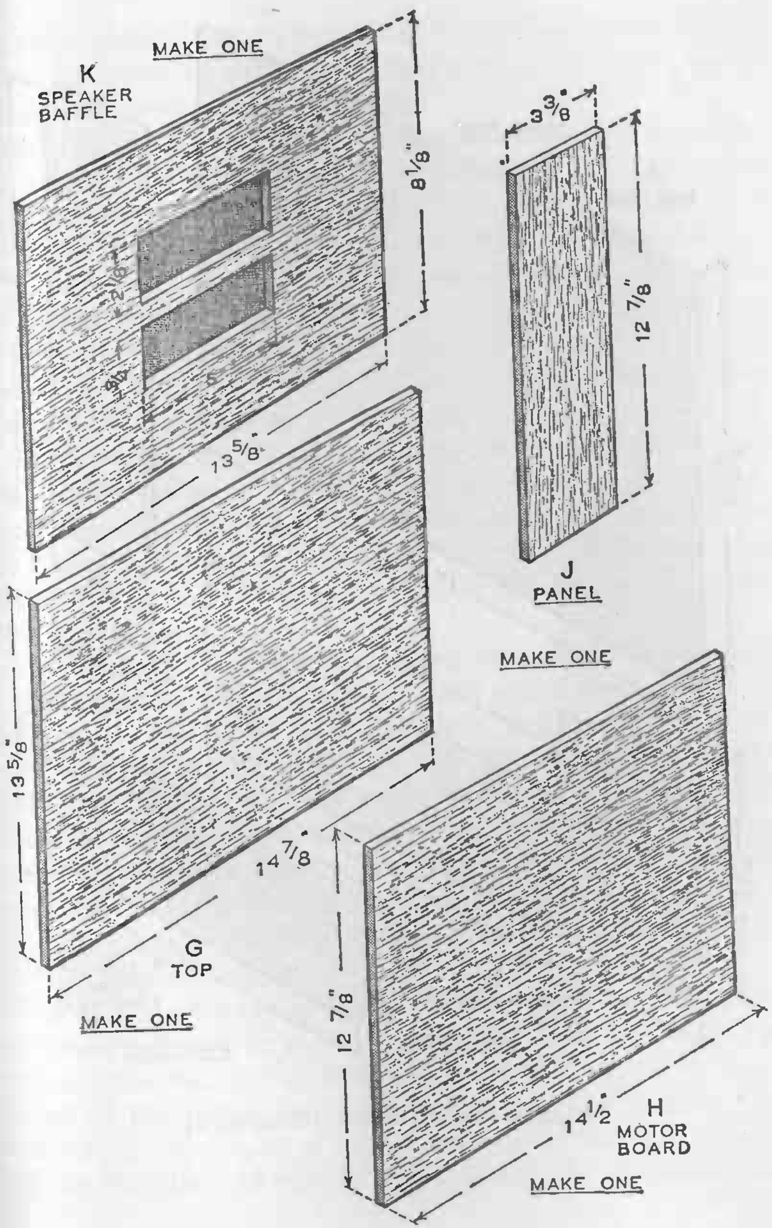
The cabinet for the model which was built for this book was made entirely of ⅜-inch fir plywood. After assembling, the surface was smoothed with fine sandpaper (No. 00), then given a coat of light maple stain, a coat of white shellac, and two coats of varnish. The shellac coat was rubbed to a dull finish with fine steel wool before the first coat of furniture varnish was applied. Both coats of varnish were rubbed to a smooth finish with a piece of felt dipped in a thin paste of pumice stone and water.

It is not necessary to make the cabinet out of fir plywood. The player will operate equally well if the cabinet is of fir plywood, mahogany, or unfinished lumber. In other words, the material of which it is made is of small importance except from the standpoint of appearance and the work involved. It is recommended that the motorboard be made of ⅜-inch plywood. The motorboard is the flat top which supports the motor, turntable, and pickup.

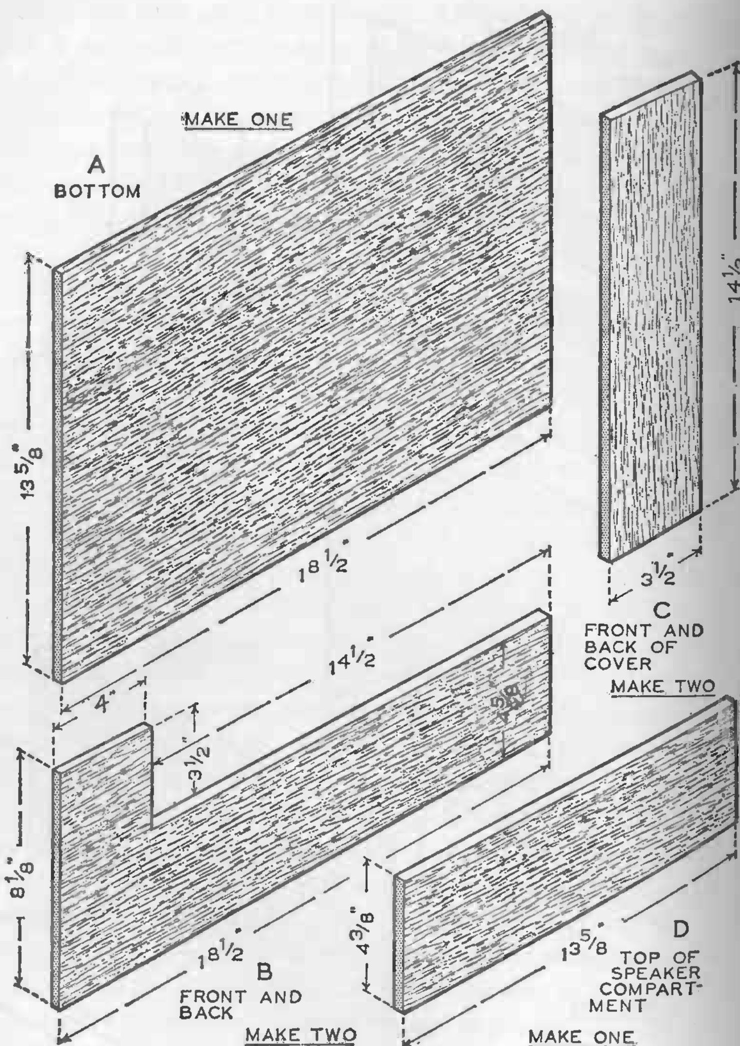
One of the illustrations shows all of the cabinet parts. They are named and numbered from A to K. Those which are identified by a letter preceded by an asterisk are parts of the cover. Perhaps you can make the cabinet in your school workshop where proper woodworking tools are available. The main essential is to cut the parts smoothly and accurately to size and shape. Sawing plywood will leave a rough edge unless it is cut by using a sharp, fine-toothed saw. It can be cut by hand satisfactorily by using a back saw. A good method is to lay the plywood on a piece of thin scrap lumber or plywood and cut through both pieces at the same time. This will prevent splintering the underside of the plywood which is to become part of the cabinet. If a power circular saw is employed, the saw blade should be one made especially for plywood. The exact dimensions of the parts are shown in the illustrations.

The location, size, and shape of the opening and holes in the motorboard will depend upon the particular motor and pickup which is used. Use the template which comes with the motor to locate the holes. Cut the large opening for the motor with a power jig saw or a hand fret saw. The motor should be mounted so that the center of the turntable is located where two diagonal lines drawn between opposite corners of the motor board meet.

A paper template is usually supplied with each pickup. Ask for one when you buy the pickup. It may be in the box with the pickup. It is worth the trouble to check and make sure you receive one. The pickup should be mounted to the right of the



PLAYER CABINET PARTS (*Continued*)



PLAYER CABINET PARTS *(Continued)*

turntable and located so that when the pickup arm is swung from side to side the stylus would move in an arc which passes through the center of the turntable.

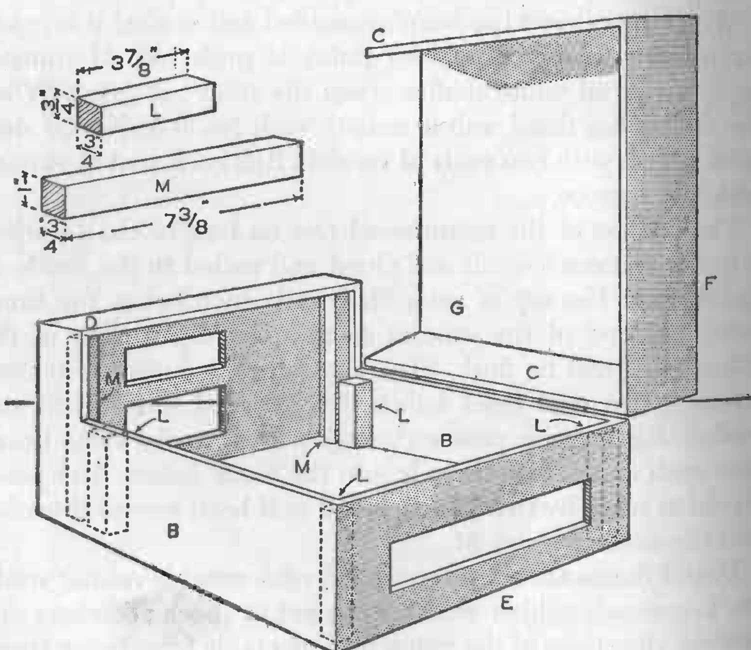
Make all holes necessary in the motorboard, speaker baffle, and end of base before assembling the cabinet. Use both glue and small wire nails to fasten the cabinet together. Do not glue the motor board in place. Drive the nail heads below the surface of the wood and fill the indentations with plastic wood. When the glue has set for 12 to 24 hours smooth the outside of the cabinet with No. 2/0-100 production paper. Imperfections in the edges of the plywood can be concealed by filling with plastic wood and smoothing with sandpaper when hard.

When the cabinet has been assembled and sanded it is ready for staining unless a painted finish is preferred. If stained, apply a coat of white shellac when the stain has dried. When the shellac has dried, rub it smooth with No. 0 or No. 00 steel wool. Finish with two coats of varnish. Rub each coat of varnish with wet pumice.

The corners of the motorboard rest on four blocks (marked L in illustrations) which are glued and nailed to the inside of the cabinet. The top of each block is ⅜ inch below the front, back, and end of the cabinet so that the top surface of the motorboard will be flush. The motorboard is fastened at each corner by an oval head 1-inch, No. 8 wood screw with cup washer. Each screw passes through a hole in the motorboard near each corner and threads into the block below. The panel is held in place by two 1-inch, No. 6 oval head screws threaded into the vertical strips M.

Unless the motor comes equipped with suitable rubber washers, homemade rubber washers can act as shock absorbers and prevent vibrations of the motor and turntable from being transmitted to the motorboard and so reaching the pickup. The washers can be cut out of an old inner tube from an automobile tire. Six pieces of tube ¾ inch x ¾ inch are required. Drill a hole through each with a ⅛-inch drill. The upper plate on the motor is fastened to the motorboard by three ¾-inch, 8-32 round head machine screws and nuts. Place a rubber washer on each screw between the motor and motorboard and also between the underside of the motorboard and the metal washer which is slipped over the screw before placing on the nut.

The rubber-covered power cord passes through a ⅜-inch hole in the motorboard. The ends of the two wires are soldered to a tie point fastened to the inside of the cabinet.



THE PLAYER CABINET ASSEMBLED

The letters identify the parts with those in the preceding drawings.

WOODEN PARTS REQUIRED FOR BUILDING THE CABINET FOR THE RECORD PLAYER

1 Piece plywood 14½ in. x 12⅞ in. x ⅜ in. (H)
1 Piece plywood 14⅞ in. x 13⅝ in. x ⅜ in. (G)
1 Piece plywood 13⅝ in. x 8⅛ in. x ⅜ in. (K)
1 Piece plywood 18½ in. x 13⅝ in. x ⅜ in. (A)
2 Pieces plywood 18½ in. x 8⅛ in. x ⅜ in. (B)
1 Piece plywood 12⅞ in. x 3⅜ in. x ⅜ in. (J)
2 Pieces plywood 14½ in. x 3½ in. x ⅜ in. (C)
1 Piece plywood 13⅝ in. x 4⅜ in. x ⅜ in. (D)
1 Piece plywood 13⅝ in. x 4⅝ in. x ⅜ in. (E)
1 Piece plywood 13⅝ in. x 4½ in. x ⅜ in. (F)
4 Pieces white pine 3⅞ in. x ¾ in. x ¾ in. (L)
2 Pieces white pine 7⅜ in. x 1 in. x ¾ in. (M)

NECESSARY HARDWARE

1 Pair of suitcase catches (9)
2 2-in. brass butt hinges
1 Suitcase handle (10)
⅜-in. screws for above fittings
6 Oval head, nickel-plated, No. 7 wood screws 1-inch long (12)
6 Nickel-plated brass cup washers (12)
1 Piece grille cloth 12 in. x 3½ in.
1 Piece grille cloth 8 in. x 7 in.
1-inch wire finishing nails, glue, white shellac, furniture varnish, No. 0 steel wool, powdered pumice, plastic wood, finishing paper.

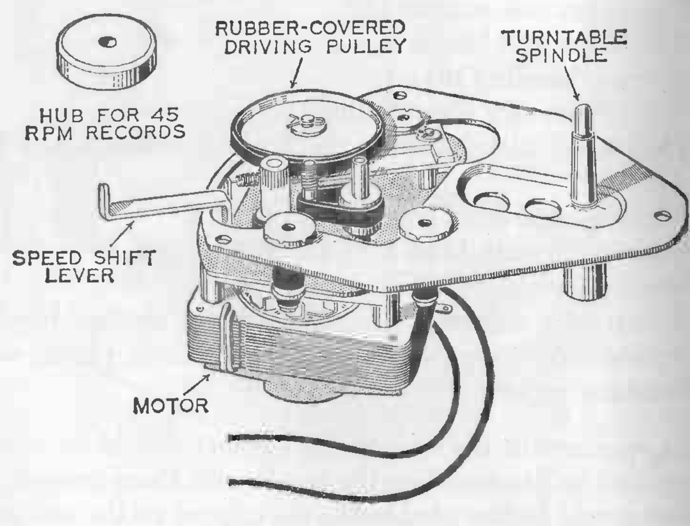
The openings in the ends of the cabinet should be covered with grille cloth fastened on the inside with Duco cement. The speaker should be mounted inside the cabinet on the end which has the double opening (left-hand). Use four machine screws with a lock washer and nut on the inside end of each.

INSTALLING THE TWO-STAGE AMPLIFIER DESCRIBED IN CHAPTER NINE IN THE PLAYER CABINET

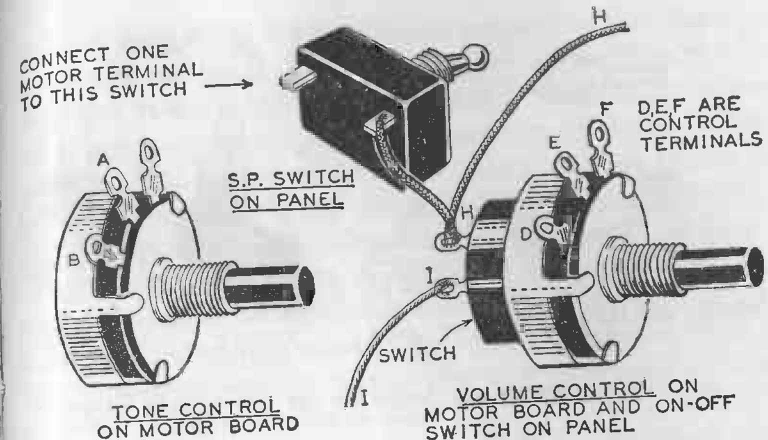
When the player cabinet is finished and the amplifier wiring completed, install the amplifier inside the cabinet. Fasten it to the base at the right of the motor.

The volume control (12) and the tone control (13) are mounted on the underside of the motorboard in the right-hand forward corner. The shafts project through the motorboard so that the knobs which turn the controls are accessible above the top surface. The only components mounted on the AMPLIFIER panel are the two phono jacks.

Terminals A and B on the tie point on the amplifier base should be connected to the center terminal and to one outside terminal on the volume control. Terminals F, D, and E on the



THE PHONOGRAPH MOTOR



THE VOLUME CONTROL AND TONE CONTROL ARE MOUNTED ON THE UNDERSIDE OF THE MOTORBOARD

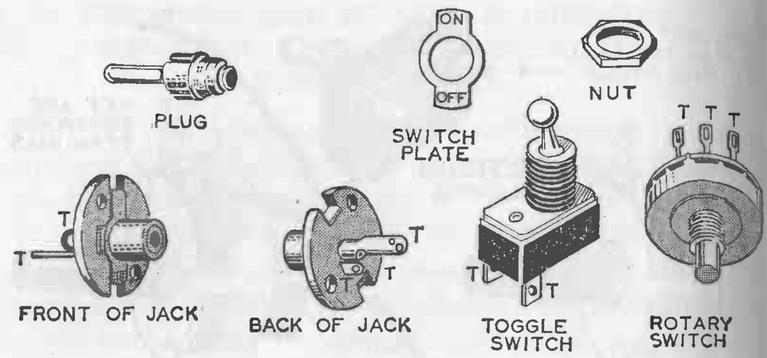
The letters which identify the terminals and wires correspond to the lettering used on the amplifier plans. For example, terminals A and B should be connected to terminals A and B on the amplifier.

tie point on the amplifier base are connected to the volume control on the motorboard.

