Basic Information For The OLD-TIME-RADIO Builder. . .

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Allied Radio
KNIGHT KIT
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Circa

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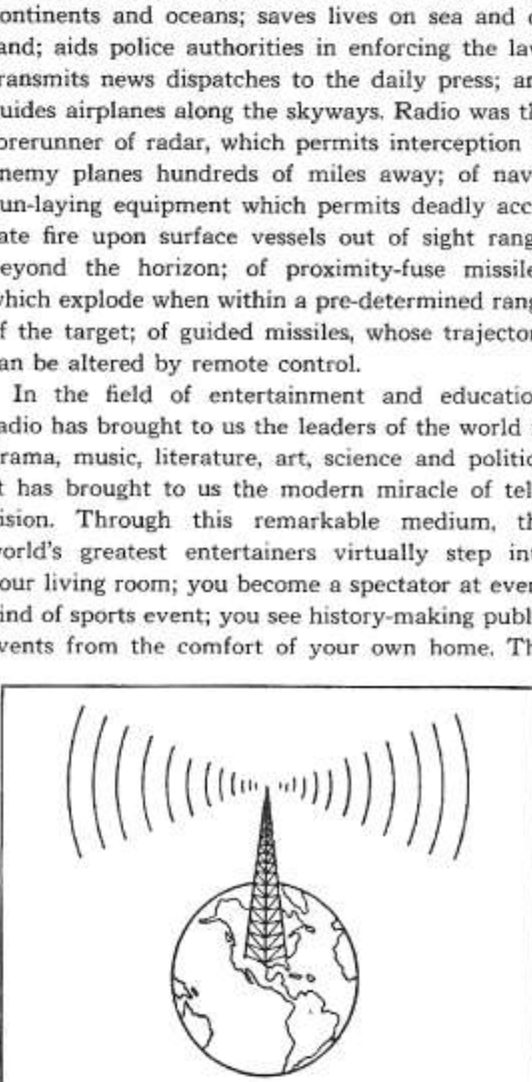
How Radio Earned Its Place In The Sun

When Guglielmo Marconi finally succeeded in 1895 in transmitting a "wireless" message over a distance of a mile and a half, he set in motion a chain of development that has revolutionized the art of communication. Marconi did not "invent" radio nor was he alone in the early work in this new art. Yet from that small beginning, radio has steadily advanced to the point where today its influence is felt in every phase of our lives. Today, radio provides communications facilities across continents and oceans; saves lives on sea and on land; aids police authorities in enforcing the law; transmits news dispatches to the daily press; and guides airplanes along the skyways. Radio was the forerunner of radar, which permits interception of enemy planes hundreds of miles away; of naval gun-laying equipment which permits deadly accurate fire upon surface vessels out of sight range, beyond the horizon; of proximity-fuse missiles, which explode when within a pre-determined range of the target; of guided missiles, whose trajectory can be altered by remote control.

In the field of entertainment and education, radio has brought to us the leaders of the world in drama, music, literature, art, science and politics. It has brought to us the modern miracle of television. Through this remarkable medium, the world's greatest entertainers virtually step into your living room; you become a spectator at every kind of sports event; you see history-making public events from the comfort of your own home. The full impact of television upon our lives cannot be measured by those of us living in this thrilling period of its development. Historians of the future will be able to assess the far-reaching effects of television upon the development of modern society.



Radio has made the world smaller.

Yes, after many years of perseverance against countless obstacles, of unstinted toil by thousands of people in the vanguard of science — radio has earned its place in the sun. For radio has proved itself to be the greatest force in the twentieth century for bringing knowledge, pleasure and joy to all mankind.

Radio Is A Fascinating Hobby Easy To Learn

The average radio listener regards radio as a deep mystery. But radio need not be a dark mystery. To thousands of government-licensed Amateurs and to multitudes of experimenters and radio builders, radio is a fascinating hobby that gives endless hours of real thrills, a vast store of useful knowledge, and the deep satisfaction of knowing that the radio equipment one has built himself will really work.

To you, therefore, who are interested in the science of radio—in learning how to build practical radio circuits, in understanding some of the fundamentals of radio—this book is addressed. We have not attempted to make this an exhaustive complicated treatise. We think that you will get more real help by covering thoroughly only those basic details and practical applications that will be of use to you. Our aim, in short, has been to give you a good working knowledge of radio building and experimentation, and to set you on the right path toward more advanced work.

A word of advice: study each section thoroughly before going on to the next section.

What Is A Radio Signal?

Before going any further, let's take a quick glance at the overall picture of a radio signal being transmitted from a broadcast studio to your home.

A "Signal" is any intelligence that we wish to transmit. Suppose we wish to transmit music. The variations in frequency (pitch) and intensity (loudness) of the music — comprise the signal. If we transmit this signal by the standard AM (amplitude-modulation) broadcast system, this is what happens:

In the studio, the sound waves produced by the music cause vibrations of a diaphragm in the microphone. From this point on, until the music is reproduced in your home, the form of this signal changes; it may be a current wave, an electromagnetic wave, a voltage wave, etc. However, in every case, the character of the signal is scrupulously preserved. In other words, the variations in current, voltage, etc. correspond to the variations of the music in the studio. Thus, the received signal (ideally) is an exact duplicate of the transmitted signal.

The varying currents from the microphone are known as "audio frequency" (AF) impulses. These are amplified millions of times, and then super-imposed on a powerful "radio frequency" (RF) current known as the "carrier." RF waves are much shorter than AF waves, and will travel great distances through space—whereas the AF waves will not.

We now have a "modulated carrier." The energy in this carrier is transmitted through space (in all directions) by electromagnetic and electrostatic fields, generated by the high-frequency currents fed into the transmitting antenna. Many thousands of watts of energy is radiated, but most of it is lost in space; only a very small portion of it (a few millionths of a volt) reaches the antenna of your receiver at home.

This feeble signal is picked up by your radio receiver's antenna, amplified many times, and is then converted back to audio impulses. After further amplification, these impulses are fed into your headphones or loudspeaker, where vibrations are produced, creating sound waves which correspond to the sound waves in the studio, where the signal originated.

All this happens in a fraction of a second. With the speed of RF waves at 186,000 miles a second, you can readily see how quickly this takes place. Actually you hear the broadcast program from your radio before the audience hears it in the studio. This is because sound waves travel through the air at the rate of only 1,086 feet per second as compared with the speed of radio waves.

Other Kinds Of Transmission

In addition to the amplitude-modulation method of transmission, there are other types: Code (Continuous Wave or CW), for sending messages; Frequency Modulation, for noise-free sound, and Television.

Code (CW)

Code transmitters do not require audio. The carrier is broken into dots and dashes by means of a telegraph key and relays. It is heard in the receiver (if of the regenerative type or superheterodyne with beat frequency oscillator) as an intermittent tone or whistle. Another less common type of code transmission does make use of a modulator. In this method a "tone oscillator" is keyed.

Frequency Modulation (FM)

In frequency modulation, as the name implies, the frequency of the carrier is changed—above and below the mean frequency. Amplitude remains constant. The main advantage of FM over AM is a high degree of noise reduction at the receiver. This is possible because all noises in the radio spectrum are RF oscillations which vary in amplitude, and the FM receiver does not respond to amplitude variations.

Television (TV)

Television requires transmission of two signals: the audio signal and the video (picture) signal. The audio is an FM signal; the video is an AM signal. Both RF carriers are transmitted at the same time. At the receiver, these signals are amplified, detected, and fed to the speaker and picture tube, respectively. Television also requires transmission of special synchronizing ("sync") and blanking pulses. The sync pulses coordinate the picture-tracing on the face of the picture tube with the scanning of the subject in the TV studio. The blanking pulses blank out the picture tube during the short retrace periods of the horizontal and vertical "sweep" oscillators. Thus the television signal is extremely complex, and requires a receiver more complex than any FM or AM set.

In both FM and TV, the RF carrier frequencies are much higher than on AM. Such high frequencies are limited in range, because they travel in a straight line and do not follow the curvature of the earth, as do the longer waves (lower frequencies) used in standard AM broadcasting. Therefore, during average conditions, the transmission radius is 50-150 miles.

The Experimenter-Builder And What He Does

No matter how far radio progresses, there will always be a place for the experimenter-builder. He is the fellow who tries out new circuit designs and new gadgets. Sometimes he stumbles across a new idea that is of distinct value to radio manufacturers. Sometimes he plans a career for himself as a radio engineer or a servicing expert. Sometimes he decides to make radio a hobby, becomes an Amateur and goes on the air with his own transmitter.

However, generally the experimenter-builder is a "fan." He is in radio because he likes it—because he likes to build his own sets, experiment with circuit layouts, and try to improve the results he gets. But whatever *your* reason for taking up radio and whatever the facilities you have available for work, you will get as much out of your hobby as you put into it. If, some day, you can turn your hobby into your profession, all the better. But even if your interest in radio remains a hobby you will get from it the advantages of acquiring some mechanical skill, learning to use tools properly, joining a wide fellowship of friendly men and boys, developing your ingenuity, and doing constructive work.

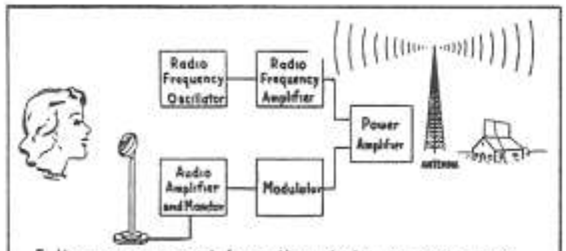
Radio need not be an expensive hobby. The tools required for the beginner are few and inexpensive. And parts used in building any one circuit can almost always be used again in many other circuits.

Getting A Start In Radio Building

For the average radio newcomer, the best way to learn radio is by "doing." Do you remember how you learned to play baseball, or to drive a car, or to do any one of a hundred different things that require a development of skill? Not all the explanations in the world seemed of much use until you had actually tried out these methods yourself. Not until you had actually experienced playing baseball or driving a car, did you begin to see how different the job really was from what it had sounded like.

Now, in the same way you can learn radio by doing simple but effective practical work, by putting the knowledge you gain to actual use, and by working up gradually to more advanced material.

By building a simple radio set from a circuit diagram, you will become familiar with basic radio parts and their functions, with set layout and construction, with the meaning of the various radio symbols, and with some of the fundamental ideas behind radio design. You will develop a feeling of real achievement when you find that the first simple set you build will actually work. And, finally, you will bring an intelligent understanding to your work when you approach the more difficult phases of radio.



Following a signal from the studio to your set

The audio signal leaves the microphone, is amplified in the AF amplifier stages, and then fed into the final transmitter stage, the RF power amplifier. There it is superimposed on the RF carrier wave. It is then fed into the transmitting antenna, which radiates the carrier into space.

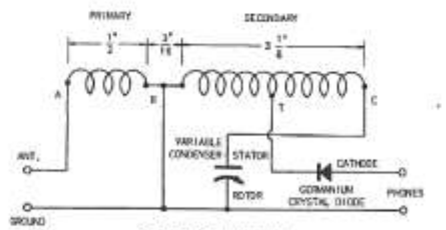
Accordingly, in our discussion, we shall keep uppermost in our minds the needs of the radio newcomer whose first goal is to build a radio set that will work. We shall discuss the tools and materials you will need. We shall find out the most efficient way of putting a radio set together. And we shall introduce whatever theoretical knowledge you need as you need it—and when you are ready for it.

What Kind Of Set Should Be Built First?

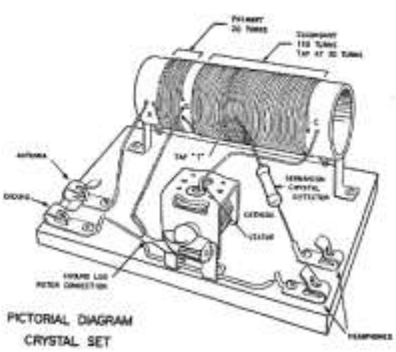
Since the crystal set is the simplest of all receivers, it is a good idea to build one as your first step on the road to radio skill. A crystal set offers several advantages to the beginner. It requires only a few inexpensive components, very simple wiring, uses no power, and operates indefinitely. The diagrams on the following page show just how simple it is to build. The set described in these diagrams is available in kit form at Allied. The kit includes a fixed-type germanium crystal, permanently adjusted to the most sensitive point.

Best results are obtained when using a good high antenna of fifty feet or longer; the ground connection can be made to a cold water pipe. Headphones used should have an impedance of 1000 ohms or greater. Headphones and antenna, available as accessories, are also listed in the Allied catalog.

knight CRYSTAL SET KIT



SCHEMATIC DIAGRAM
CRYSTAL SET



PICTORIAL DIAGRAM
CRYSTAL SET

What Next?

Crystal sets detect signals without providing any amplification. For this reason, they do not have enough sensitivity to receive really weak stations. The Knight-Kit "Span Master" 4-Band Regenerative Receiver Kit which is described on pages 36 and 37 of this book has sufficient sensitivity to receive standard broadcast stations from all over the country, as well as foreign and domestic shortwave stations. The "Span Master" receiver makes an excellent and worthwhile project after completing assembly of the crystal set.

The construction of a modern superheterodyne broadcast receiver should be quick and easy for anyone who has gained some wiring and soldering experience. The Knight-Kit 12-In-1 Electronic Lab Kit described on pages 33-35 is an excellent training kit. When you are ready to build a superhet, you'll find the Knight-Kit "Ranger III" described on pages 38 and 39 an up-to-the-minute set, worthy of consideration.

The electronic lab kit mentioned above permits building any one of 12 interesting electronic gadgets, including a simple regenerative standard broadcast receiver. This kit offers a very wide scope of experience and certainly warrants consideration by the beginner.

The Radio Spectrum

The table below covers only the major portion of the radio spectrum. Above 545 meters, there are weather report and time signal stations, aircraft beacons, and some foreign long-wave stations. Below 10 meters, there are Television, FM, Aircraft, Amateur and Police Stations.