A double-pole, double-throw rotary switch or a toggle switch if preferred, a single-pole, on-off toggle switch, and a phono jack are mounted on the back of the PLAYER cabinet panel.

Connect lug H to one terminal of the switch on volume control and to one terminal of toggle switch on panel. Connect lug I to the other terminal of the switch on control. Connect the second terminal of the toggle switch on cabinet panel to one of the motor terminals. Connect the other motor terminal to G.

The single-pole toggle switch on the cabinet panel is connected in series with the power supply so that it will serve as an ON-OFF switch for both the motor and the amplifier.

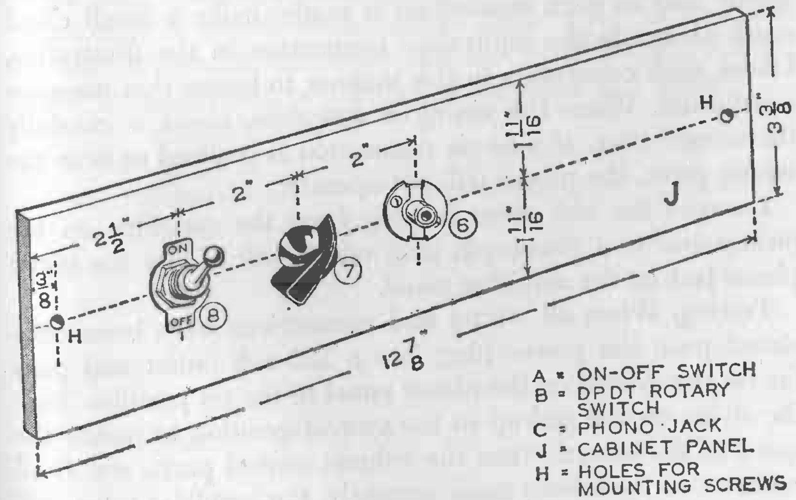


COMPONENTS WHICH ARE MOUNTED ON THE PLAYER PANEL

The 50L6 output transformer should be fastened to the bottom of the cabinet near the amplifier. A 50L6 output transformer usually has three primary wires. Only two are connected to this amplifier. Usually, one of the wires is dark brown, one is green, and one is white. The white wire is the center tap, connected to the center of the primary winding. Use only the brown and green terminal wires. Connect them to a short piece of shielded phono wire. Connect one terminal to the wire and the other terminal to the shield. The shield or shielding is a layer of bare wire or "armor" woven on the outside of phono wire which prevents the currents in the phono wire from being influenced or distorted by currents in neighboring wires. Connect a phono plug to the opposite end of the shield and wire. The phono wire should be long enough to reach from the transformer to the OUTPUT jack on the amplifier panel.

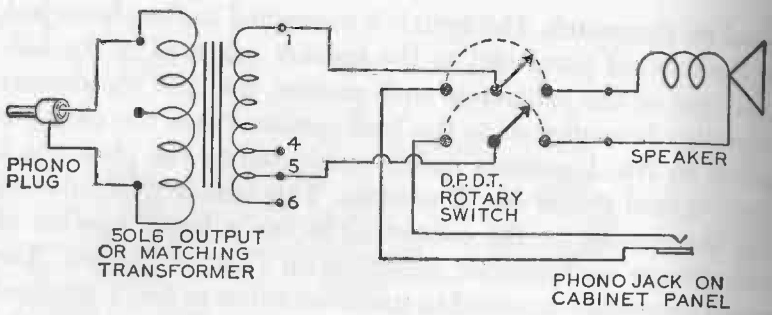
The secondary winding of a 50L6 output transformer has six metal terminals. They are numbered 1 to 6. The No. 1 terminal should be connected to one of the center terminals on the double-pole, double-throw rotary switch or double-pole, double-throw toggle switch mounted on the cabinet panel. One of the other secondary terminals is connected to the other center ter-

minal on the switch. The switch is connected to the phono jack on the cabinet panel and to the speaker mounted in the left-hand end of the cabinet in such manner that the transformer secondary is connected to the loud-speaker when the switch is turned to No. 1 position and is connected to the phono jack when turned to the No. 2 position. This makes it possible to play the speaker in the cabinet or to use a larger speaker of wider range such as that described in Chapter Eleven. The proper secondary terminal to use in addition to No. 1 terminal is selected by testing when the amplifier is connected to the built-in speaker and the record player is in operation. It will probably prove to be No. 4, 5, or 6, depending upon the impedance of the voice coil in the speaker. The terminal which gives the best tone is the "match" for the speaker and is the one to which the wire should be permanently connected.



THE FRONT OF THE PLAYER PANEL

The correct positions of the two switches and the jack are shown.



CIRCUIT DIAGRAM FOR CONNECTING COMPONENTS ON PLAYER PANEL (OR CABINET PANEL) TO THE OUTPUT TRANSFORMER AND SPEAKER

There is plenty of opportunity for errors in wiring the record player but the correct hookup is not difficult if you follow the schematic circuit and the plan drawings carefully. Have a pencil handy 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. When the wiring is complete, check it carefully the second time. If a single connection is omitted or is in the wrong place, the player will not operate.

Connect the two wires leading from the cartridge on the pickup arm to a phono pin plug which will fit into the INPUT phono jack on the amplifier panel.

Testing. When all wiring and connections have been completed push the power plug into a 120-volt outlet and push the ON-OFF switch on the player panel to the ON position. Turn the stylus on the pickup to the correct position to match the speed of the record. Turn the volume control partly ON. If all connections have been made correctly, the amplifier tubes will warm up and the turntable will spin. Place a record on the turntable and set the speed control lever to the correct speed. Turn the double-pole, double-throw switch on the cabinet panel so

that the output transformer is connected to the speaker. Place the stylus in position on the record. The music of the recording should come forth from the speaker. Use the volume and tone control to regulate the sound.

If no sound comes out of the speaker, check all connections. If no fault can be found in the wiring, pull out the phono plug connected to the cartridge on the pickup. Connect a pair of 2000-ohm headphones to the terminals of the cartridge while the record is playing. The sound of the record playing should be heard in the receivers. If not, there is a fault in the pickup or the connections to it.

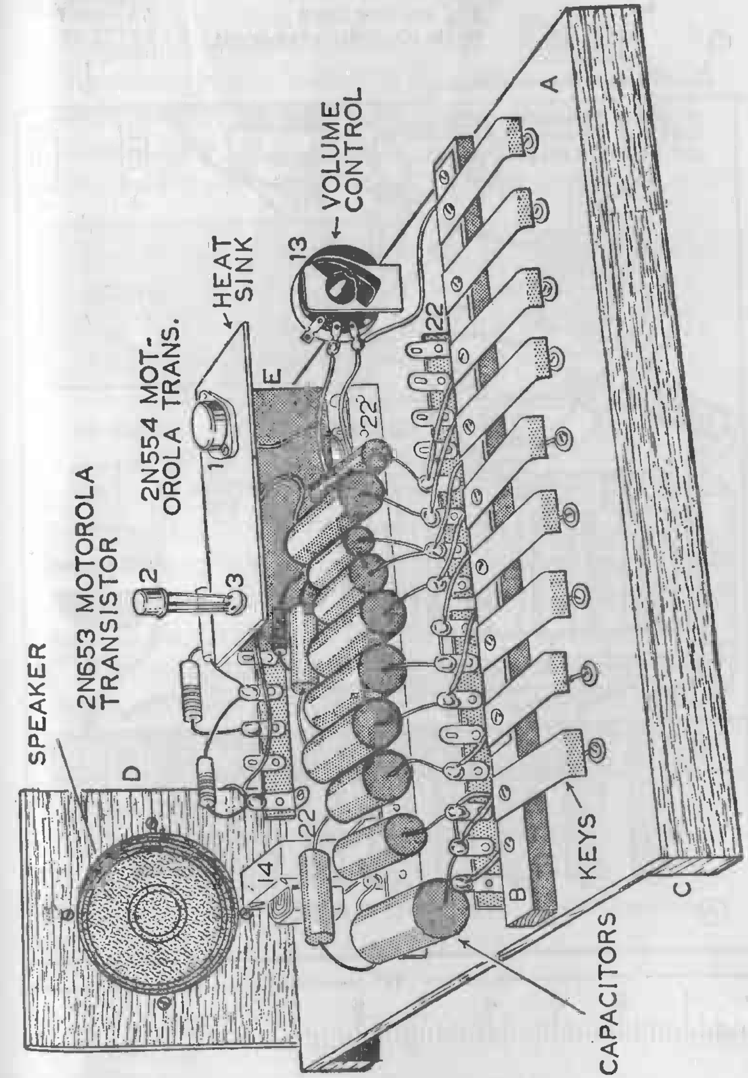
If the player operates but the sound is disagreeable, adjust the volume and tone controls. If an objectionable noise is still present connect a 0.01 mfd. bypass capacitor to the center terminal on the input jack and to the ground. The center terminal on the jack is the one that makes contact with the pin on a phono plug when it is pushed into place. This capacitor and its connections are shown by dotted lines in two of the illustrations. Remember that noise can also be caused by a worn record, a worn stylus, or a damaged cartridge and stylus.

Chapter Eleven

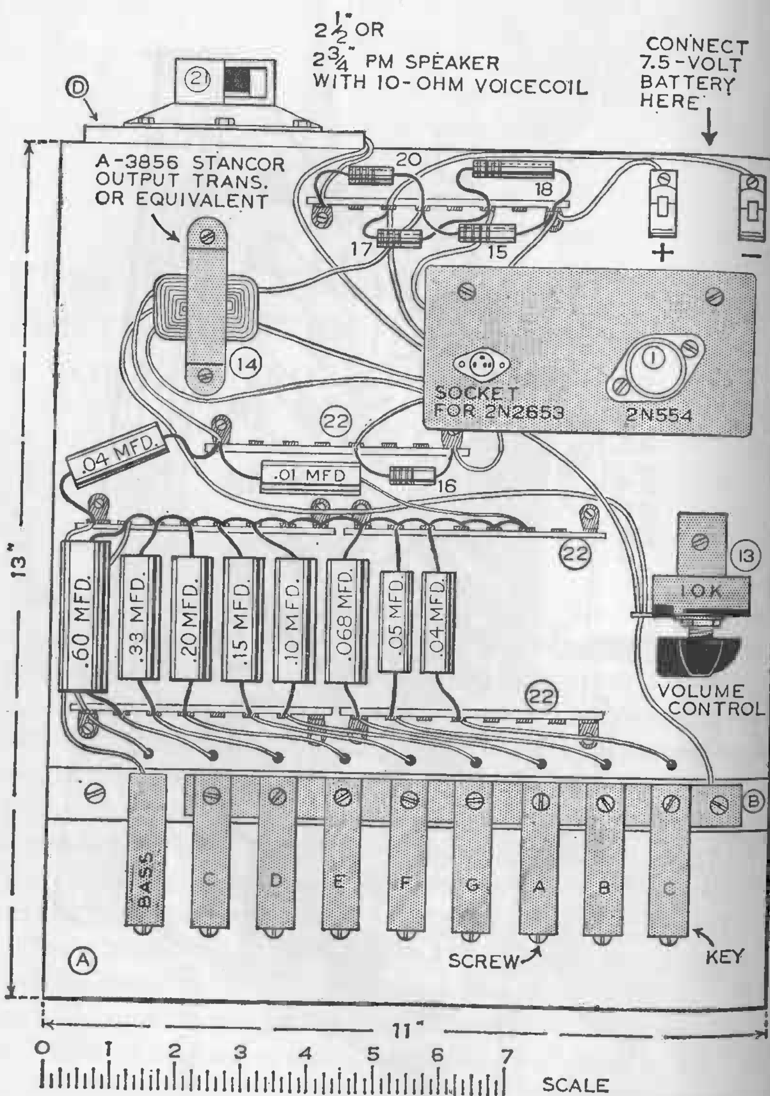
MUSIC FROM TRANSISTORS—THE CONSTRUCTION OF A TOY ELECTRONIC ORGAN

When the schematic circuit diagram for the toy electronic organ is examined it may seem rather complicated at first glance. A more careful examination will reveal that it is a simple transistor audio oscillator tuned to oscillate over one octave (8 notes) of the musical scale from middle C. The tuning necessary to produce the different notes is accomplished with tubular paper capacitors connected to nine homemade switches serving as organ "keys." The ninth key (at the far left and marked BASS) lowers all eight notes in the scale by approximately one octave when pressed.

The transistor in the oscillator circuit may be a Motorola 2N653, 2N654, or 2N655 general-purpose audio transistor. The audio-frequency currents generated in the oscillator circuit are fed into an audio-frequency amplifier employing a Motorola 2N554 transistor. The output of the amplifier is connected to a small loud-speaker. The amplifier output is approximately ¼ watt. This is sufficient power to produce ample sound volume in a toy organ.



THE TOY ELECTRONIC ORGAN



PLAN OF THE ELECTRONIC ORGAN

PARTS AND MATERIALS NEEDED TO CONSTRUCT THE TOY ORGAN

1 Plywood base 13 in. x 11 in. x ¼ in. (A)
1 Plywood speaker baffle 5½ in. x 4¼ in. x ¼ in. (D)
2 Pine battens, 11 in. x ¾ in. x ⅝ in. (C)
1 Pine bolster 11 in. x ¾ in. x ¼ in. (B)
1 Piece of sheet copper, aluminum or brass 5 in. x 2½ in. for heat sink
1 Piece of spring brass sheet 8½ in. x 2½ in. for making keys and bus bar
1 Heat sink support 4¾ in. x 1½ in. x ¾ in. (E)
1 Motorola 2N554 power transistor (1)
1 MK-15 Motorola power transistor mounting kit
1 Motorola 2N653 transistor (2)
1 Socket for 2N653 transistor (3)
1 0.60 mfd. 200 V.D.C. tubular paper capacitor (4)
1 0.33 mfd. 200 V.D.C. tubular paper capacitor (5)
1 0.20 mfd. 200 V.D.C. tubular paper capacitor (6)
1 0.15 mfd. 200 V.D.C. tubular paper capacitor (7)
1 0.10 mfd. 200 V.D.C. tubular paper capacitor (8)
1 0.068 mfd. 200 V.D.C. tubular paper capacitor (9)
1 0.05 mfd. 200 V.D.C. tubular paper capacitor (10)
2 0.04 mfd. 200 V.D.C. tubular paper capacitors (11)
1 0.01 mfd. 200 V.D.C. tubular paper capacitor (12)
1 10,000-ohm, 2-watt volume control (13) with "L" shaped mounting bracket and knob
1 Triad T42X or one Chicago Standard Transformer Corporation's No. A-3856 Universal output transformer (14)
1 22-ohm, 1-watt carbon resistor (15)
1 15,000-ohm, 1-watt carbon resistor (16)
1 3,300-ohm, 1-watt carbon resistor (17)
1 1,000-ohm, 1-watt carbon resistor (18)
1 8,200-ohm, 1-watt carbon resistor (20)
1 2½ in. or 2¾ inch PM speaker with 10-ohm voice coil (21)
6 8-terminal solder lug strips or tie points (22)

4 ⅜-in., 6-32 round head machine screws with hex nuts
2 binding posts or Fahnestock connectors
5 size C or D flashlight cells or other source of 7.5 volts
9 solder lug terminals for No. 6 screws
12 ½-in., No. 6 round head brass screws
28 ⅜-in., No. 4 round head brass screws

HOW TO IDENTIFY THE RESISTORS

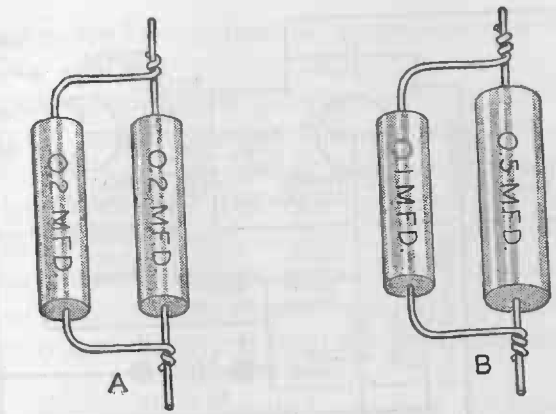
PART NO.	RESISTANCE IN OHMS	COLOR BANDS
15	22	red, red, black, silver
18	1,000	brown, black, red, silver
17	3,300	orange, orange, red, silver
20	8,200	gray, red, red, silver
16	15,000	brown, green, orange, silver

Read the following discussion of some of the parts required before purchasing them and starting to build the organ.

All of the parts, with the exception of the battery, are mounted on a ¼-inch plywood base. Two ¾-inch x ⅝-inch wood battens on the underside and flush with the front and rear edges raise the base above any surface upon which it rests and make it possible to conceal some of the wiring underneath.

The Heat Sink. In most apparatus utilizing a 2N554 medium-power transistor, means for dissipating the heat developed in the transistor is necessary. The device used is called a HEAT SINK and consists of a piece of sheet metal, metal chassis, or metal cabinet to which the base of the 2N554 can be bolted. A heat sink is hardly necessary in the construction of the toy organ but one is included in the design because it provides a simple method of mounting both transistors.

Mounting Kit. The mounting kit required for a 2N554 or equivalent medium-power transistor is described and illustrated in another section of this book. See index.