The tuning range of Short Wave sets varies according to the range of the coils used. Usually, this range is from about 9.5 to about 217 meters, and covers Amateur stations, police calls, ships-at-sea, airplane calls, commercial radiophone transmission, and foreign Short Wave stations.

Kilocycles	*Meters*	*Types of Stations and General Characteristics*
550 to 1500	545 to 200	BROADCAST BAND—Local standard broadcast stations. Cross-country reception during ing evening and early morning hours.
1500 to 5770	200 to 52	INTERMEDIATE SHORT WAVE BAND—Police, Amateurs, aircraft, foreign broadcasting stations. Best reception during evening and early morning hours.
5770 to 30,000	52 to 10	SHORT WAVE BAND—Amateurs, foreign broadcasting stations, commercial telegraph, ships-at-sea. Best reception during daylight hours.

In the above table, the frequency of each band is given in kilocycles. This is a common practice below 10,000 kilocycles. However, above this figure, the numbers tend to become cumbersome and the larger unit of megacycles is used. 1 megacycle is equal to 1,000,000 cycles whereas 1 kilocycle is equal to 1,000 cycles. Thus, 10,000 kilocycles are equal to 10 megacycles, 20,000 kilocycles are equal to 20 megacycles, etc.

Types Of Circuits

The chief characteristics to be looked for in any radio set are: selectivity (ability to separate stations); sensitivity (ability to pick up weak signals); stability (ability to stay dependably tuned to a signal); and fidelity (ability to reproduce exactly what is put on the air from the transmitter).

The most selective type of circuit is the Superheterodyne. It provides, in greatest measure, all the desirable characteristics in radio.

The Tuned Radio Frequency (T.R.F.) circuit is one in which R.F. amplifier circuits are tuned to the desired frequency by varying inductance or capacity. This circuit offers good fidelity, but is less selective than the superhet.

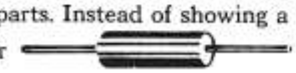
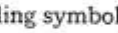
The Regenerative circuit is the third chief type. In such a circuit, in effect, sensitivity is greatly increased by returning some of the amplified signal for still more amplification. A regenerative-type circuit is less selective than a superhet. For the purposes of the beginner, the Regenerative circuit is probably the best because it is easiest to wire, most inexpensive insofar as parts are required, and selective and sensitive enough for ordinary use.

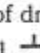
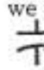
How To Read Schematic Diagrams

Now, if you have already turned ahead to look at the diagrams in the latter portion of this book, you will have seen that they consist of numerous symbols, lines, circles, and arrows, with occasional labels in words or letters. Let us see why radio circuits must be represented in terms of such symbols.

In the first place, you will agree that some sort of diagram or blueprint is necessary as a basis for construction work. The function of such a diagram is, of course, the same as that of any blueprint used in constructing a desk, a table, a ship model, or a house. You want to know just how every part fits together. You want to have an accurate guide to follow.

The circuits described in detail later on are shown in both pictorial and schematic forms. Pictorial diagrams are the easiest to follow and enable you to quickly determine the layout of all parts. Since pictorial diagrams require a great deal of effort and the skill of an artist to make, they are seldom used. Instead, most magazine construction articles, most radio handbooks, and even beginners' manuals employ what are known as schematic diagrams.

The symbols used in schematic diagrams are explained in the chart on the next page. These symbols are merely a kind of shorthand to represent component parts. Instead of showing a picture of a fixed resistor  every time this part is used in a circuit, we employ the corresponding symbol, . This symbol always means a fixed resistor. If you will turn ahead to one of the diagrams at the back of this book, you will easily be able to pick out the portions of the circuit in which a fixed resistor is used.

Again, instead of drawing a picture of a capacitor we use the symbol  ; or, for a variable capacitor  ; and so on. Examine the chart of symbol explanations shown on page 10. Once you understand the meanings of the symbols, radio circuit diagrams will no longer seem mysterious to you. You might also refer to your Allied catalog to see what the actual items look like.

Since you will frequently find it necessary to use symbols in drawing circuits by yourself it is also advisable for you to obtain practice in drawing these symbols as well as in recognizing them. It is suggested that you first learn how to draw the individual symbols—memorizing them as you draw them. After a time, you will find it beneficial to copy an entire diagram so that you can gain proficiency in arranging the elements in a diagram. After sufficient practice, you ought to be able to draw simple diagrams from memory.

When constructing a unit from a diagram, always work systematically. Read the diagram step by step, checking off each part, wire and connection as it is installed. Mount parts in logical sequence, so that those connnected first will not interfere with installation of the rest.

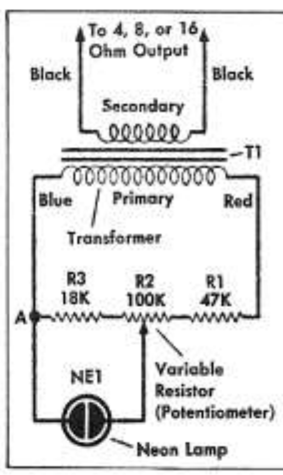


Figure 1. A simple schematic diagram.

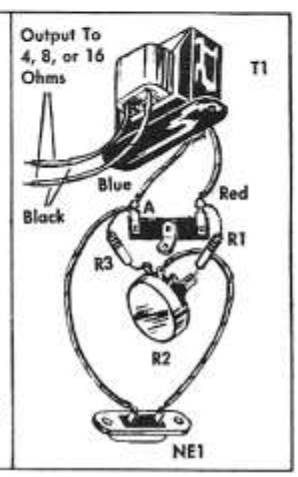


Figure 2. Pictorial diagram of the circuit of Figure 1.

An illustration of a schematic diagram and its associated pictorial counterpart is shown in Figs. 1 and 2. Let us consider Fig. 1 first. This circuit contains a transformer, three resistors of which one is variable, and a neon bulb. The three resistors are connected so that one fixed resistor attaches to one side of the variable resistor and the other fixed resistor attaches to the other side. This combination is then hung across one transformer winding, the side with the red and blue wires. Finally, the neon bulb is connected across the 18,000-ohm resistor.

Now compare the schematic diagram of this circuit with the pictorial diagram in Fig. 2. A good place to start is with the red and blue wires coming from the transformer. The blue wire connects to a soldering lug on a small terminal strip. One side of the neon bulb goes to the same lug, as well as one wire from the 18,000-ohm resistor. At this point the three wires would be soldered together. To identify this point in the pictorial diagram with the same point in the schematic diagram, both have the letter A.

We might stop here and note that the small terminal strip is found only in the pictorial diagram; it does not appear in the schematic diagram. This is because this component is not necessary to the circuit. Rather, it is a convenience item designed to make it easier to wire several parts together. We could take the three wires from the transformer, the neon bulb, and the 18,000-ohm resistor and simply twist them together in mid-air and obtain the connection that way. However, this is not a secure way of wiring a circuit. Much more desirable is a rigid point, such as a terminal lug, to which all three wires can be solidly attached. Such tie points are quite common and found in all but the simplest circuits. Note, however, that they seldom appear on the schematic diagram.

Incidentally, another item not shown in the schematic diagram is the chassis on which all the parts are mounted. However, a chassis is always used and so this is understood.

The second lug on the terminal strip in Fig. 2 holds the red wire from the transformer and one end of resistor R1. The other end of R1 attaches to one end terminal of variable resistor, R2. The other end terminal of R2 has the unattached lead from R3 connected to it. This still leaves the center terminal of R2 free and if we carefully examine the schematic diagram of this circuit, we note that one wire from the neon bulb goes here. With this final connection, the circuit wiring is complete.

While the foregoing deals with a very simple circuit, it covers all the elements of wiring that any other circuit, simple or complex, would follow. The only significant difference would be the number of connections that would have to be made.

Some Theoretical Background

At this point we shall take time to discuss, briefly, some of the theoretical considerations which underlie the whole science of radio. We shall not go into too great detail, but we shall describe radio theory to the extent necessary for your purpose as a radio-builder.

To begin with, radio and electricity are both branches of the science of Physics, which the dictionary defines as:

> The science that treats of the phenomena associated with matter in general, especially its relations to energy, and of the laws governing these phenomena, excluding the special laws and phenomena peculiar to living matter (biology) or to special kinds of matter (chemistry). Physics is generally held to treat of (1) the constitution and properties of matter, (2) mechanics, (3) acoustics, (4) heat, (5) optics, and (6) electricity and magnetism.

The force of electricity plays a leading role in making possible the whole range of radio transmission and reception. In the first place, your home radio depends on the electrical power line or on batteries (which are reservoirs of electrical power) for operating current. This electrical power may be changed in form and increased or decreased in voltage (electrical pressure) before it is made to serve the circuit. In the second place, besides this external electrical energy, the incoming electro-magnetic waves striking the antenna of your radio produce minute but definite electrical currents in the input circuits of the radio receiver.

Electricity itself is a mysterious agent made to serve our needs in many ways. While we are able to control and use this energy quite safely, we really do not know exactly what it is. Over a period of years, however, scientists have been able to devise a useful theory which fits all the facts and is now generally accepted.

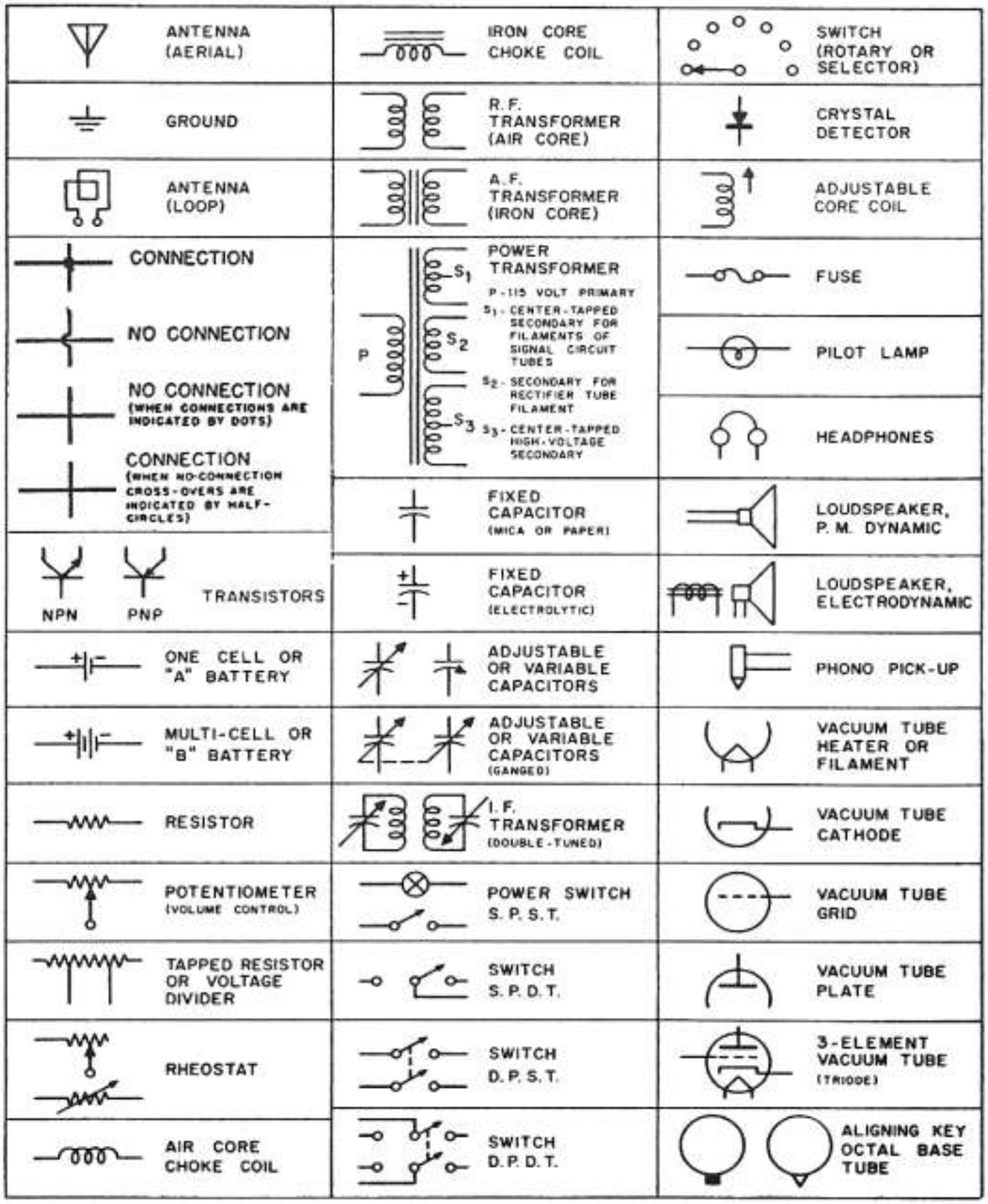
The Electron Theory

Briefly, this theory might be summarized somewhat as follows: All matter in the world is made up of about 100 fundamental materials called elements. These include such familiar elements as oxygen, hydrogen, carbon, gold, etc., and some rare substances known as radium, tungsten, yttrium, helium, etc. A combination of these elements yields other

SCHEMATIC SYMBOLS USED IN RADIO

The symbols below are standard in radio, TV and electronics diagrams. Popular components are represented. An industry-wide attempt is being made to standardize schematic diagrams. All current diagrams will be enough like these to easily identify the components. Note the two methods used to indicate a wire connection and a crossover. Both are in common use, but the curved wire crossover and dotted connection is preferred.

The symbol for a ground point may indicate an actual connection to the metal chassis, or a connection to a common lead, usually the B– voltage point. All ground points may usually be assumed to be connected together electrically.



substances; for example, hydrogen and oxygen, combined in proper proportions, result in water. The elements themselves are composed of a number of atoms. No one has ever seen an atom, since even the most powerful microscope cannot magnify an atom sufficiently to make it visible.