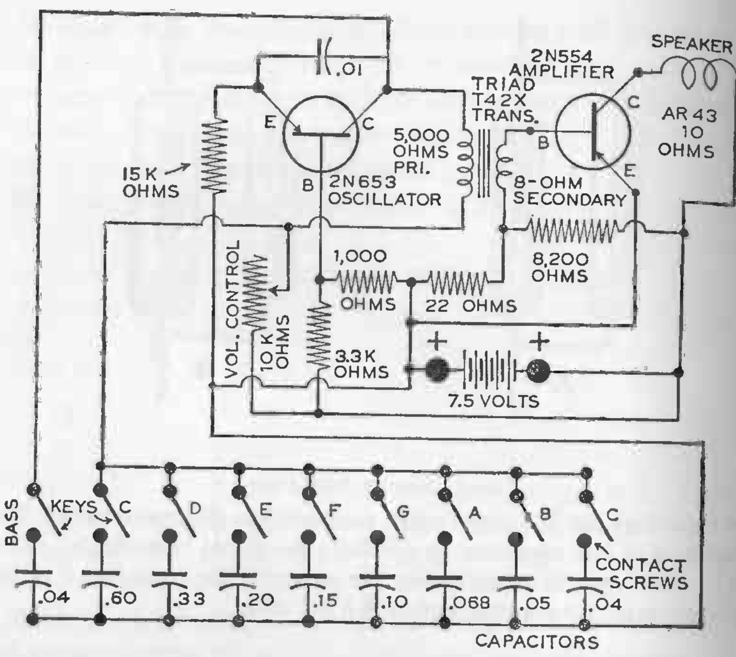


CAPACITORS IN PARALLEL

Two capacitors are in parallel when connected as illustrated above. The capacitance of two capacitors in parallel (also called in multiple) is the sum of their separate capacitances. For example, the capacitance of the combination at A is 0.4 mfd. and at B is 0.6 mfd.

Tubular Paper Capacitors. The dielectric strength of the capacitors in the list of parts and materials is specified as 200 volts D.C. In order to obtain the capacitances named it may be necessary to accept some with dielectric which will withstand 400 or 600 volts. Capacitors of 0.60 mfd. and 0.04 mfd. capacitance are not listed in the catalogs of stock tubular paper capacitors. It is necessary to buy an 0.5 mfd. and an 0.1 mfd. capacitor and connect the two in parallel. To obtain 0.04 mfd. capacitance, connect two 0.02 mfd. capacitors in parallel.

The Loud-speaker. Small loud-speakers usually have a voice coil impedance of 3 to 5 ohms. A speaker with more than 4- to 5-ohm impedance will give better results with the toy organ; 2½-inch speakers with 10-ohm voice coils are standard and one having this impedance should be selected. An AR-43, 10-ohm, 0.25-watt speaker will fulfill all requirements.



SCHEMATIC CIRCUIT DIAGRAM OF TOY ELECTRONIC ORGAN

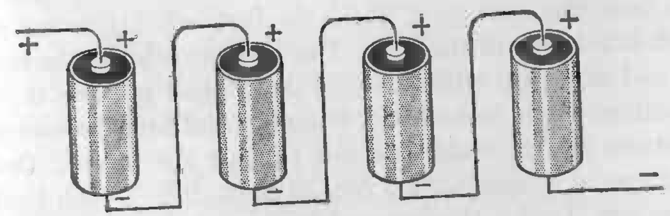
The speaker is mounted on a 5½-inch x 4¼-inch x ¼-inch baffle attached to the back of the base at the rear left-hand corner. The baffle has a 2½-inch or 2¾-inch circular hole depending upon the size of the speaker. The speaker is mounted on the back surface of the baffle.

Transformer. The audio oscillator circuit should be coupled to the amplifier by a transformer which has a 5,000-ohm primary and an 8- to 10-ohm secondary. The primary of the transformer is made part of the oscillator circuit. The secondary is connected to the 2N554 transistor and speaker voice coil. A Triad T42X or a Stancor No. A3856 Universal output transformer made by the Chicago Standard Transformer Corporation is recommended. Whichever transformer is used, it should

be fastened to the base in front of the speaker with two round head screws.

The Stancor Transformer has three primary terminal wires marked P, CT, and P. They are blue, red, and brown. The red wire (CT) is a center tap; that is, it is connected to the center of the primary winding. The blue and brown wires are connected to the first and last turns of the primary. The secondary has six small tinned terminals marked 1, 2, 3, 4, 5, and 6. When assembling and connecting the parts of the organ do not solder any wires to the transformer until the following test has been made:

Connect secondary terminals 1 and 6 on the transformer to the 2N554 transistor and 8,200-ohm resistor as shown in the circuit diagram. Connect the blue and brown (outside) terminals of the transformer primary to the 2N653 transistor and the 100,000-ohm volume control as indicated in the circuit diagram. When all other connections have been made and a 7.5-volt dry battery has been connected to the battery terminals, press the keys one at a time. Then change the transformer con-



FOUR FLASHLIGHT CELLS IN SERIES

The brass cap in the center of the top of a flashlight cell is the positive or + terminal. The bottom of the cell is the negative terminal. When four cells are in series, a wire from the negative terminal of the first cell is connected to the positive terminal of the second. Another wire from the negative of the second cell is connected to the positive of the third cell. A third wire, connected to the negative of the third cell, is connected to the positive of the fourth cell.

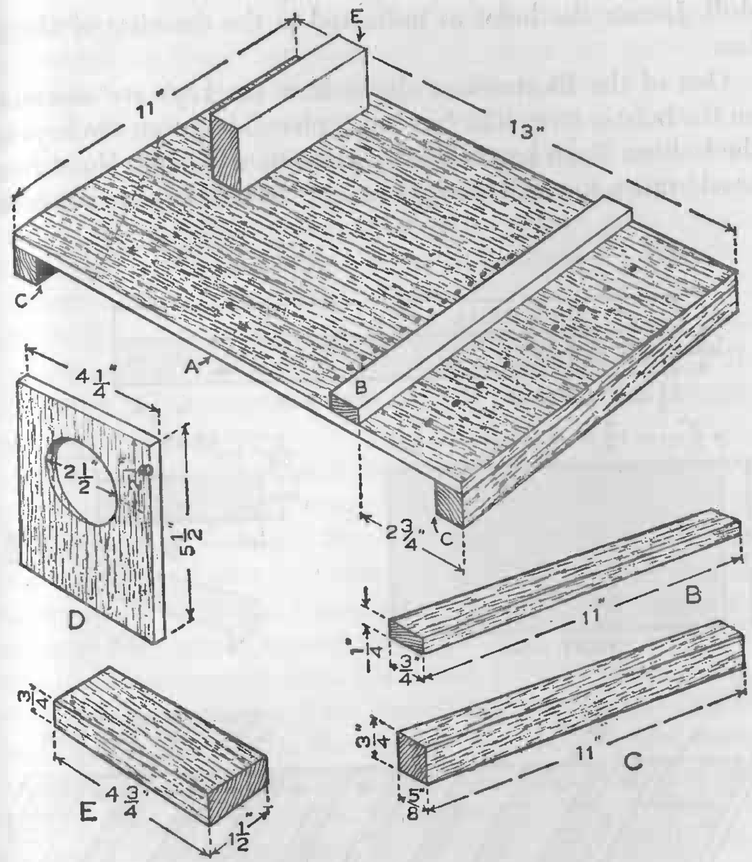
nections by disconnecting one of the primary wires and substituting the red center tap for it. Press the keys one at a time and note any difference in the performance of the organ produced by the change in connections. Probably the first method will prove to be better than the second. Solder the connections which produce the best results.

Construction of the organ is begun by making the wood and metal parts which are required. These are all illustrated by dimensioned sketches and should not offer any problem.

Wood parts should be given a coat of white shellac to seal them against moisture and prevent warping. The battens (C and C) are fastened to the underside of the base (A) and flush with the front and back edges. The bolster strip (B) which supports the bus bar and one end of all the organ keys should be fastened across the upper surface of the base 2¾ inches back from the front edge. Use small wire nails to fasten the battens (C and C), the speaker baffle (D), and the heat sink support (E). Fasten the bolster strip (B) to the base with two round head brass screws. Locate the screws near the end of the bolster but not in contact with the bus bar.

Make 9 small holes, 1 inch apart, in a row in the base 1⅛ inches from the front edge. Make the first hole 1½ inches from the left-hand side of the base. The holes can be made with a small awl or drilled with a No. 50 drill. Their purpose is to fix the location of the ½-inch No. 6 round head brass screws used as contacts and to make it easier to start the screws. Drill a second row of 9 holes with a No. 36 twist drill ¾ inch back of the first row. Drill a third row of fourteen holes with a No. 36 twist drill ½ inch apart and ½ inch from the rear edge of the bolster strip. The holes made with the No. 36 drill are for the wires which connect the contact screws with the capacitors.

The Keys. The keys are a simple form of switch made from 2½-inch x ⅝-inch spring brass strip .008 inch to .010 inch thick. The strips are cut to size with a pair of snips from a piece of sheet brass. Bend each strip at right angles 5⁄16 inch

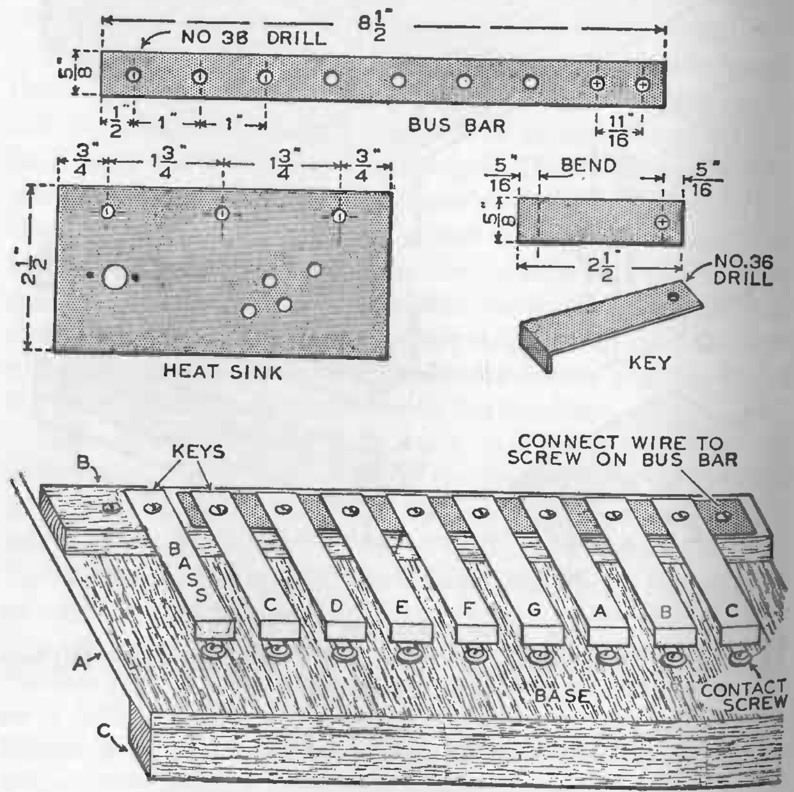


THE WOOD PARTS FOR THE ORGAN

(A) base; (B) bolster strip; (C) battens; (D) baffle for speaker; (E) support for heat sink.

back from one end. Drill a hole with a No. 34 twist drill in each strip 5⁄16 inch in from the opposite end. (See illustration.) The bus bar is a piece of copper or brass sheet ⅝ inch wide and 8½ inches long. Drill nine holes in the strip with a No. 34 twist drill. Locate the holes as indicated in the drawing of the bus bar.

One of the illustrations shows how the keys are assembled on the bolster strip. The bus bar is placed between the keys and the bolster. Each key is held in place by a ⅜-inch, No. 4 round head brass screw. All the keys except the bass key are connected



DETAILS OF THE BUS BAR, HEAT SINK, AND KEYS
The bottom sketch shows how the keys are mounted.

together by the bus bar. Notice that the bus bar does not extend far enough to touch the bass key. A solder lug terminal is placed under the head of each of the No. 6 round head brass screws which form the contacts. The keys are adjusted by bending so that the edge of the bent-over end of each key is about 3/16 inch above the contact screw unless pressed down by a finger. When pressed, the lower edge should make contact with its corresponding screw. A piece of insulated wire about 5 inches long is connected to each solder lug terminal. The wire is then pushed through the nearest hole, passed under the base and up through a hole back of the bolster where it is connected to the capacitor which will produce the note corresponding to that key.

When all parts have been assembled on the base and connected, check the wiring to see that it is in accordance with the circuit diagram. Connect five dry cells in series so that they form a 7.5-volt battery. Connect the positive terminal to the battery to the left-hand Fahnestock clip in the rear right-hand corner of the organ. Connect the negative of the battery to the right-hand Fahnestock clip. Place the 2N653 transistor in its socket on the heat sink. Turn the volume control to a halfway position and press one of the keys. If the assembly and hookup are correct, a pure musical note should come from the loudspeaker. Only one key should be pressed at a time with the exception of the left-hand BASS key. Pressing the BASS key when any one of the other eight keys are pressed at the same time will lower the pitch of the note one octave.

The battery should be disconnected when the organ is not in use.

The organ will not give exactly correct pitch for each note because of variations and inaccuracies in the capacitors. Anyone who wishes to take the trouble could, by the use of trimmer capacitors, adjust the capacitance so that each circuit would produce true pitch.

Chapter Twelve

A HIGH-FIDELITY SOUND SYSTEM

What is High Fidelity? For the past few years "high fidelity" has played an increasing role in home entertainment. The ordinary phonograph produces enjoyable music but electronic improvements in making recordings, amplifiers and in speakers and their enclosures, popularly called hi-fi (short for high fidelity), give range and depth to music reproduction not formerly obtainable. In few words, hi-fi is the reproduction of music as it was originally played; nothing is lost, nothing is added. There is nothing to destroy the illusion that the artist or orchestra is in your living room.

Sound. Sound, insofar as the human ear is concerned, consists of air waves at frequencies of 18 to 20,000 cycles per second. Persons with defective hearing and older persons do not hear all frequencies in this range. Many older persons cannot hear frequencies above 10,000 to 12,000 cycles per second.

Harmonics. Each tone of the human voice and note of a musical instrument consists of a fundamental tone and a number of following overtones called HARMONICS. The harmonics have frequencies which are multiples of the fundamental tones. They are responsible for the quality or timbre of sounds. Without these harmonics, a note played on one type of instrument would sound exactly like the same note produced on any other type of instrument. A bass viol and a tin whistle would sound alike without harmonics.

The frequency of the fundamental notes of an orchestra may range from 25 to 5,000 per second but the frequency of the harmonics are often as high as three or four times the frequency of the fundamentals.

To reproduce music with high fidelity an amplifier and loudspeaker system must have a frequency range of about 20 to 20,000 cycles per second and provide equal amplification for both the fundamental and harmonic frequencies.

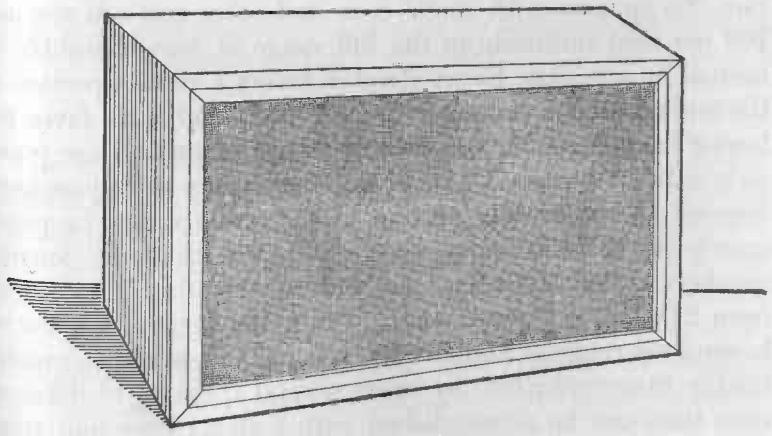
The basic components of a high-fidelity system are:

1. a high-fidelity amplifier
2. a record player
3. a first-class pickup cartridge
4. a speaker and enclosure

To this can be added when you can afford it:

1. an FM radio tuner
2. a TV tuner
3. a tape recorder

For the average room, or in an apartment where music at "orchestra level" might annoy neighbors, a 5-watt amplifier is



BOOKSHELF BASS REFLEX SPEAKER

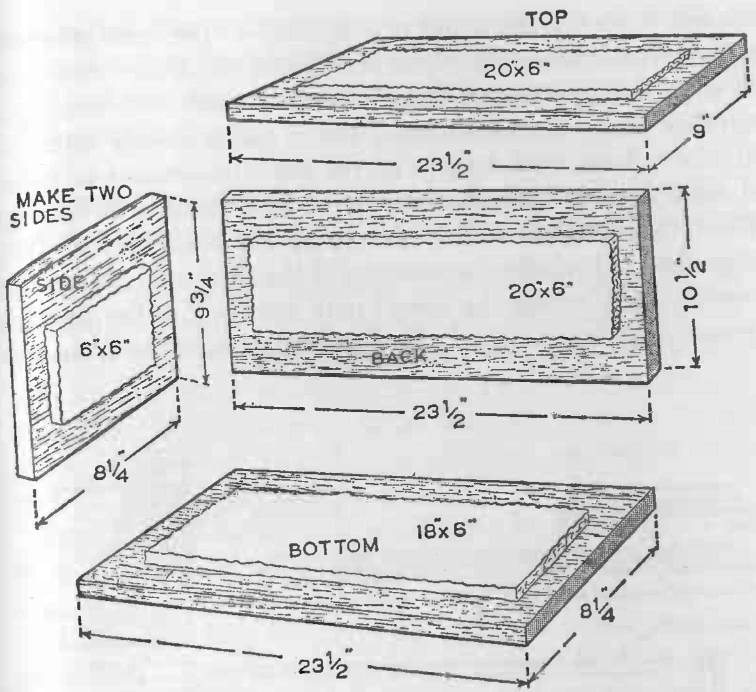
adequate. An amplifier with a power of 10 watts or more may be required for carpeted and heavily draped larger rooms.