If an atom could be isolated, however, we should find, according to modern theory, that it is made of a central body of positively charged electricity consisting of a number of protons, surrounding which are bodies of negatively charged electricity called electrons. The opposing electrical forces in the proton and electron serve to keep the atom united. Electrons and protons are the same in all atoms. The difference between atoms lies in the number of electrons and protons which make up the atom and in the method of their combination.

Each electron, of course, is very small, and millions upon millions are required to form the current used to heat the filament of a single radio tube.

Electrons exist everywhere in nature and free electrons tend to be present in equal numbers in all places. If a body has more electrons than surrounding bodies it is negatively charged. But if a body lacks sufficient electrons to be neutral, it will be positively charged. Now, if a positively charged body is brought into contact with a negative body, there will be a flow of electrons from the negative to the positive (see Fig. 3) until both bodies will become neutral (that is, both will have an equal number of electrons). In short, electrons, being negative in potential, are always attracted to a positively charged body.

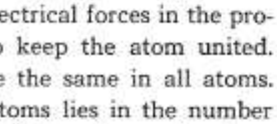


Figure 3. Diagram shows flow of electrons.

The charged bodies need not be brought into direct contact for the electrons to flow—a wire which acts as a conductor may be used instead. Practically all metals are good conductors of electricity. Silver is the best, but since it is too expensive for ordinary use, the next best conductor, copper, is widely used.

Resistance

Any conductor, however, has a certain amount of opposing force to the passage of electrons. This opposition is known as resistance. Silver or copper wire has very little resistance (which is why copper is so extensively used for carrying electrical current). Iron wire, on the other hand, has quite a bit of resistance, and may become hot when many electrons are retarded in their passage. Heavy thick wire—which permits the easy passage of millions of electrons — has less resistance than fine, thin wire of the same material—which slows up the electron flow (See Fig. 4).

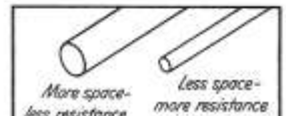


Figure 4. Relation of wire-size to resistance.

Some substances other than metals have extremely high resistance; they permit very few electrons to pass. Some of these substances are rubber, bakelite, glass, and porcelain. Because of their high resistance they are used as insulators. There is no such thing as an absolute non-conductor.

The unit of measurement for resistance is the ohm. Assume that we have a battery of one volt connected to a wire of one ohm resistance. Then an electrical current of one amp will flow. You can see, now, that the voltage, the current, and the resistance of any circuit are inter-related. In Direct Current circuits, this relationship is expressed mathematically according to Ohm's law: $E = I \times R$. In this formula, each symbol stands for one factor; E for voltage, I for current in Amperes, and R for resistance in ohms.

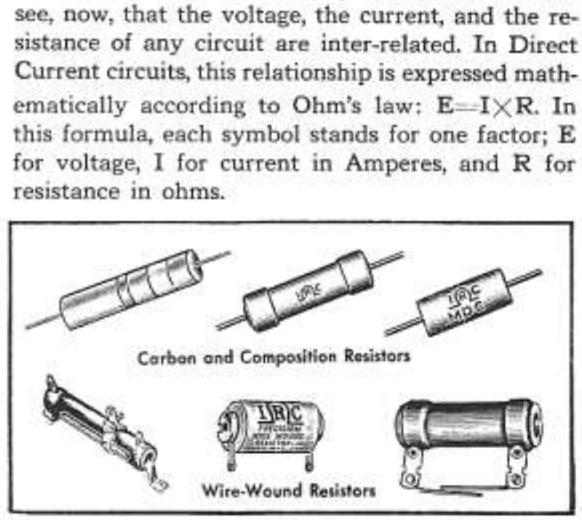


Figure 5. Several different types of fixed resistance.

Commercial resistances, or resistors, possess a variety of physical shapes, some of which are shown in Fig. 5. The two most common types possess either carbon or composition construction. They occur largely in the tubular form shown in Fig. 5 and are available in a wide range of values from a few ohms to many millions of ohms. The values may either be printed in figures on the side of the resistor body or a color code may be employed. For the latter, the Electronic Industries Association (EIA) has adopted a standard system assigning numbers to specific colors to indicate the resistance value. Since resistors are used in all radio circuits, it is important that the radio beginner learn how to read this color code.

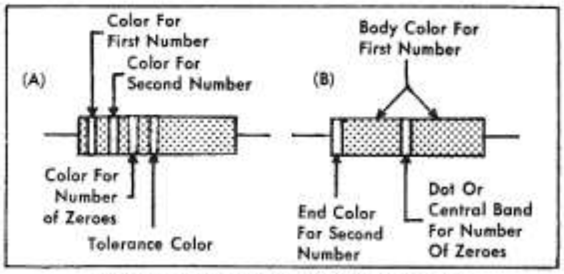


Figure 6. Two ways of color-coding resistors.

Most manufacturers use three colored bands painted at one end of the resistor. See Fig. 6A. Reading from left to right, the first band indicates the first figure, the second band the second figure, and the third band the number of zeros following. For example, if the colors on a resistor are Red, Violet and Orange, its value is 27,000 ohms (2 for Red, 7 for Violet, 000 for Orange). The table below indicates all color and figure combinations.

First Band (1st Figure)	Second Band (2nd Figure)	Third Band (3rd Figure)
0—Black	0—Black	None—Black
1—Brown	1—Brown	0—Brown
2—Red	2—Red	00—Red
3—Orange	3—Orange	000—Orange
4—Yellow	4—Yellow	0000—Yellow
5—Green	5—Green	00000—Green
6—Blue	6—Blue	000000—Blue
7—Violet	7—Violet	
8—Gray	8—Gray	
9—White	9—White	

A fourth band may be used to indicate tolerance, that is, a measurement of the maximum amount by which the resistor may vary from its rated figure. Silver indicates 10%, Gold 5%. 20% is indicated if no special tolerance band is present. A 10% or 20% resistor is commonly used in radio circuits unless close tolerance is specifically demanded.

Some manufacturers use another system, in which "Body", "End" and "Dot" colors are employed. See Fig. 6B. Body color indicates the first figure, an end color the second, while the dot represents the number of zeros following. Color values are the same as those in the other system.

A handy pocket-size guide with rotary discs showing band or body, end and dot colors of resistors according to EIA standard color-code can be purchased from Allied. This pocket guide shows the figure for each color on each scale so that resistance values can be obtained instantly.

Another important characteristic of a resistor which must be specified when resistors are purchased is the wattage rating. This indicates the ability of the resistor to dissipate the heat which is generated when current flows through it. The unit of measurement is the watt. The most common wattage ratings for carbon and composition resistors are ¼, ½, 1 and 2 watts.

The heat generated by a resistor is governed by two factors: the amount of current passing through the unit and the value of its resistance. Of the two, current is more important because if we double the current, we increase the power dissipation by the square of this or 4 times. On the other hand, if we keep the current the same and double the resistance, the power dissipated also rises by a factor of 2.

It is important that the proper wattage rating be specified, because a resistor with too low a rating will soon char and burn out. On the other hand, there is no point in using a resistor with a much higher than needed rating because cost rises rapidly with power rating.