A HIGH-FIDELITY 5-WATT SOUND SYSTEM

The 5-watt high-fidelity amplifier descriped in Chapter Nine and the bass reflex speaker described in this chapter can be combined to form a first-class hi-fi sound system for reproducing the music of phonograph records, tapes, and FM radio programs. The quality of reproduction is faithful enough to satisfy anyone but those who would have you believe their ears are superior to yours.

An ideal sound system for reproducing music consists of an amplifier with power enough to operate at least three different sizes of loud-speaker. Forty watts power is desirable when several speakers are operated by the amplifier. Such an installation costs from one hundred to several hundred dollars. The 5-watt high-fidelity amplifier and the bass reflex speaker can be built at a total cost of thirty dollars for parts and materials.

When a speaker is chosen for a particular purpose, its size and the method of mounting must be given careful consideration. No speaker with single cone and voice coil can respond 100 per cent faithfully to the full range of sounds audible to normal human ears. Every speaker favors a certain portion of the audio range. Speakers with an 8- to 12-inch cone favor the lowest frequencies in the audible sound range and are popularly called "woofers." The 6- to 8-inch cones or "squawkers" respond to the middle portion of the audio range (approximately 500 to 6,000 cycles per second) most efficiently. Smaller speakers, called "tweeters," respond most faithfully to sounds from 2,000 cycles per second up into the higher frequencies beyond the range of human ears. It is possible to obtain greater fidelity in reproduction by using several speakers of different sizes than can be accomplished with a single cone and voice coil.

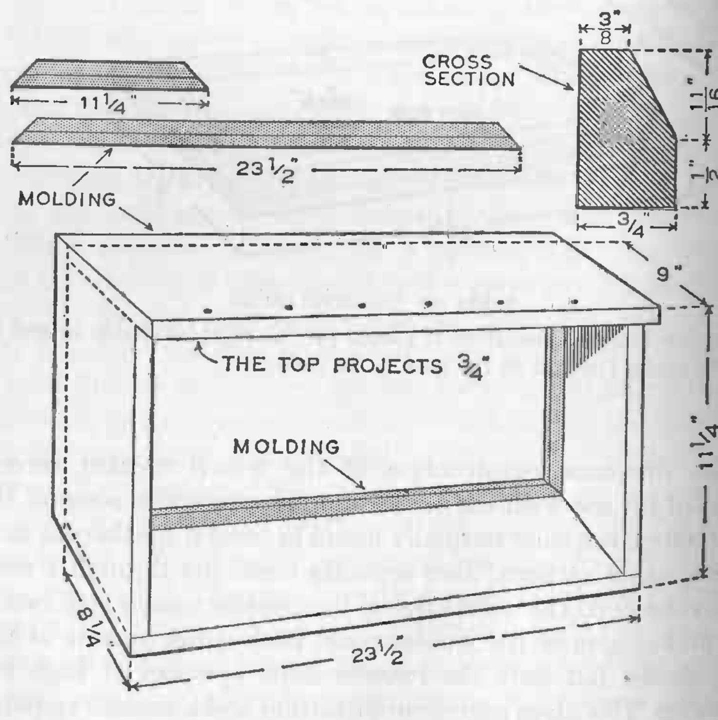


PARTS OF THE ENCLOSURE

Note: No acoustic insulation is placed on the right-hand side or end of the enclosure (nearest to the port in the baffle).

The duo-cone construction of the 8-inch speaker recommended for use with the 5-watt amplifier provides some of the wide-range response normally found in coaxial speakers or multiple speaker systems. Two separate cones act through a common voice coil. The outer edge of the tweeter cone is attached to the mid-section of the woofer cone. Both cones operate at low frequencies but only the tweeter cone operates at high frequencies. This gives minimum distortion and a smooth response over a range of 40 to 16,000 cycles per second.

No speaker can give faithful reproduction unless it is properly mounted. Both the front and rear surfaces of the cone generate sound waves. The sound waves from the back of the cone may mix with those from the front and alternately reinforce and neutralize them. This unwanted action can seriously interfere with the volume and fidelity of the low frequencies of voice and music. It can be remedied by use of a BAFFLE. A speaker baffle is a partition, a flat surface or an open-backed box, designed so as to delay the meeting of the front and rear sound waves by lengthening the sound path over which the rear set of waves must travel. The baffle does not prevent the front and



THE ENCLOSURE PARTLY ASSEMBLED

The back and the baffle board which supports the speaker are not in place.

rear waves from mixing it; it CHANGES THE TIME of their meeting so that they do not interfere with each other. In many radio and television receivers, the baffle arrangement is part of the receiver cabinet.

HOW TO BUILD A BASS REFLEX ENCLOSURE FOR A 6-INCH OR 8-INCH DUO-CONE HI-FI SPEAKER

The cabinet or enclosure is the bookshelf type but the design is versatile enough to be used in more ways than one. For example, it can be placed in a horizontal position in or on a bookshelf or stood vertically on the floor. The enclosure is a rectangular box measuring 22 inches x 9¾ inches x 7½ inches inside. It is made of ¾-inch thick plywood, preferably furniture grade if finish is important.

Expensive woodworking equipment is not needed to construct the enclosure. The wood parts can be made with a hand saw, fret saw, drill, and plane. A screwdriver and a hammer are used in assembling the parts. If an 8-inch power circular saw fitted with a smooth cutting hollow-ground blade is available, it will save the labor of hand sawing and cut the pieces more accurately than can be done with a hand saw. Perhaps an amateur craftsman in your neighborhood who has a home workshop equipped with a circular saw will do this work for you. Other possible sources of aid are the school manual training shop and the local planing mill.

WOOD PARTS REQUIRED

1 Bottom 23½ in. x 8¼ in. x ¾ in.
1 Top 23½ in. x 9 in. x ¾ in.
1 Back 23½ in. x 10 ½ in. x ¾ in.
2 Sides 9¾ in. x 8¼ in. x ¾ in.
1 Baffle 21¹⁵⁄₁₆ in. x 9¹¹⁄₁₆ in. x ¾ in.
2 Pieces of molding 23½ in. x ¾ in. x 1³⁄₁₆ in.
2 Pieces of molding 11¼ in. x ¾ in. x 1³⁄₁₆ in.

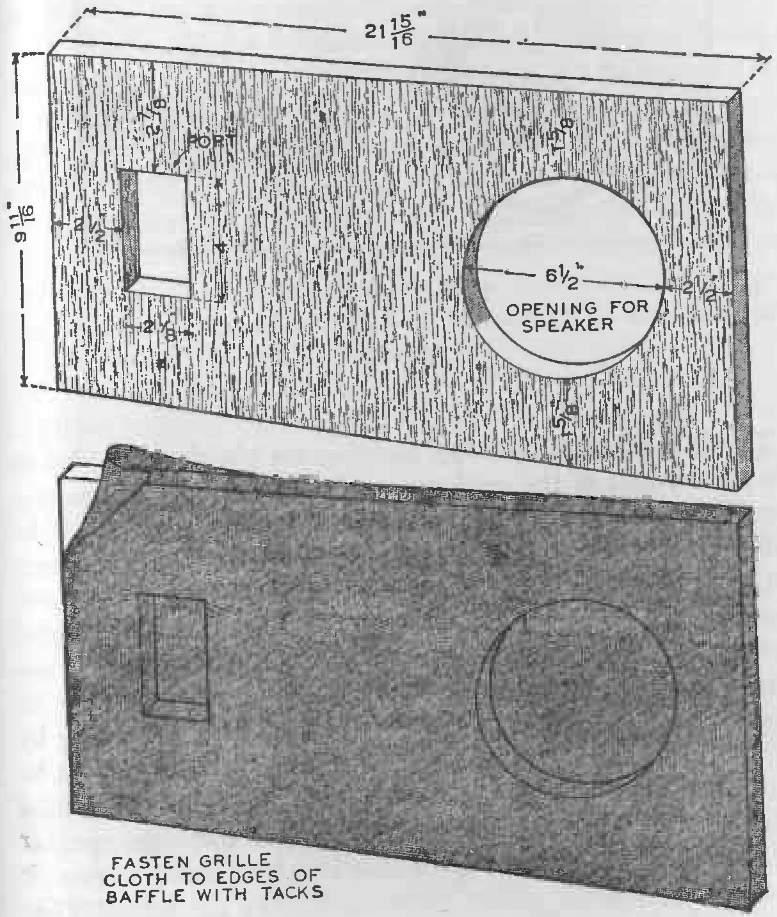
OTHER PARTS AND MATERIALS NECESSARY

1 Lafayette 8-in. duo-cone hi-fi speaker
1 Piece of grille cloth 18 in. x 24 in.
6 Feet double conductor line cord (parallel wires)
2 Pieces Tufflex fiber glass insulation 20 in. x 6 in. x ½ in.
1 Piece of Tufflex fiber glass insulation 18 in. x 6 in. x ½ in.
1 Piece Tufflex fiber glass insulation 6 in. x 6 in. x ½ in.
1¼-in., No. 7 flat head wood screws, double pointed tacks, wood stain, shellac, varnish

Grille Cloth. A dozen patterns and colors of grille cloth are listed in some of the catalogs of radio supplies. Choose a color which will harmonize with the finish applied to the enclosure and the general décor of the room where the speaker is to be located. Grille cloth is sold in pieces 36 inches x 36 inches and 24 inches x 18 inches. The smaller piece is sufficient.

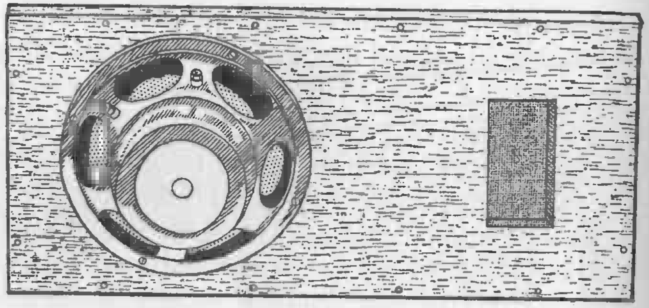
Acoustic Insulation. All inside surfaces of the enclosure except the end next to the port are partly covered with sound-absorbing material called Tufflex. This is sold in 11-inch widths and in two thicknesses, ½ inch and 1 inch. Use the ½-inch thickness. Seven feet of the 11-inch material is the minimum length sold. One of the illustrations shows the size of the Tufflex panels to be attached to the inside of the enclosure. Tufflex can be cut with a large pair of scissors. It is fastened to the enclosure by a few double-pointed tacks. The effect of the Tufflex is to damp medium- and high-frequency reverberation and distortion.

Assembling. One of the illustrations shows how the enclosure is assembled. The sides are placed between the top and bottom flush with the ends of the latter. The joints are glued. The enclosure is held together by several finishing nails while the glue is drying. Before the enclosure is stained and varnished, the heads of the nails should be driven below the surface with a nail set. The indentations above each nail head should be filled with plastic wood and the latter sanded smooth when it has dried.



THE BAFFLE

The front of the baffle is covered with grille cloth which conceals the port and the circular opening for the speaker. The speaker is fastened to the back of the baffle.



REAR OF BAFFLE

The grille cloth on the front of the baffle can be seen through the port opening.

The four mitered pieces of molding are glued and nailed to the front edges of the enclosure and when assembled make a sort of "picture frame" for the baffle. The front surface of the baffle is covered with grille cloth and pushed into the enclosure until it is snug against the molding on the front of the enclosure. The cloth is fastened to the edges of the baffle with small tacks. The baffle is made slightly smaller than the interior of the enclosure so that it will slide into place with the grill cloth on its edges. The baffle is held firmly to the back of the molding by eight 1¼-inch, No. 7 flat head wood screws. The baffle must be put in the enclosure and fastened before the Tufflex insulation is fastened to the inside surfaces. The 8-inch duo-cone speaker is fastened to the back of the baffle by three wood screws. It should be concentric with the circular hole in the baffle. When making the baffle, cut the circular speaker hole and the rectangular port the size and in the location shown in the illustration. Fasten a double-conductor cord about 6 feet long to the speaker terminals.

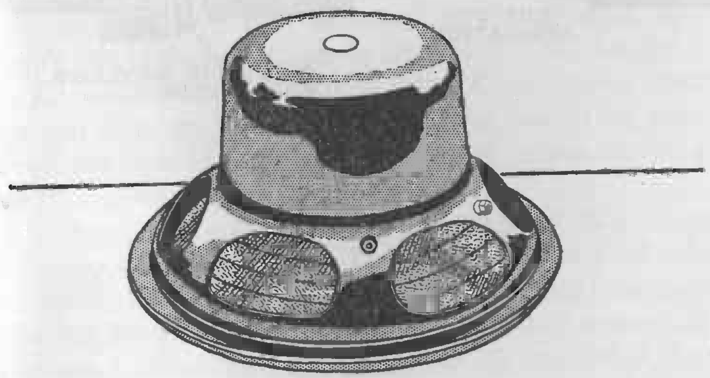
Before fastening the back of the enclosure in place drill a hole in it near the bottom edge. Tie a knot in the speaker cord which will not slip through the hole and pass the end of the

cord through. If the cord is pulled or jerked, the knot will prevent the strain from reaching the speaker terminals.

The finish for the outside of the enclosure is somewhat a matter of personal choice but it should also be suitable for the wood used. The usual method of finishing is to apply wood stain after all surfaces have been smoothed with fine sandpaper. When the stain has dried, brush on a single coat of white shellac. Rub the shellac with fine steel wool and finish with one or two coats of furniture varnish. All sandpapering and wood finishing should be completed before the baffle is put in place.

The back of the enclosure is fastened with twelve 1¼-inch, No. 7 flat head wood screws. Eight of the screws go through the back and into the edges of the sides and bottom of the enclosure. Four of the screws pass down through the projecting edge of the top and into the back.

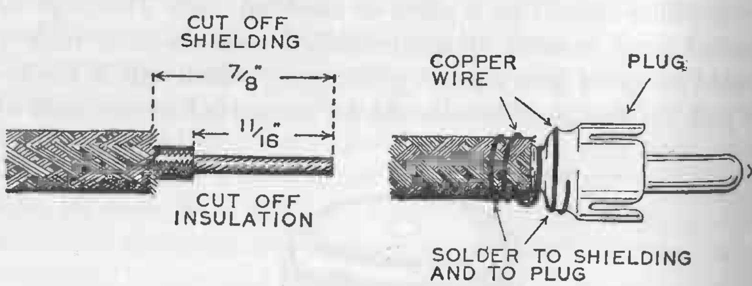
The conductor from the pickup on the player to the input on the amplifier should be a piece of shielded wire. This type of shielded wire consists of an insulated wire covered with a braided shield of bare wire. A phono-plug which will fit the input jack on the amplifier should be connected to one end of



8-INCH DUO-CONE HI-FI SPEAKER

the shielded wire. Untwist the braided shielding back about ⅞ inch on one end of the shielded wire and cut it off to expose the insulation on the inner wire as shown in one of the illustrations. Cut off about 11/16 inch of the insulation from the inner wire. Twist the stranded inner wire tight and push it into the back of the plug until it projects slightly through the end marked X in the illustration. Solder at X. Wrap a short piece of bare copper wire around the outside of the body of the plug and around the braided shielding. Solder the wire to the plug and to the shielding The shielding serves as one conductor and the insulated wire as the other. Connect the other end of the shielded wire to the player pickup, to an FM radio, however may be necessary.

A PIECE OF SHIELDED WIRE CONNECTED TO A PHONO-PLUG IS USED TO HOOK UP THE INPUT OF THE AMPLIFIER TO THE PICKUP



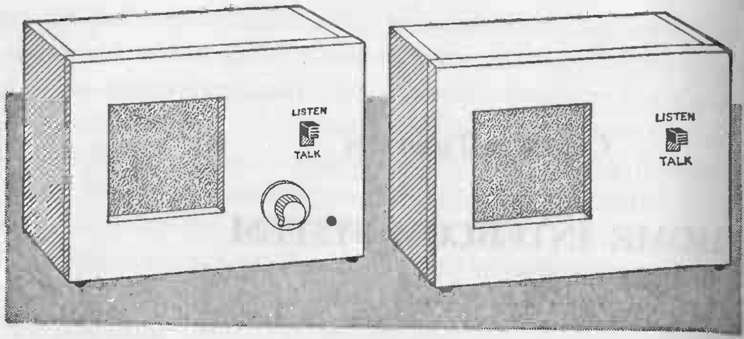
CHAPTER THIRTEEN

A HOME INTERCOM SYSTEM

A two-way "intercom" system is one of the must useful electronic devices that can be built in the home workshop. It consists of a Master station and one or more Remote stations. Each station is equipped with a permanent magnet speaker which is used also as a microphone. A two-stage, high-gain audio amplifier is located at the Master station. A Master station, installed in a convenient location, can be used to communicate with Remote stations on another floor, in the garage, basement, playroom, or backyard. A Remote unit with the switch left in the "Talk" position installed in a baby's room becomes an "electronic baby sitter." It will pick up and transmit the slightest sounds which occur in the room.

The two-way intercom described in this chapter uses the same circuit and components as the No. 83Y297 Knight Intercom Kit manufactured by Allied Radio Corporation. Specifications and sketches based on those in the Knight-kit assembly manual are printed here by courtesy and permission of Allied Radio Corporation.

It is simpler to buy the complete kit of parts than to acquire the components individually. Two ivory-finished steel cabinets (one for the Master and one for a Remote station) are included in the kit. Everything needed down to the last screw and nut is furnished. When the amplifier parts are assembled they are mounted on a steel chassis. The chassis is one of the parts



THE HOME INTERCOM

The wood cabinets are homemade. The Master station is at the left. A Remote station is at the right. Remote stations have no volume control or pilot light.

furnished in the kit. Kits for additional Remote stations are also available.

The dimensions of the chassis and of wood cabinets for both Master and Remote stations are given at the end of the chapter for those who may prefer to make some of the parts of the intercom. For example, wood cabinets with mahogany or other furniture-matching finish may be preferred to the ivory-finished metal cabinets.

HOW THE INTERCOM OPERATES

There are three basic circuits in the intercom: an audio amplifier, two or more speakers, and a switching arrangement.

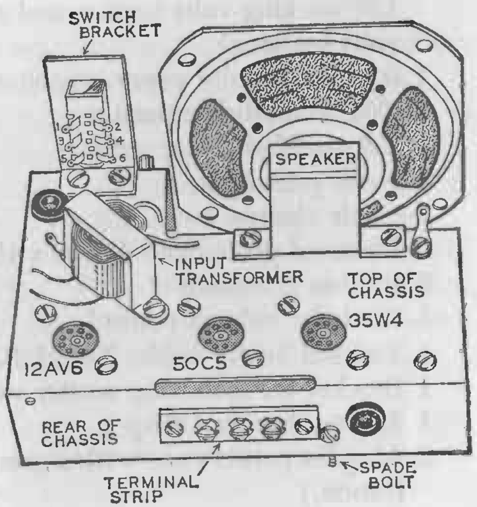
When a Master and a Remote station are used the switching station connects the two speakers to the amplifier so that they serve alternately as speaker and microphone. For example, when someone is speaking at the Master station and the Master switch is in the TALK position, the speaker at the Master station is connected to the input of the audio amplifier and operates as a microphone. When the Remote switch is in the LISTEN position the speaker at the Remote station is connected to the output of the amplifier and operates as a conventional loud-speaker. Reversing the position of the switches reverses the operation of the speakers. The speaker at the Remote station becomes a microphone connected to the input of the amplifier and the speaker at the Master station operates in its normal role of a loud-speaker.

The two stations of the intercom may be located as far as 50 feet apart using the No. 22 B.S. gauge 3-wire cable supplied in the kit of parts. Larger wire must be used if the stations are located more than 50 feet apart. The stations may be located as far as 200 feet apart if No. 18 B.S. gauge wire is used.

To assemble the kit of parts you will need only the following tools: a soldering iron, a medium-size screwdriver, a small screwdriver for set screws, a pair of long-nose pliers, and a pair of diagonal cutting pliers.

If you make the cabinets and chassis you will need also a fine-toothed saw, small plane, small hammer, tinner's snips, several

TOP PARTS MOUNTING VIEW



sizes of twist drills, center punch, files, and either a hand or an electric drill to drive the twist drills.

PARTS AND MATERIALS REQUIRED TO BUILD THE TWO-STAGE AUDIO AMPLIFIER

1 12 AV6 radio tube
1 50 C5 radio tube
1 35 W4 radio tube
3 7-pin miniature tube sockets
2 4-in. permanent magnet speakers with 2.5-ohm voice coil
1 1-megohm volume control with SPST POWER OFF switch
1 Cabinet for Master station
1 Cabinet for Remote station
1 Chassis for Master station
1 Line cord and plug
1 SPDT remote LISTEN-TALK slide switch
1 DPDT master LISTEN-TALK slide switch
1 Input transformer (Allied part No. 104200)
1 Output transformer (Allied part No. 102200)
1 Triple section tubular electrolytic capacitor (1-20 mfd., 125 working volts section and two 30 mfd., 150 working volts sections)
1 0.1 mfd. tubular paper capacitor
2 .0047 mfd. disk capacitor
1 330 mmfd. disk capacitor
1 Neon pilot light
2 Cable clamps
2 Pieces of grille cloth 4½ in. x 4½ in.
2 Rubber grommets
1 Knob for volume control
1 Twisted 3-wire cable, No. 22 B.S. gauge or larger
1 Bracket for mounting master switch
1 3-screw terminal strip
2 4-lug tie points (one with a grounded terminal. See illustration.)

1 4-in. length of large spaghetti
1 24-in. length of small spaghetti
1 36-in. length of rosin-core solder
4 Solder lugs
24 ¼-in., 6-32 round head machine screws
2 5/16-in., 6-32 flat head machine screws
8 ½-in., 6-32 flat head machine screws
36 ¼-in. 6-32 hex nuts
4 No. 4 self tapping flat head screws
1 5-in. length shielded phono cable
1 12-in. length No. 20 or No. 22 bare copper wire
1 6-32 spade bolt
5 feet of hookup wire in various colors, one tube of rubber cement

The Tubes. All three tubes are the 7-prong miniature type. The 35W4 tube is used as a half-wave rectifier to supply the necessary plate circuit voltage and current to the amplifier. The amplifier uses two tubes, a 12AV6 voltage amplifier and a 50C5 power amplifier. The 12AV6 is a combination twin-diode high-mu triode.* Only the triode section of the tube is used in the amplifier. The 50C5 is a beam-power tube.

The heaters of the three tubes are connected in series and also in series with a 200-ohm, 7-watt resistor.

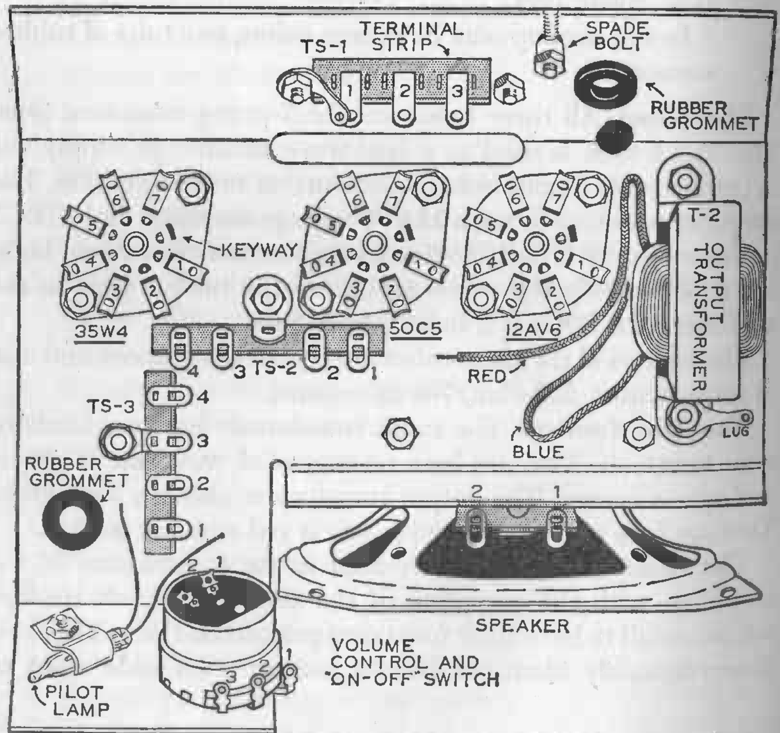
The Transformers. The input transformer has four leads or wire terminals. Two are bare or enameled wire, one is green, and one is brown. The output transformer also has four leads. Two are bare or enameled wire, one is red and one is blue.

The Resistors. The resistors used in the construction of the amplifier, with the exception of the 200-ohm, 7-watt resistor, are too small to have their resistance printed on them. They are, however, easily identified from a resistor color code chart or

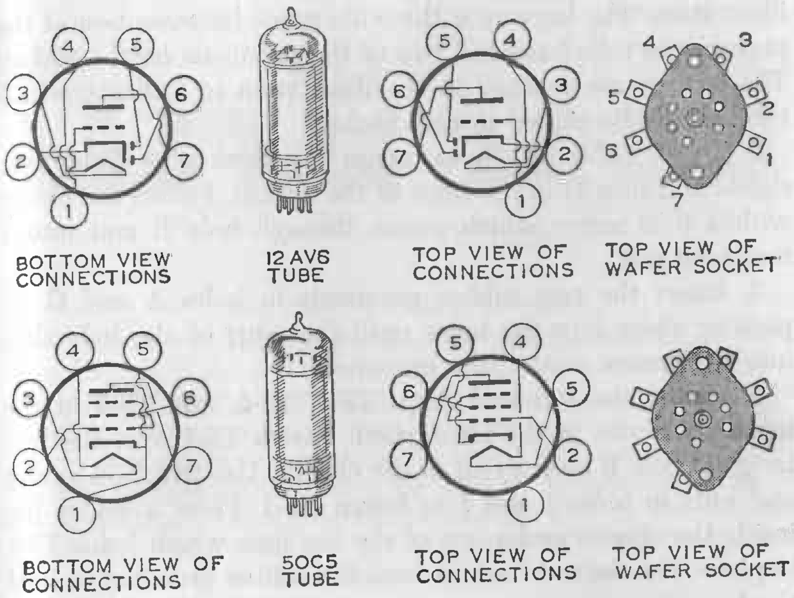
* The ability of a tube to amplify is called the amplification factor and is represented by the Greek letter mu. A high-mu tube will provide more amplification than a medium-mu tube.

from the following description of their color bands. The resistance and wattage of the 200-ohm, 7-watt resistor are printed on it.

RESISTANCE	COLOR BANDS
150 ohms	Brown, green, brown, silver
10,000 ohms	Brown, black, orange, silver
47,000 ohms	Yellow, purple, orange, silver
470,000 ohms	Yellow, purple, yellow, silver
1 megohm	Brown, black, green, silver
10 megohms	Brown, black, blue, silver



VIEW OF UNDERSIDE OF CHASSIS WITH ALL PARTS IN PLACE AND READY FOR WIRING



TWO OF THE TUBES USED IN THE INTERCOM

A third tube (35W4) is also required. This is illustrated in the section on the 5-watt amplifier.

Capacitors. If the capacity of capacitors is not printed on them, their value may be determined by referring to a capacitor color-code chart.

HOW TO ASSEMBLE THE PARTS OF THE MASTER STATION ON THE CHASSIS

Turn the chassis upside down.

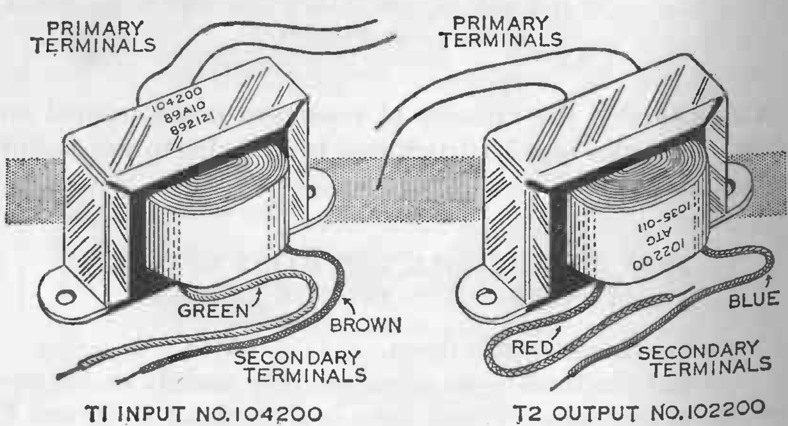
1. Mount the three 7-pin miniature tube sockets on the underside of the chassis. Fasten them over the holes D, E, and F in the chassis, using two 6-32 screws with matching nuts for each socket in holes K, K, K, K, K, K. Turn the sockets so that the "keyway" on each will be in the position shown in the

illustration. The keyway is the wide space between two of the pins on the tube base and two of the terminals on the socket. The sockets are marked in the illustration to indicate which tube should be placed in each socket.

2. Use a cable clamp to mount the neon pilot light over right-hand hole H in the front of the chassis. Fasten the clamp with a 6-32 screw which passes through hole R and into a matching nut.

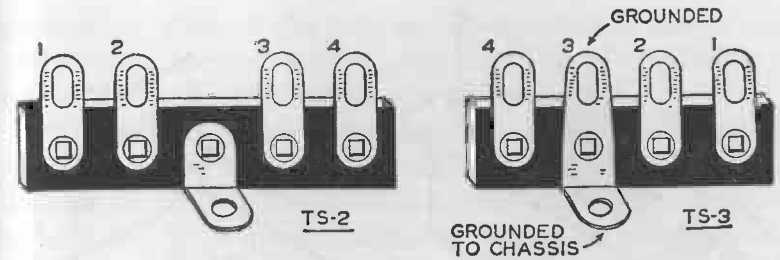
3. Insert the two rubber grommets in holes A and G by pushing them into the holes until the edge of the hole slips into the groove around the grommet.

4. Fasten the terminal strips TS-1, TS-2, and TS-3 in the locations shown in the illustration. Fasten TS-1 over the rectangular hole B on the rear of the chassis. Use two 6-32 screws and nuts in holes J and J to fasten TS-1. Place a solder lug inside the chassis under one of the hex nuts which holds TS-1 in place. Use the nut farthest from the rubber grommet to hold the lug.



THE TRANSFORMERS

The primary leads are usually bare or black enameled.

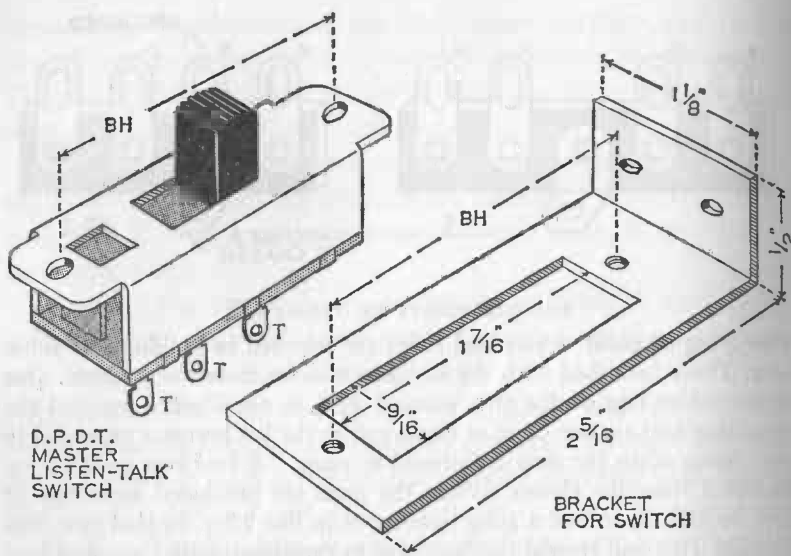


THE TIE POINTS OR TERMINALS

Two 4-lug tie-point or terminal strips are required in building the intercom. Those furnished with the Knight kit differ from one another. One of the solder lugs on the strip marked TS-3 in the illustrations and the mounting foot are one piece of metal and so the lug becomes grounded to the chassis when the strip is fastened in place. All four lugs on TS-2 are insulated from the chassis. When the parts are purchased separately, it may be difficult to find a 4-lug terminal strip like TS-3. In that case, buy two like TS-2 and ground the No. 3 lug to the chassis with a piece of bare wire one end of which is soldered to the lug. The other end is clamped under the mounting nut.

5. If a metal cabinet is to be used, fasten a spade bolt in the elongated hole in the chassis between TS-1 and the rubber grommet. When the chassis has been wired and is ready to put in the cabinet the spade bolt is slipped into a hole in the bottom of the cabinet to hold the chassis in place. The Bakelite tie points or solder lug terminal strips TS-2 and TS-3 are each fastened on the underside of the chassis with 6-32 screws and nuts which also hold the INPUT transformer T-1 in place on top of the chassis.

6. Mount the INPUT TRANSFORMER T-1 on the top surface of the chassis using the same screws and nuts which fasten TS-2 and TS-3. The screws pass through holes P and P. Fasten a solder lug on top of the chassis under the head of the screw nearest the grommet. Mount the OUTPUT transformer T-2 on the underside of the chassis using two 6-32 screws and nuts in



THE MASTER SWITCH AND THE BRACKET UPON WHICH IT IS MOUNTED

Only three of the six terminals, T, T, T, on the Master LISTEN-TALK switch show in the sketch.

holes L and L. Mount two solder lugs, one on top of the chassis and one underneath using the screw which holds the transformer and is nearest the front.

Place the transformers so that the brown and green leads and the red and blue leads are on the sides shown in the illustrations.

7. Mount the 1-megohm volume control in the left-hand hole marked H in the illustration. The body of the volume control and the ON-OFF switch should be on the inside of the chassis and the shaft should project through to outside.

Place one of the large hex nuts on the threaded bushing from which the control shaft projects. Tighten the nut against the control and then slip the large lockwasher on the bushing. Push

the bushing through the hole in the chassis and thread the second large hex nut on the projecting end of the bushing. Tighten the nut until the control is secure.

8. One of the speakers in the Knight kit will have a mounting bracket attached so that the speaker can be fastened on the front of the chassis by two 6-32 screws and nuts, using the holes M and M. A speaker purchased separately will probably not be equipped with a mounting bracket and should be mounted on the rear surface of the front of the cabinet directly over the opening. Use four 6-32 machine screws and nuts. Drill four holes in the cabinet front to align with the four holes in the corners of the speaker.