Generally speaking, the longer and wider a resistor, the higher its power rating.

Another type of resistor that is widely used because of its ability to be designed with high wattage ratings is the wire-wound resistor. This can either be fixed in value, or come with a central slider ring that enables the user to obtain various resistance values from zero up to the full value of the unit. In general, these resistors are not available with values as high as carbon or composition resistors, but they are seldom required above 100,000 ohms. They find their greatest application in power supply circuits where high currents prevail.

Wire-wound resistors are seldom color coded; rather their actual value is stamped somewhere on the unit. In the higher wattage ratings, these units may possess a hollow core to assist in dissipating the heat generated.

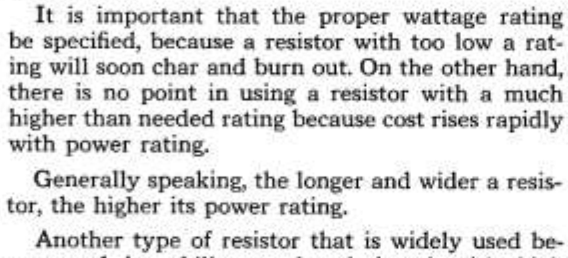


Figure 7. Several types of variable resistors.

Also part of the resistor family are the potentiometers and rheostats shown in Fig. 7. These units are circular in shape, with a central arm that has a shaft attached to it. When the unit is mounted on a chassis, the shaft protrudes far enough out to enable it to be grasped and rotated. The movable arm makes contact with the internal resistance element of the rheostat or potentiometer and, as it rotates, the amount of resistance between the arm and either end terminal varies. Thus, if we place a certain voltage across the unit, we can pick off any portion we desire simply by rotating the arm.

This, incidentally, is the way the volume control (which is a potentiometer) on a radio set operates. Potentiometers and rheostats are used also for tone, contrast and brightness controls, to mention a few of their more common applications.

Potentiometers and rheostats are similar in many respects, their chief difference being the fact that in a rheostat, only one end terminal and the center arm are electrically connected into the circuit. A potentiometer has both end terminals and the arm active in the circuit.

The Battery

In the early days of radio, batteries were used as the source of power. Even today in communities not yet reached by power lines, battery-operated radio receivers of the modern type afford facilities for quality reception.

Batteries are simple chemical machines producing electrical current from a chemical reaction. A battery consists of a number of cells, each cell producing a quantity of electricity. The ordinary flashlight cell, for example, produces $1\frac{1}{2}$ volts. In such a battery the zinc can is used as the negative terminal, and a carbon rod in the center of the cell is used as the positive terminal. Inside the cell are a number of chemicals; a chem-reaction takes place each time current is drawn from the battery. The larger "B" batteries are simply composed of a number of these smaller cells connected together.

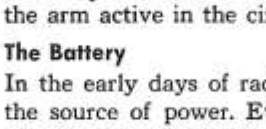
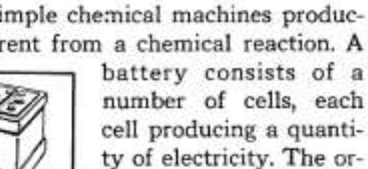


Figure 8. Electric power is obtained from battery or light outlet.

Figure 9. Common dry-cell batteries.



There are two chief types of batteries. One which produces electrical current of itself until it is discharged, and must then be discarded, uses primary cells. This is the familiar dry cell described above. The other, the storage battery used in automobiles and for radio service, is known as the secondary cell type. It acts as a reservoir of electrical energy. First, the electricity must be "poured" in—that is, the battery must be charged. After the battery has been charged, electricity may be drawn out until the battery becomes discharged, at which time it must be charged again, and so on.

Magnetism

Another force closely related to many radio and electrical components is magnetism. Transformers, motors and generators, loudspeakers, relays, and other radio parts, operate on the principle of magnetism. Since magnetism is similar to electricity, we cannot really see it or feel it, but its effect can be detected and accurately measured.

As you already know, a magnet will attract objects made of iron or steel. This is accounted for by the fact that any magnet has two poles of opposite polarity (that is, of opposite force). When two separate magnets are brought together, the like poles will repel each other, while the unlike poles will have a strong attraction for each other. This is the same as the action of electrons and protons. Since the entire earth may be considered as a giant magnet, a compass using a small magnet on a pivot will tend to point to the North and South Poles.

One of the laws of magnetism we might mention is that the force of attraction and repulsion between two magnets is inversely proportional to the square of the distance. North and South magnetic poles will attract each other four times as much at a distance of one inch, as at a distance of two inches. When a magnet is dipped into iron filings, most of the filings stick to the poles, indicating that the force of attraction is greatest at the poles (Fig. 10).

Magnetism may also be produced by the flow of electrical current through a conductor. Every wire which carries electrical current has a magnetic field around it proportional to the current strength and the placement of the wire. By winding a number of turns of wire in the form of a coil, a much stronger magnetic field can be produced, since the field of each individual turn will add up. And, since the magnetic field of force of each turn is added to that of the next turn, the greater the number of turns of wire, the stronger the magnetic field.

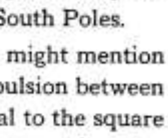


Figure 10.

The total magnetic flux (lines of force) depends on the number of turns and the strength of the current. If the current is strong, relatively few turns of thick wire will be required. On the other hand, if the current is weak, a great many turns of thin wire will be needed for the same magnetic force.

A stronger electromagnet can be made if a bar of iron is placed in the center of a coil, since the lines of force produced will be concentrated and stronger magnetic action will result. In any electromagnet, of course, the magnetism will be lost immediately when the current is shut off, whereas in natural magnets the magnetism is more or less permanent.

Inductance And Reactance

The property of a coil to set up a magnetic field when current is flowing through it is called inductance. Such a coil tends to oppose any changes in current intensity.

The opposing force of an inductance, known as reactance, is directly proportional to the inductance of the coil. The inductance is measured in units called henries, while the reactance is measured in ohms. (In radio work, the henry is rather too large, and so the millihenry—one thousandth of a henry—and the microhenry—one millionth of a henry—are commonly used terms.) The same inductance will have a greater reactance at a higher frequency. This is why an R.F. choke will have a "choking" effect on high radio frequencies, but will permit low frequencies and D.C. (direct current) to pass unobstructed.

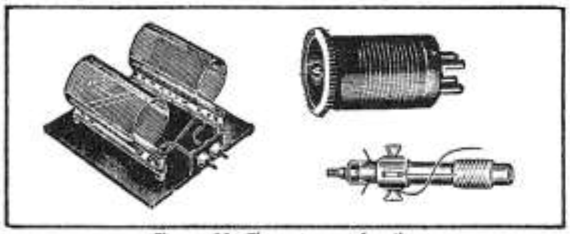


Figure 11. Three types of coils.

Some of the forms and shapes that coils take are shown in Fig. 11. For low-frequency operation, as in the power supply section of a receiver where the operating frequency is either 60 cycles or 120 cycles, iron-core coils known as chokes are used. At much higher frequencies, such as those found in the signal tuning circuits of a receiver, the coils either have nothing but air at their center (hence known as air-core coils), or else they possess small powdered iron cores. In general, the high-frequency coils tend to be smaller in physical size than the low-frequency coils.