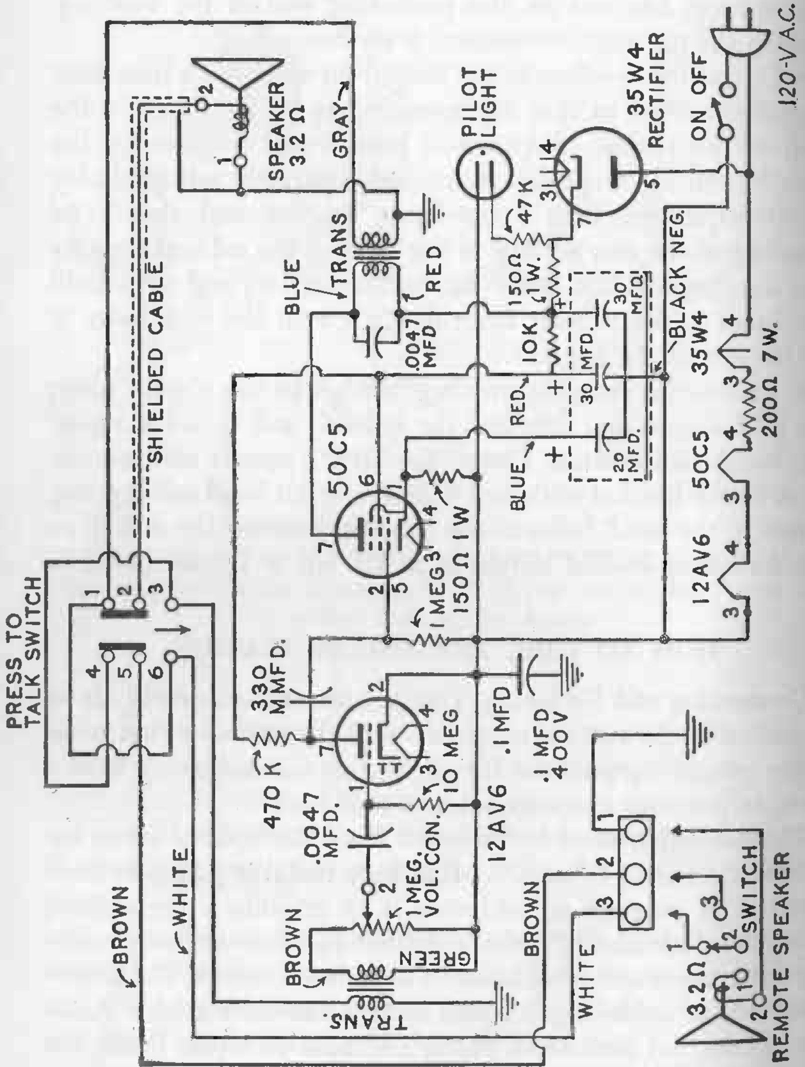
9. Fasten the switch mounting bracket to the chassis using two 6-32 screws and nuts and the holes Q and Q in the top of the chassis at the front. Fasten the DPDT master LISTEN-TALK screw to the bracket with two 4-36, No. 4 flat head self-tapping screws in the small holes in the bracket. Position the switch so that its spring-loaded button is in the up or LISTEN position.

HOW TO WIRE THE MASTER STATION

Connecting and Soldering. This portion of the assembly is so important to the successful operation of the intercom that some of the general instructions for connecting and soldering wiring given in previous chapters are repeated here.

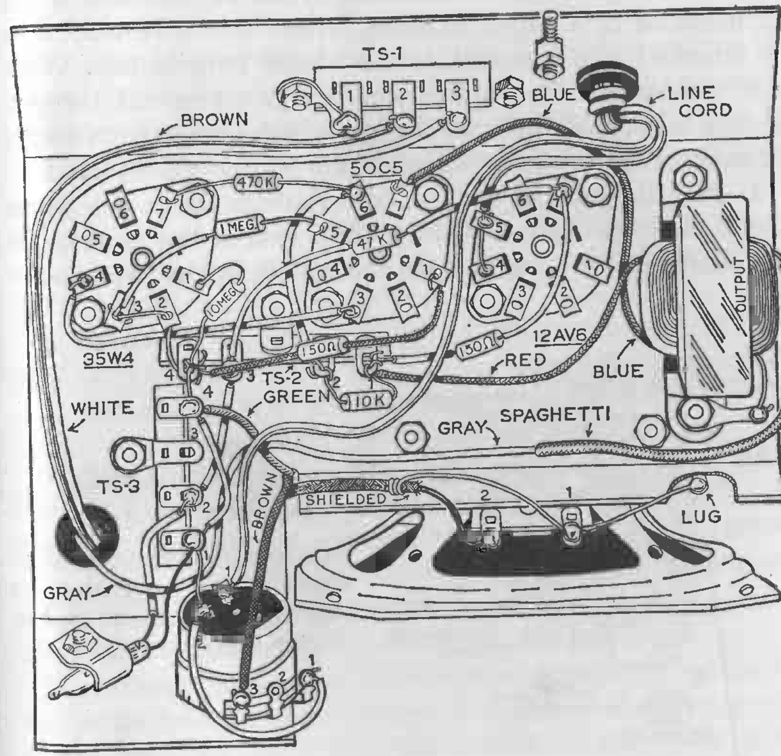
The insulation must be removed from the ends of wires for a short distance (¼ inch) so that bare metal is joined to bare metal. The purpose of soldering is to provide a permanent, unbroken path through which current can flow without meeting any unnecessary resistance or any short circuits. Use a 100-watt electric soldering iron and ONLY ROSIN-CORE solder. Acid-core solder, sal ammoniac paste, and acid or liquid fluxes are TABOO in ALL electronic work.

Wipe the copper tip of the soldering iron occasionally with a rag to remove oxide, dirt, and other heat-insulating sub-



SCHEMATIC CIRCUIT DIAGRAM OF THE HOME INTERCOM

stances. Keep the tip coated with solder and keep it bright and clean. Hold the iron on a joint or connection long enough for solder to flow over all the surfaces of the connection. If wires are accidentally moved while the solder is cooling after the iron has been removed, apply the iron again and reheat until the solder flows freely. A well-soldered connection is smooth and bright and shining. If it is rough, dull, or flaky, or the solder has not flowed and followed the shape of the surfaces, not enough heat has been applied.

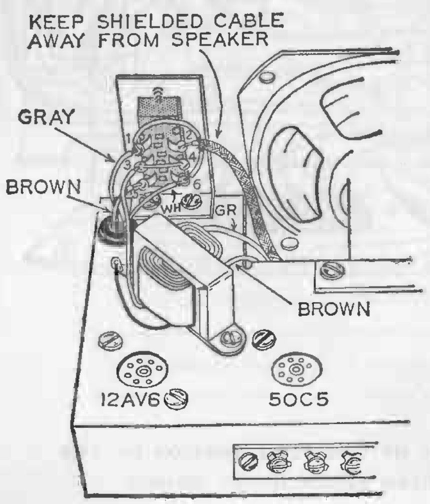


PICTORIAL CIRCUIT DIAGRAM OF THE FIRST PORTION OF THE WIRING TO BE INSTALLED BENEATH THE CHASSIS

The bared end of a wire or lead should be pulled through the holes in terminals or lugs and bent around it with long-nosed pliers before soldering. Excess wire should be cut off with diagonal cutting pliers. The terminal leads of resistors, capacitors, transformers, in fact all wires, should be as short as possible unless otherwise stated in the wiring instructions.

Before any wiring is done study the schematic circuit diagram carefully. Also examine the illustrations which show "pictorial" wiring on the chassis. The pictorial wiring has been divided between two illustrations because it would be confusing and some connections would be hidden by the capacitors if it was all included in a single drawing. When one wire only is to be attached to a terminal, it is soldered immediately. When two or more wires are to be connected to a terminal, the connection is not soldered until the last wire is attached. Of course all connections are soldered when the wiring is completed.

1. Push the ends of the line cord through the rubber grommet in the rear of the chassis. Make a knot in this cord, inside the chassis about 6 inches from the end. Split the two conductors apart from the bared ends back to the knot. Cut one wire to length so that a bared end will conveniently reach terminal 1 on the ON-OFF switch on the back of the volume control. Cut the other wire so that a bared end will conveniently reach terminals 4 and 5 on the socket for the 12AV6 tube. Attach one wire of the line cord to these socket terminals and solder. Attach the other line cord wire to terminal 1 on the ON-OFF switch and solder.



PICTORIAL CIRCUIT DIAGRAM OF WIRING TO MASTER LISTEN-TALK SWITCH AND TRANSFORMER ON THE TOP OF THE CHASSIS

2. Connect one of the wire leads on the pilot lamp to lug 2 on TS-3. Do not solder. Before connecting the lead, cover all but the tip with a piece of small spaghetti.

3. Connect the other lead on the pilot lamp to lug 1 on TS-3. Use a piece of bare wire to connect lug 1 to terminal 2 on the ON-OFF switch. Connect terminal 2 on the switch to terminal 1 on the control with a piece of insulated wire. Solder the wire to lug 1 on TS-3. Also the wire to terminal 1 on the volume control.

4. Solder one end of a short piece of insulated wire to terminal 2 on the ON-OFF switch. Connect the other end of the wire to lug 4 on TS-3. Do not solder.

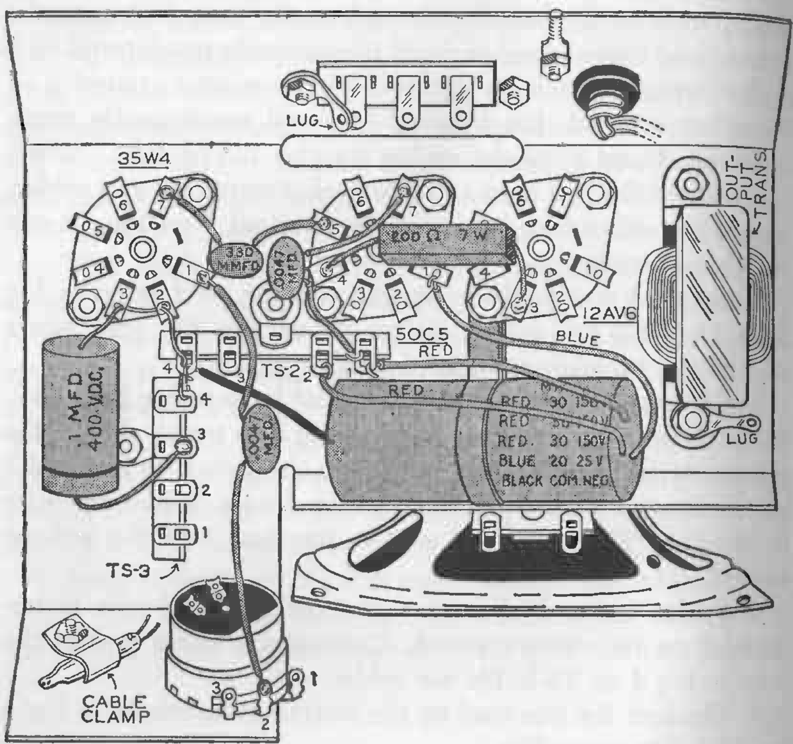
5. Connect the RED lead on the OUTPUT transformer to lug 1 on TS-2. Do not solder.

6. Connect the BLUE lead on the OUTPUT transformer to terminal 7 on the socket for the 50C5 tube. Do not solder.

7. Connect the bared end of a piece of insulated wire to lug 2 on TS-2. Connect the other end to terminal 6 on the socket for the 50C5 tube. Do not solder either connection.

8. Solder one lead of a 470,000-ohm resistor to terminal 6 on the 50C5 tube socket. Connect the other lead of the resistor to terminal 7 on the 35W4 tube socket. Do not solder.

9. Connect one lead of a 1-megohm resistor to terminal 5 on the 50C5 tube socket. Connect the other lead of the resistor to terminal 3 on the 35W4 tube socket. Do not solder either connection. Cover both leads of the resistor with enough spaghetti to prevent a short circuit with other wires and terminals.



PICTORIAL DIAGRAM OF THE BALANCE OF THE WIRING BENEATH THE CHASSIS

None of the wires previously installed are shown in this sketch in order to avoid confusion.

10. Solder one end of a piece of insulated wire to terminal 3 on the 50C5 tube socket. Solder the other end to terminal 4 on the socket for the 35W4 tube.

11. Solder the lug mounted next to TS-1 to terminal 1 on TS-1.

12. Connect lug 4 on TS-3 to lug 4 on TS-2 and to terminals 2 and 3 on tube socket 35W4 with a bare wire. Do not solder.

13. Connect one lead of a 10-megohm resistor to terminal 1 on the 35W4 tube socket and the second lead to lug 4 on TS-2. Do not solder either connection.

14. Cover the leads of a 47,000-ohm resistor with spaghetti. Connect one lead to terminal 7 on the 12AV6 tube socket. Do not solder. Connect and solder the second lead to lug 3 on TS-2. Connect and solder lug 3 on TS-2 to lug 2 on TS-3.

15. Cover one lead of an 150-ohm, 1-watt resistor with spaghetti and solder it to terminal 7 on socket for the 12AV6 tube. Connect the second lead to lug 1 on TS-2. Do not solder. Connect one lead of a 10,000-ohm resistor to lug 1 on TS-2 and connect the other lead to lug 2 on TS-2. Solder later.

NOTE: If four different colored hookup wires are used to make connections to the Master LISTEN-TALK switch it will be easier to trace the wiring when the final checkup is made.

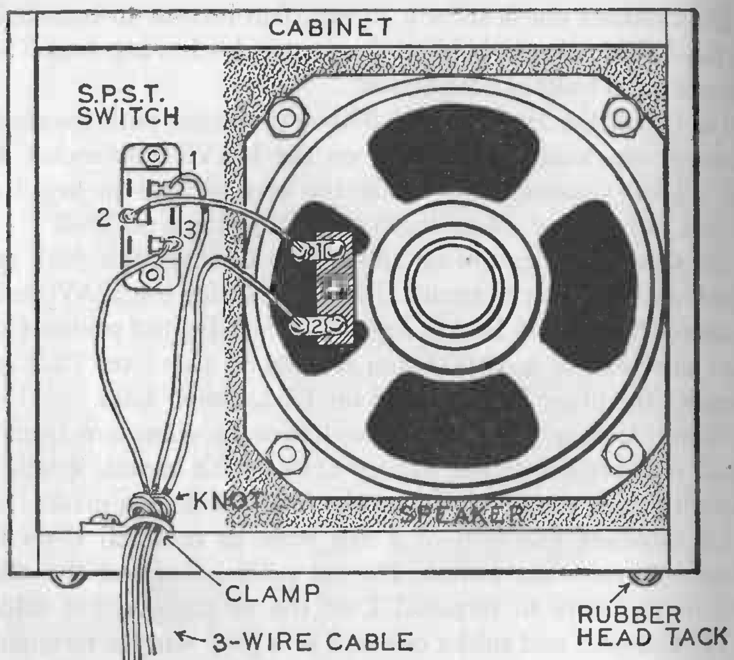
16. Connect one end of a red wire to terminal 6 on the Master LISTEN-TALK switch. Do not solder. Connect the other end of this wire to terminal 1 on the switch. Do not solder.

17. Connect and solder one end of a gray wire to terminal 1 on the Master LISTEN-TALK switch. Push the other end through the grommet. Slip a 4-inch length of large spaghetti over the gray wire. Solder the gray wire to one of the bare leads of the OUTPUT transformer as shown in the illustration. Slide the spaghetti over the bare wire and the splice so that they are entirely covered with this insulation.

18. Solder the remaining bare wire lead on the OUTPUT transformer to the solder lug clamped under the transformer.

19. Solder one end of a white wire to terminal 6 on the Master LISTEN-TALK switch. Push the other end of this wire through the rubber grommet and solder it to terminal 3 of TS-1. Place the wire in the same position shown in the illustration.

20. Solder one end of a brown wire to terminal 5 on the Master LISTEN-TALK switch. Push the other end of this wire through the rubber grommet and solder it to terminal 2 on



REMOTE STATION

View from the rear showing speaker and grille cloth on the back of the panel. The wiring of the Remote LISTEN-TALK switch and speaker is also shown.

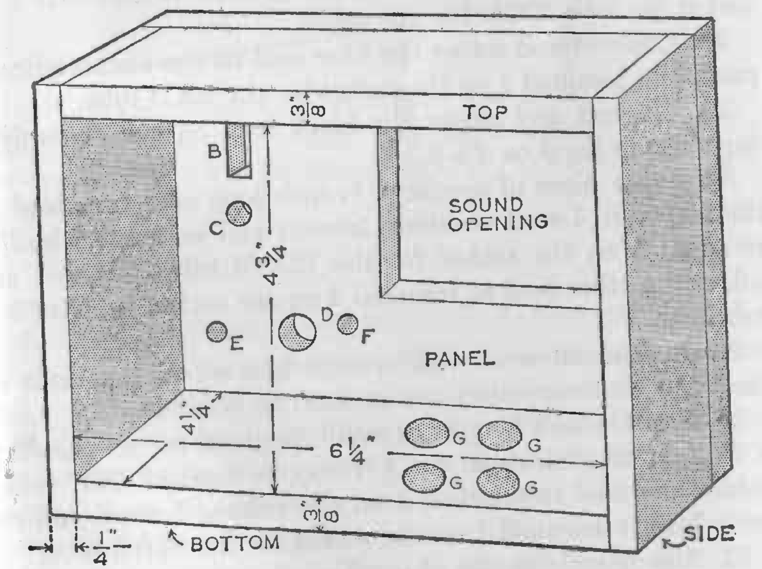
TS-1. Route the brown wire under the chassis alongside the white wire as illustrated. Otherwise the intercom may not operate properly when completed.

21. Solder the brown INPUT transformer lead to terminal 3 on the volume control. Connect the green INPUT transformer lead to lug 4 on TS-3 but do not solder.

22. Solder the bare wire lead on the INPUT transformer nearest the rear of the chassis to the solder lug clamped under the transformer. Solder the remaining bare wire terminal to terminals 3 and 4 on the Master LISTEN-TALK switch.