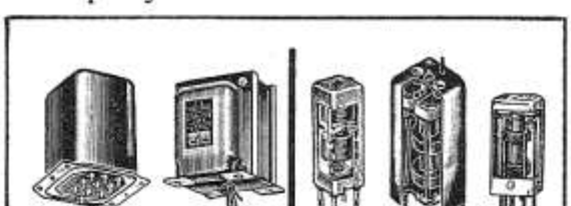


Figure 12. Low and high-frequency transformers.

The name coil is reserved generally for inductances having a single winding. When two or more coils are wound on one form so that their magnetic fields interact, the combination is known as a transformer. As with coils, low-frequency transformers (such as the power transformer in a receiver) possess iron laminations (see Fig. 12A); at higher frequencies the core may either be air or powdered iron. (See Fig. 12B).

So far, in talking of electric current, we have assumed that it is a steady flow of electrons in one direction. However, unlike Direct Current, which is a steady flow in one direction, Alternating Current (A.C.) is constantly varying in intensity and in direction. A.C. current—as the name implies—flows first in one direction and then in the opposite direction. The change in direction does not occur abruptly. In one-half a cycle the voltage and current will rise from zero to a peak value and go down to zero again. Then, without stopping to take a breath, it starts in the opposite direction, rising to a peak value and then decreasing to zero. This completes the cycle (Fig. 13). The same variations go on as long as current is flowing. In 60 cycle current, which is now largely standard for power circuits in the United States, these complete cycles take place sixty times each second. In radio circuits the changes (frequency) may take place many thousands or even millions of times per second.

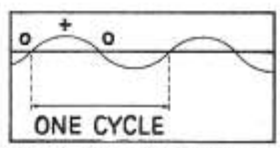


Figure 13. The alternating current cycle.

Capacitance

Two similar metal plates facing each other, but separated by air or a thin piece of insulation (dielectric), form a capacitor. If such a capacitor is connected to a battery, electrons will flow from the plate connected to the positive terminal of the battery, through the battery to the opposite plate. By disconnecting the battery and shorting the capacitor, the electrons will pass back through the shorting wire and on to the other plate again. (Fig. 14).

Capacitance (storage ability) of a capacitor depends on three factors: (1) size of plates, (2) spacing of plates, and (3) the dielectric used. The larger the plate area, of course, the greater the capacity.

The unit of measurement is the farad. However, one farad of capacity is a much higher value than is ever used commercially; therefore, the microfarad (millionth of a farad) or the micro-microfarad (millionth of a microfarad) is used. These are abbreviated thus: mfd, mmf (or mmfd).

Different dielectrics give different total capacities, even though the plates and spacing are not altered in any way. If a capacitor has a given capacity with air as the dielectric, it will have seven times the capacity with mica substituted as the dielectric. The dielectric constant of air is taken as 1, of mica as 7; other substances have their corresponding dielectric constants.

Capacitors not only store up energy, but are also important in radio work for another reason. If a capacitor is connected in a circuit with direct current being supplied, it permits the current to flow only for a very short time while it is being charged. If alternating current (see Fig. 13) is supplied, the capacitor will permit the current to flow through the circuit. Thus, a capacitor which permits A.C. to flow, but does not allow D.C. to pass through, is called a blocking capacitor; one which permits A.C. to pass through a shorter path than D.C. would follow, is called a by-pass capacitor.

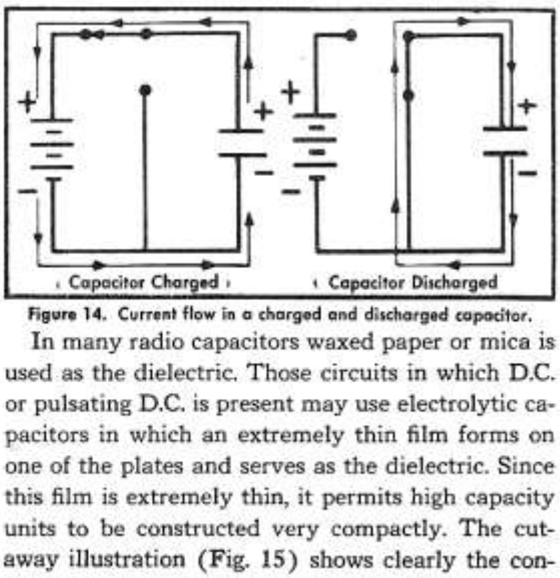


Figure 14. Current flow in a charged and discharged capacitor.

In many radio capacitors waxed paper or mica is used as the dielectric. Those circuits in which D.C. or pulsating D.C. is present may use electrolytic capacitors in which an extremely thin film forms on one of the plates and serves as the dielectric. Since this film is extremely thin, it permits high capacity units to be constructed very compactly. The cutaway illustration (Fig. 15) shows clearly the construction of an electrolytic capacitor. The cathode and anode foils are the plates.

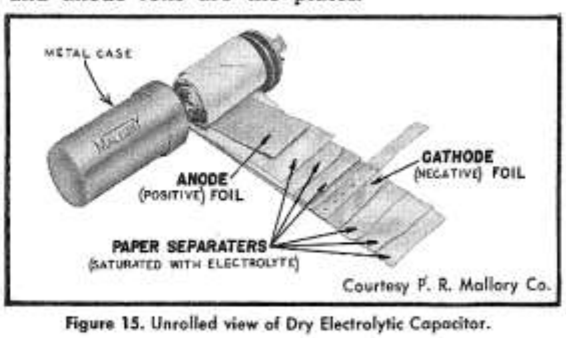


Figure 15. Unrolled view of Dry Electrolytic Capacitor.

The chemical nature of electrolytic capacitors adapts them particularly to use in power supply circuits which deliver up to 600 volts D.C.

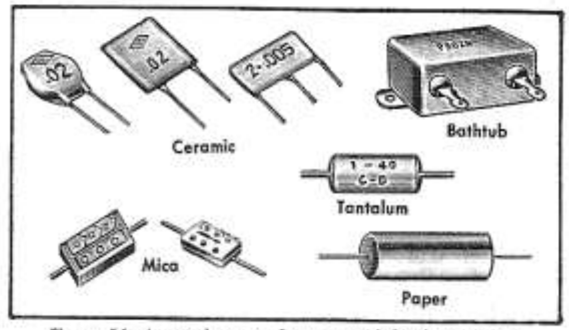


Figure 16. Assorted types of commercial fixed capacitors.

A wide variety of other commonly used capacitors is shown in Fig. 16. The names of most of these are derived from the type of dielectric employed internally, i.e., mica, ceramic, metallized paper, etc. Others are designated according to shape, as "bathtub," tubular, disc, etc.

In specifying capacitors, two qualities are important, capacitive value and voltage rating. The latter figure represents the highest voltage that a capacitor should be subjected to. Thus, a 200-volt unit should not be used in any circuit where the voltage rises over 200 volts, even momentarily. While most capacitors possess a safety factor beyond the voltage stated, it is not recommended that this be taken advantage of.