23. Untwist the braided metallic shielding back about ½ inch on both ends of a 5-inch length of shielded cable and trim off the metal so as to expose the insulation on the inner wire. Trim off about ¼ inch of the insulation from both ends of the stranded inner wire. Twist both ends of the inner wire tight. Solder one end to terminal 2 of Master LISTEN-TALK switch. Solder the other end of the inner wire to terminal 2 on the speaker. This shielded cable must be kept as far away from the speaker as possible.

24. Use a piece of bare copper wire 4 inches long to ground the braided shield and terminal 1 on the speaker to the chassis. Wrap one end of the wire around the braided shielding of the shielded cable near terminal 2 on the speaker. Solder it there.



REAR VIEW OF WOOD CABINET FOR INTERCOM

(B) hole for switch; (C) hole for switch screw; (D) hole for volume control; (E) hole over pilot lamp; (F) hole for mounting speaker.

Slip the other end through the hole in speaker terminal 1 and also through the hole in the solder lug fastened under the INPUT transformer on top of the chassis. Solder the wire to both the lug and the speaker terminal.

25. Remove the mounting nut nearest the center of the chassis which holds one end of the socket for the 12AV6 tube and fasten the mounting strap on the triple section electrolytic condenser under this nut. The end of the condenser with three terminal leads should be next to the output transformer.

26. Connect one of the red leads from the electrolytic capacitor to lug 2 on TS-2. Connect the remaining red lead to lug 1 of TS-2.

27. Cover the leads of a 150-ohm resistor with small spaghetti except for about ¼ inch at their tips. Connect one lead to lug 4 on TS-2. Connect the other lead to terminal 1 on socket for tube 50C5. Do not solder.

28. Connect and solder the blue lead on the electrolytic capacitor to terminal 1 on the socket for the 50C5 tube.

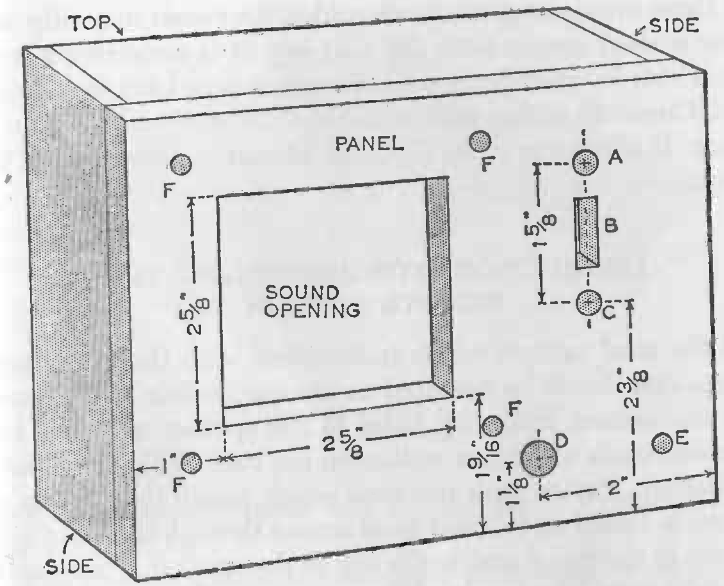
29. Connect and solder the black lead on the electrolytic capacitor to lug 4 on TS-2.

30. Slip a piece of spaghetti ¾ inch long over each lead on the 200-ohm, 7-watt resistor. Connect and solder one lead to terminal 3 on the socket for the 12AV6 tube. Connect and solder the other lead to terminal 4 on the socket for the 50C5 tube.

NOTE: The intercom will operate best when the leads on the three disk capacitors are as short as possible.

31. Slip 1¼-inch lengths of small spaghetti on both leads of a 4700 mmfd. disk capacitor. (It may be marked .0047 mfd.) Solder one lead to terminal 2 on the volume control and the other lead to terminal 1 on the socket for the 35W4 tube.

32. Slip ½-inch lengths of small spaghetti over both leads of a 4700 mmfd. disk capacitor. (It may be marked .0047 mfd.) Solder one lead to terminal 7 on the socket for the 50C5 tube. Connect and solder the other lead to lug 1 on TS-2.



FRONT VIEW OF WOOD CABINET FOR INTERCOM

(A and C) holes for switch screw; (B) hole for switch; (D) hole for volume control; (E) hole over pilot lamp; (F, F, F, F) holes for mounting speaker.

33. Solder one lead of a 330 mmfd. disk capacitor to terminal 5 on the socket for the 50C5 tube. Solder the other lead to terminal 7 on the socket for the 35W4 tube.

34. Solder the lead at the banded end of a 0.1 mfd. 400 VDC tubular condenser to lug 3 on TS-3. Solder the other lead to terminal 3 on the socket for the 35W4 tube. Notice that terminals 3 and 2 on this socket are connected together and are also connected to lug 4 on TS-2 and to lug 4 on TS-3.

35. Check all connections and solder any which have not been soldered. Give special attention to the lugs on TS-2 and TS-3 to which several wires have been connected. When solder-

ing these avoid using too much solder. An excess may drip and cause a short circuit with the next lug. It is necessary also to inspect for "cold-solder" connections resulting from insufficient heat. Check all wiring with both the schematic and circuit diagrams. If all proves to be O.K. the Master station is ready for its cabinet.

INSTRUCTIONS FOR ASSEMBLING THE REMOTE STATION

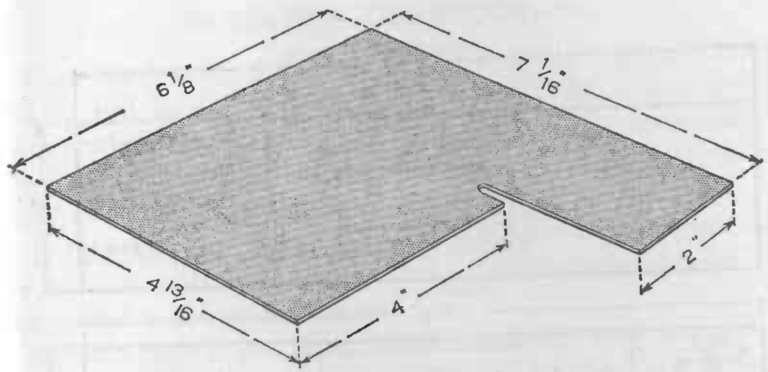
If the steel cabinet which is furnished with the kit is used, the speaker should be mounted on the rear surface of the panel. Slip the bottom mounting holes in the speaker over the two threaded studs which are welded to the back of the panel near the bottom. Fasten with two nuts which match the threads on the studs. Push two 6-32 flat head screws through the holes near the top of the panel and in the top of the speaker. Fasten with two 6-32 nuts. The heads of the screws should be on the outside of the panel.

Mount the SPDT LISTEN-TALK switch inside the cabinet with the knob projecting through the rectangular hole.

When the switch and speaker are in place apply the adhesive perforated plastic grille to the front of the panel. Press it firmly into place. Put the switch labels on last.

Tie a knot in the 3-wire interconnecting cable about 5 inches from the end. If the three wires are different colors it will be easier to trace them and make connections to the Master station than it will if they are the same color. Use a cable clamp to anchor the wires to the bottom of the cabinet with the knot inside the cabinet.

At the end of the cable nearest the knot solder one wire to terminal 2 on the speaker. Solder one end of the second wire to terminal 1 on the switch. Solder the third wire to terminal 3. Solder one end of a short piece of wire to terminal 2 on the



SHEET-METAL BLANK FOR CHASSIS

switch. Solder the other end of the wire to terminal 1 on the speaker.

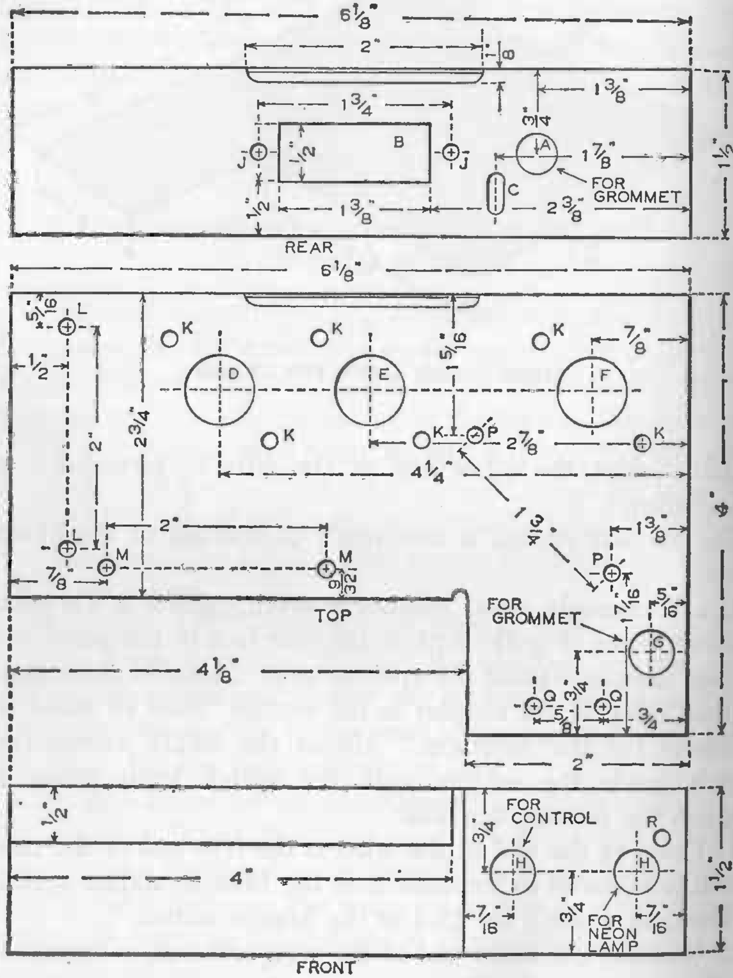
The Remote station is now ready to connect to the Master station.

If a homemade wood cabinet is used, cement a 4½-inch x 4½-inch piece of grille cloth to the rear face of the panel with rubber cement. Mount the speaker over the grille cloth as explained later in this chapter in the section "How to Make the Cabinets for the Intercom." Mount the SPDT LISTEN-TALK switch inside the cabinet with the switch knob projecting through the rectangular hole.

1. Connect the end of the wire at the free end of the cable which is soldered to terminal 2 on the Remote station speaker to terminal screw 1 on TS-1 at the Master station.

2. Connect the other end of the wire soldered to terminal 3 on the switch at the Remote station to terminal screw 2 on TS-1 at the Master station.

3. Connect the end of the wire at the free end of the cable which is soldered to terminal 1 on the switch at the Remote station to terminal screw 3 on TS-1 at the Master station.



DETAILS OF THE FINISHED CHASSIS

OPERATING THE INTERCOM

Place the Remote station about 25 feet away from the Master station and in a different room if possible. Place the Master station where the line cord can be plugged into a power outlet. Do not place either station on or near a radiator, sink, metal table, or other grounded metal object.

1. Push the plug attached to the line cord into a power outlet. Do not touch any connections on the intercom while it is connected to the power source.

2. Turn the VOLUME control knob clockwise until the click of the ON-OFF switch is heard. Turn the knob about halfway around and allow a minute or two for the tubes to light up. If the power is on, the pilot lamp will glow.

The LISTEN-TALK switch must be pushed DOWN to talk from either station. The switch at the Master station must be UP in the LISTEN position to hear a call or response from a Remote station. A call or message from the Master station will be heard at a Remote station when the switch at the Remote station is in either the LISTEN or TALK position. The Master station will always hear a call from a Remote station because the spring-loaded switch returns automatically to the LISTEN position when it is released.

Ask someone to stand by at the Remote station. Press the switch at the Master station DOWN to the TALK position and ask if the Remote station can hear you. Speak in a normal voice and about 18 inches away from the front of the intercom. Ask the person at the Remote station to push the switch to the TALK position and speak to you. The instant you cease speaking release the switch button at the Master station. If both stations operate the intercom is ready to install wherever it will provide a convenient means of short-distance communication. When installed in a permanent location cut off any of the 3-wire cable which is not needed.

Turning the VOLUME control knob adjusts the volume of sound from the speakers. It is also an ON-OFF power control.

When the knob is turned counter-clockwise until a click is heard the power is OFF.

If a squeal comes from the Master station when the volume control is turned on full, pull the line cord plug out and remove the chassis from its cabinet. Be careful not to touch any of the connections with the fingers. Use a dry piece of wood to move the shielded wire away from the speaker to a position where the squeal disappears. Then replace the chassis in its cabinet.

When the Master and Remote stations are too close together one of the speakers may produce a squeal. This is due to "feedback" and may be eliminated by turning the volume control down or by moving the stations farther apart.

When the intercom is operated on alternating current (A.C.) there may be a humming noise in the speakers. Reversing the position of the line cord plug in the power outlet usually stops this.

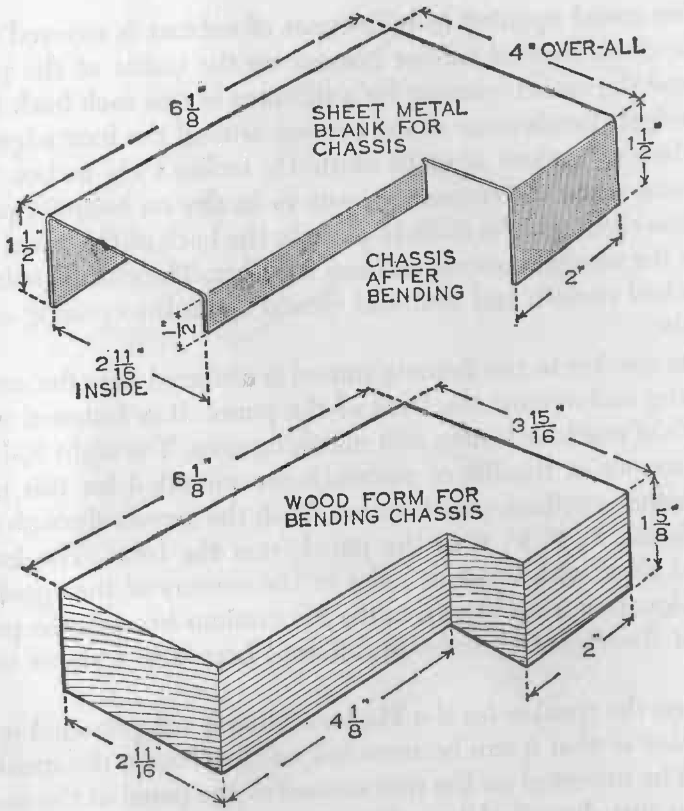
When operated on direct current (D.C.) the intercom will perform only in one position of the line cord in the outlet.

HOW TO MAKE THE CABINETS FOR THE INTERCOM

Wood cabinets for the intercom are simple boxes with an open back. They may be constructed of ¼-inch and ⅜-inch plywood or of any other wood of your choice. The dimensions are shown in the illustrations. The inside dimensions are important, especially those of the cabinet for the Master station for it must fit the chassis. The outside dimensions may vary with the thickness of the wood used.

The cabinet for a Remote station is the same size as the cabinet for a Master station but the holes in the panel differ. Since the Remote station has no volume control or pilot lamp, holes (D and E) to accommodate these parts are not required.

The cabinet for a Master station should have several ⅝-inch diameter holes (G) bored through the bottom to increase the



THE CHASSIS AFTER FORMING AND THE "JIG" FOR BENDING IT

ventilation which is necessary in order to dissipate the heat generated in the tubes. No heat is developed in a Remote station and holes in the bottom of the cabinet may be omitted. If a rubber head tack is driven into each corner of the bottom of both types of cabinet, the tacks will prevent scratching any surfaces upon which the stations are placed and will allow air to enter the holes in the bottom of the Master cabinet.

Sandpaper the outside of the cabinets and finish with stain and varnish.

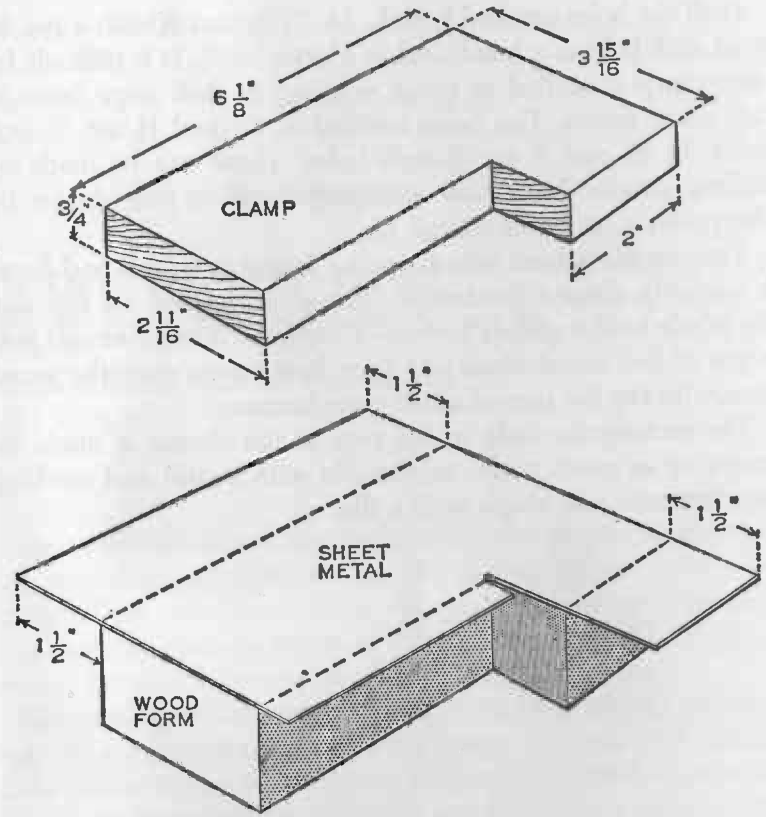
The sound opening in both types of cabinet is covered with grille cloth. Spread rubber cement on the inside of the panel around the sound opening for a distance of one inch back from the edges. Brush some of the cement around the four edges on one face of a piece of grille cloth 4½ inches x 4½ inches. The moment when the cement appears to be dry on both the panel and the cloth put the cloth in place in the back of the panel and press the cement covered surfaces together. The cloth should be stretched smooth and taut and should cover the opening completely.

The speaker in the Remote station is centered over the sound opening and against the back of the panel. It is fastened with four 6-32 machine screws and matching nuts. The eight ½-inch 6-32 screws in the list of materials are intended for this purpose when a ¼-inch panel is used. Push the screws through the four holes, F, F, F, F in the panel from the front. The holes should align with the four holes in the corners of the speaker. Their location is not shown in the illustrations because the position of the mounting holes in different brands of speaker may vary.

When the speaker for the Master station is not provided with a bracket so that it can be mounted on the chassis, the speaker should be mounted on the rear surface of the panel in the same manner just described for a Remote station speaker.

Adhesive labels marked LISTEN and TALK are supplied in the Knight kit. In the absence of these stick a small paper label to each panel. Cut a rectangular hole in the label which will slip over the switch knob and allow the knob to be moved up and down. The word LISTEN should appear above the switch and the word TALK below.

One of the illustrations shows the shape and dimensions of the steel chassis for the amplifier in the Master station as furnished in the Knight kit. This can be duplicated in sheet metal by using .035 inch thick aluminum or galvanized iron sheet. Aluminum sheet can be purchased from many hardware stores



THE CHASSIS BLANK IN PLACE ON THE FORMING JIG AND THE WOOD CLAMP USED TO HOLD IT

and from fabricators of aluminum doors and windows. Galvanized iron sheet approximately .035 inch thick is a size used often by tinsmiths.

The first step is to cut out a "blank" in the size and shape illustrated. Make an exact size paper pattern and cement it to the metal with rubber cement. Mark the centers of all the holes. Cut out the blank with a medium-sized pair of tinner's snips. Mark the centers of all the holes with a center punch.

Drill the holes marked J, K, L, M, P, Q, and R with a No. 24 twist drill held in a hand drill or electric drill. It is difficult for one who is unskilled in metal working to drill large holes in thin sheet metal. The holes marked A, G, and H are ⅜-inch holes. D, E, and F are ⅝-inch holes. These can be made by drilling smaller holes and enlarging them to proper size by filing with a round or rat-tail file.

The chassis is bent into shape by laying it on a wood form. A similarly shaped hardwood "clamp" is aligned on top and the whole held together by two "C" clamps. The front and rear edges of the metal blank are then bent down over the wood form with the flat face of a ball-peen hammer.

The rectangular hole in the rear of the chassis is made by removing as much metal as possible with a drill and working into final size and shape with a file.

CHAPTER FOURTEEN

AN OPPORTUNITY TO BE YOUR OWN TECHNICIAN AND ELECTRONICS ENGINEER

The schematic circuit diagrams in this chapter are interesting and important applications of transistors, photo cells, and diodes. They are conservative designs which were originally developed by manufacturers of these components. The circuits are not necessarily examples of commercial practice.

Electrical specifications are given to assist in home construction. No constructional details are given. Layouts and details of the cabinets and assembly are purposely omitted to provide the young experimenter with the opportunity to exercise his own ingenuity. Here is a good chance for the experimenter to be his own technician and electronics engineer.

Success is assured if the circuits are followed accurately, if good workmanship is provided and good quality components of the given specifications are employed.

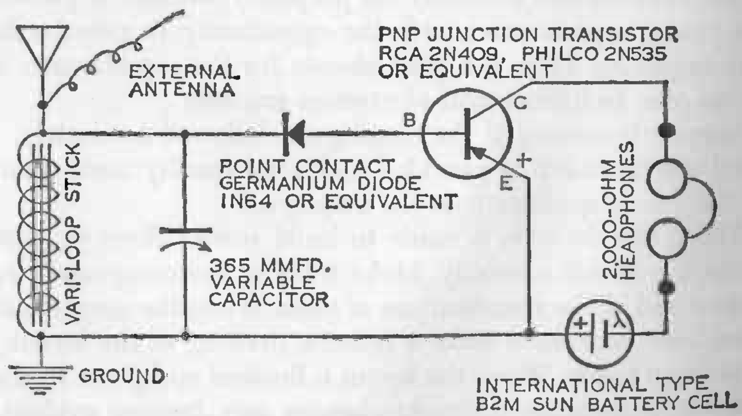
When the decision is made to build one of these projects, study the circuit carefully. Make a list of the components required and of the specifications of each. When the components have been purchased make a full-size drawing of the layout it is planned to use. When the layout is finished and given further consideration, some desirable changes may become evident.

A SUN BATTERY WILL OPERATE A RADIO RECEIVER

Small transistors function on such small amounts of energy that it is not difficult to build a radio receiver with a transistor amplifier which operates on electricity generated by the sun. The "sun battery" which converts the solar energy into electrical energy is a small, low-priced selenium photo cell such as the International type B2M sun battery cell or its equivalent. (See the discussion on photo cells in Chapter Twelve of *The Boys' Second Book of Radio and Electronics* by Alfred Morgan, published by Charles Scribner's Sons.)

The schematic circuit for a sun-powered receiver is illustrated. This does not differ greatly from the receiver described in Chapter Seven except that it also includes a one-stage transistor audio amplifier, an amplifier energized by a photo cell instead of the usual dry cell.

The antenna loopstick may be any one of the following: Thordarson-Meissner No. 14-7000 Micro-Loop, Superex Vari-Loopstick, Lafayette MS-11 Vari-Loopstick, Allied Radio No. 51C034 Vari-Loopstick, or Philmore No. 1R841 loop antenna.



A SUN-POWERED RADIO RECEIVER

The builder can make his own decision whether to mount the parts on a small wood base in "breadboard" fashion or to build a more compact receiver which can be carried in the pocket by assembling the components in a small wood or plastic box. When a pocket receiver is built, it can be made smaller if a "Poly-Vari-Con" tuning capacitor with poly-ethylene dielectric is used instead of the common air-dielectric tuning capacitor.

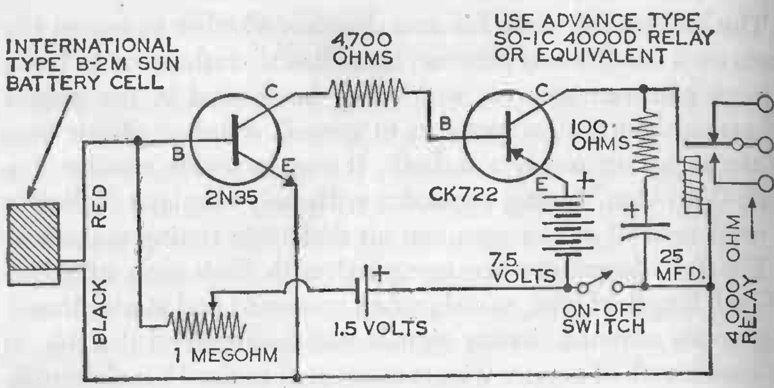
The ferri-loopsticks are equipped with their own attached 18-inch length of wire, which, when unwound and straightened, acts as an antenna. Better signals will be received if a 10- to 20-foot length of copper wire is connected to the 18-inch length. And more stations will be received with greater volume by connecting a ground at the point indicated in the schematic diagram.

The operation of the receiver is briefly:

Place the receiver where the sun battery will receive full sunlight. The resonance of the loopstick and antenna may be tuned to a frequency corresponding to that of a nearby broadcasting station by adjusting the vari-loopstick and the tuning capacitor. The 1N64 germanium diode rectifies and demodulates the incoming radio-frequency signal into an audio-frequency signal. The 2N409 transistor performs as an audio-amplifier with the D.C. voltage generated by the B2M photo cell when light falls upon it. In fact, it will perform with light intensity as low as 10-foot candles on the photocell. At night, the receiver will operate if placed about 18 inches away from a 100- to 150-watt lighted incandescent lamp.

A SENSITIVE "ELECTRIC EYE" OR PHOTO RELAY

There are several varieties of transducer which generate voltage when light shines on them. Their technical name is photo cell but they are popularly known as "electric eyes." When a photo cell is part of a circuit which includes a relay and is so arranged that changes in the intensity of the light open and close the relay, the assembly is called a PHOTO RELAY.



A SENSITIVE PHOTO RELAY

Photo cells are more sensitive than the human eye to small changes in light intensity and color. The purpose or use of a photo relay depends upon the nature of the apparatus connected to the contact points of the relay.

The photo relay illustrated by the accompanying schematic circuit can be used to:

1. count people or objects passing a given point
2. open or close a door when a person approaches it
3. sound an alarm to signal the presence of a trespasser or an intruder
4. turn lamps on when darkness comes and off when the sun comes up
5. signal the presence of smoke or fog

The beam of an ordinary flashlight will operate the relay at a distance of 20 feet when the 1-megohm control is properly adjusted.

CODE PRACTICE OSCILLATOR

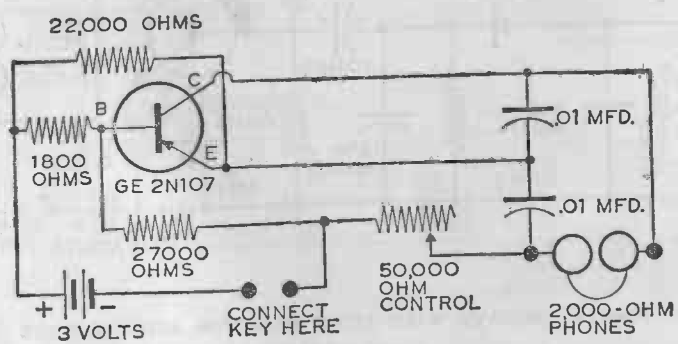
The first step in learning to send and receive radio telegraph messages is to memorize the sounds of the telegraph alphabet. A good way to do this is to connect a telegraph key to a code-

practice oscillator. One of the circuit diagrams shows how to connect a 2N107 transistor in a feedback circuit so that it will oscillate at audio frequencies. When the 50,000-ohm control is properly adjusted and the key is pressed, the sounds heard in the telephone headset will have the same pitch as the DITS and DAHS of a radio telegraph message.

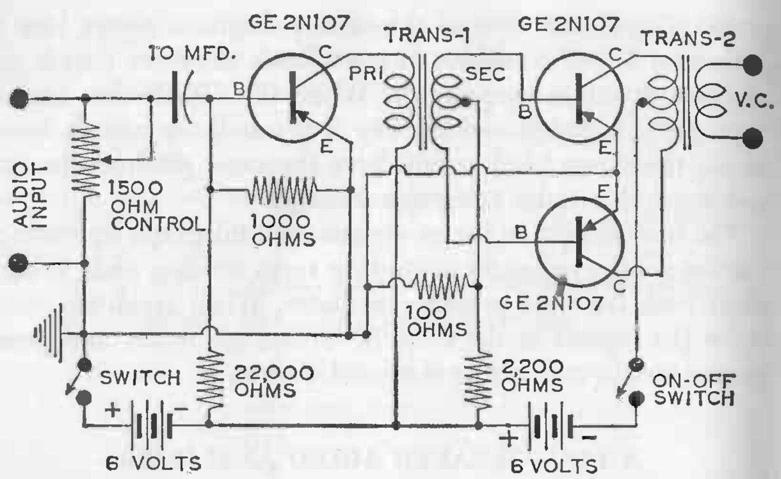
The best substitute for an experienced telegraph operator as teacher is for two beginners to take turns sending code to each other with the code practice oscillator. When receiving, write down the signals in the form of letters, numerals, and punctuation marks and not as dots and dashes.

A LOUD-SPEAKER AUDIO AMPLIFIER

The two-stage audio amplifier described in Chapter Nine has a single transistor in each stage. Such amplifiers are called SINGLE-SIDED. It is also possible to use two transistors in each stage and when this is done in the manner illustrated in the output stage of the "Loud-speaker Audio Amplifier" it is called a PUSH-PULL AMPLIFIER. Push-pull amplifiers make possible a great increase in the power output without the distortion produced by the same volume from a single-sided amplifier.

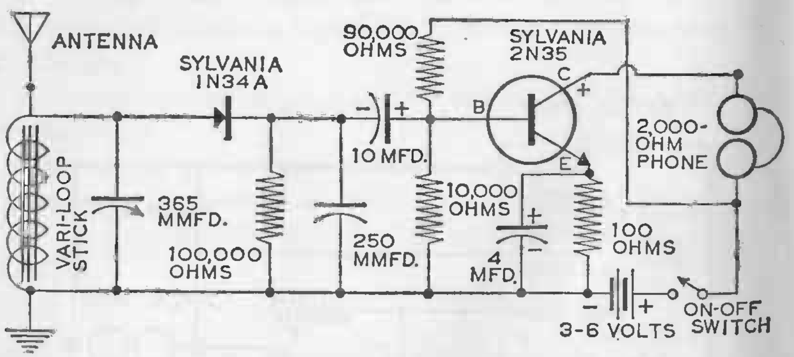


A CODE PRACTICE OSCILLATOR



THE SCHEMATIC CIRCUIT FOR A LOUD-SPEAKER AUDIO AMPLIFIER

An 8-ohm voice coil speaker should be connected to the terminals marked V.C.

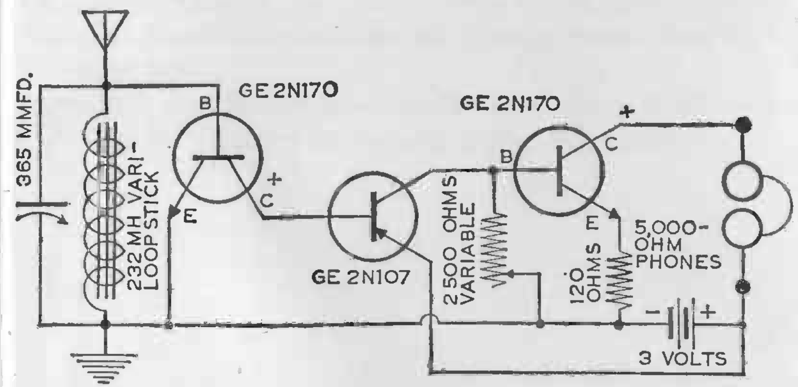


SIMPLE RECEIVER WITH DIODE DETECTOR AND ONE-STAGE AUDIO AMPLIFIER

The Loud-speaker Audio Amplifier illustrated here by a schematic circuit diagram utilizes three transistors. One is in a single-sided stage; two of them perform as a push-pull output stage. The amplifier produces sufficient volume of good quality to operate a 4-inch speaker. The interstage transformer (marked TRANS-1) should be a "Triad" A81X or the equivalent.

SIMPLE RECEIVER WITH DIODE DETECTOR AND ONE-STAGE AUDIO AMPLIFIER

This receiver and the one which follows cover the standard AM broadcast band and could be of inestimable value in an emergency. When tornadoes and floods occur and power lines are down, radio receivers operated on 120-volt A.C. are usually out of commission. A small receiver, operating on two to four flashlight cells can be the means of keeping in touch with the world at such time. Although the loopstick will pick up signals from nearby stations, the range and volume of the receiver will be greatly increased if it is connected to the ground and to a 20- to 25-foot antenna.



VEST POCKET RECEIVER WITH TWO-STAGE AUDIO AMPLIFIER

VEST-POCKET RECEIVER WITH TWO-STAGE AUDIO AMPLIFIER

This simple circuit will enable the experimenter to use his own ideas in assembling the components in a small plastic box or other suitable enclosure about the size of a package of cigarettes. It is suggested that a Poly-Vari-Con turning capacitor with polyethylene dielectric be used instead of the common air-dielectric tuning capacitor in order to save space. The receiver will pick up signals from nearby stations without an antenna and ground. Much better results will be obtained if the receiver is grounded at the point indicated in the circuit diagram and if a 20- to 25-foot length of copper wire is connected to the 18-inch piece wrapped around the loopstick.

WHERE TO OBTAIN MATERIALS

Radio and television service shops can usually supply any of the tubes, capacitors, resistors, and batteries required to build the apparatus described in this book. Other components such as transistors, transformers, coils, phonomotors, etc., can be obtained from distributors of electronic equipment. Their advertisements can be found in the radio magazines. Seven reliable firms which will send you a catalog if you request it are listed below. Neither the author nor the publisher of this book has any interest in these firms and does not assume any responsibility in your dealings or transactions with any of them.

ALLIED RADIO, 100 N. Western Avenue, Chicago 80, Illinois

LAFAYETTE RADIO ELECTRONICS CORPORATION, 111 Jericho Turnpike, Syosset, Long Island, New York

RADIO SHACK, 730 Commonwealth Avenue, Boston 17, Massachusetts

BURSTEIN APPLEBEE CO., 1012 McGee Street, Kansas City, Missouri

OLSON ELECTRONICS, INC., 260 S. Forge Street, Akron 8, Ohio

CONCORD RADIO CORPORATION, 45 Warren Street, New York 7, New York

NEWARK RADIO, 223 W. Madison Street, Chicago 6, Illinois and 4736 W. Century Boulevard, Inglewood, California

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