Many small capacitors are color coded with the same code employed for resistors. For capacitors, all readings are in micro-microfarads (mmfd). A 250 mmfd (.00025 mfd.) would be coded as follows: red dot (2), green dot (5), brown dot (1 zero). Additional information on color coding for capacitors will be found in ALLIED's ELECTRONICS DATA HANDBOOK.

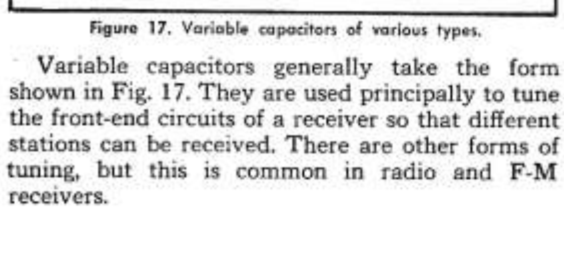


Figure 17. Variable capacitors of various types.

Variable capacitors generally take the form shown in Fig. 17. They are used principally to tune the front-end circuits of a receiver so that different stations can be received. There are other forms of tuning, but this is common in radio and F-M receivers.

The Parts Of A Radio Set And Their Functions

In the simplest language, a radio receiver is nothing more than a device to capture radio signals which travel through space and to reproduce them as audible sound.

These radio signals, of course, are emitted by the transmitter where the process is just the reverse of that in a radio receiver. In other words, a transmitter converts audible sound into radio signals and radiates these signals through space.

Now, how are these signals which we cannot see or hear or feel captured by the radio set and transformed from mere electrical impulses into the voice of a popular singer or the music of a renowned symphony orchestra?

This is a good place in which to explain the functions of the various radio parts so that when you come to a later section in which we tell you how to construct a set, you will understand why a great variety of parts is needed and what these parts do.

Broadly speaking, any radio receiving set uses all, or some, of the sections (stages) listed below, All are involved in changing those invisible, intangible radio signals into sound that you can hear. These sections are:

1—The Antenna
2—The Radio Frequency Amplifier
3—The Converter
4—The Intermediate Frequency Amplifier
5—The Detector
6—The Audio Frequency Amplifier
7—The Loudspeaker or Headphones.

And what, you will ask, do these do?

Consider first the Superheterodyne circuit. The antenna, which is a piece of wire, picks up radio signals which are travelling through space all around us at an approximate speed of 186,000 miles per second. This great speed explains why radio broadcasts can be picked up almost simultaneously by receivers located at opposite corners of the earth.

The strength of this signal on the antenna is only a few millionths of a volt—so it goes to the Radio Frequency amplifier to be strengthened. The **RF** amplifier is a tube in a circuit which can be tuned (by your radio dial) to provide maximum amplification on the frequency (station) you want to hear.

This amplified signal (from 30 to 100 times greater than the signal at the antenna) goes now to the converter where it is changed to a lower frequency which can be amplified more efficiently.

The new, lower frequency is called the Intermediate Frequency or **IF**. The **IF** passes through one or more stages, each consisting of a tube and a circuit, fixed tuned to the **IF** (usually 455 kc).

Now amplified from 100 to 150 times, the **IF** goes to the detector, where roughly speaking, the carrier frequency (**RF**) is removed and only the Audio Frequency (**AF**) component remains. The detector is usually a diode-type tube.

Next the **AF** amplifier increases the strength of the **AF** signal so it can move the speaker voice coil or headphone diaphragm and—at last—cause audible sound.

In a Tuned Radio Frequency (**TRF**) receiver the procedure differs only in that there is no converter and no **IF** stages.

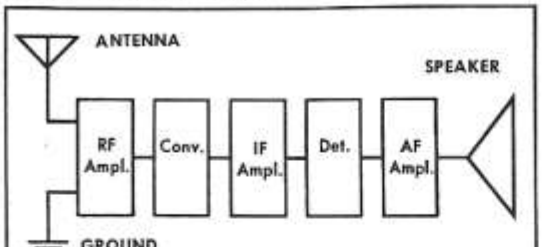


Figure 18. Parts of a radio circuit.

Actually, this whole process we have described takes place in a period of time so short that it can scarcely be measured. Practically speaking, the sound of the program you hear leaves the loudspeaker at almost the same instant it has entered the antenna as radio signals.

In order to operate the tubes used in a radio set, it is necessary to employ some form of electrical current, whether it be from batteries or from a regular electric outlet in the wall. If you live in a city, you probably have 110 volts 60 cycles Alternating Current. Since the tubes used in a radio set require direct-current power to make them operate, it is necessary to transform and convert the incoming voltage to the proper type and amount needed for the tubes.

This is the function of the transformer, the rectifier, and of the filter network in the set. These components make up what is called the power supply.

Capacitors and coils, when used together, comprise what we call the tuned circuits. When adjusted by the knob controlling the capacitor to the frequency or wave length of the station wanted, the tuned circuit passes signals from that desired station to the tubes, from which point the process goes on as we have already described it.

As for the remaining parts used in a radio set, we may say that a potentiometer is a type of variable resistor which is generally used as a volume control. A choke is a fixed inductance (see page 14) employed to prevent the passing of either audio frequency or radio frequency voltages, depending upon the type of choke used. Sockets are necessary to hold tube or coils in place and to permit correct wiring connections to be made to the various parts of the tubes or coils. A chassis base is needed to provide a foundation for the parts in the set. The dial is required so that we can revolve the tuning capacitor and locate stations at a definite point on the dial scale. Wire and hardware, including screws, cords, clips, plugs, etc., are needed to make the connections between the various parts of the circuit and to hold all parts rigidly in place.

By now we have said practically everything that the beginner needs to know about the various radio parts. Something more must be told about tubes—their various types and their functions—but we shall reserve that for a later section.

The Tools Needed For Radio Construction

In order to assemble the various parts of a radio set, you will require a number of simple, inexpensive tools. No doubt you already have some of these tools somewhere about your home.

Practically all the radio work encountered by a beginner can be taken care of with these tools:

- 1 soldering iron (60-100 watts) or soldering gun (100-250 watts).
- 1 pair of long-nose pliers
- 1 pair of diagonal cutters
- 1 screwdriver (5″ or 6″ size)
- 1 screwdriver (2″ or 3″ size)
- 1 drill kit, consisting of hand drill and assorted drills such as Nos. 11, 18 and 27
- 1 center punch
- 1 hammer
- 1 steel rule (12″ size)

Optional Tools

- 1 vise (4″ size)
- 1 hacksaw
- 1 square
- 1 file (medium coarse)

As a matter of fact, you can assemble many radio sets (for example, the Knight-Kits shown in the section beginning on page 33) with only three tools: screwdriver, soldering iron, and pliers. This is because special care has been taken to supply such kits in a form which will require a minimum of work and ingenuity on the part of the radio builder.

However, since punched and drilled chassis are not always available as, for instance, in the construction of most circuits described in the various radio magazines, the three essential tools will not be enough. You will need to make use of most or all of the tools listed above.

Care Of Soldering Irons And Guns

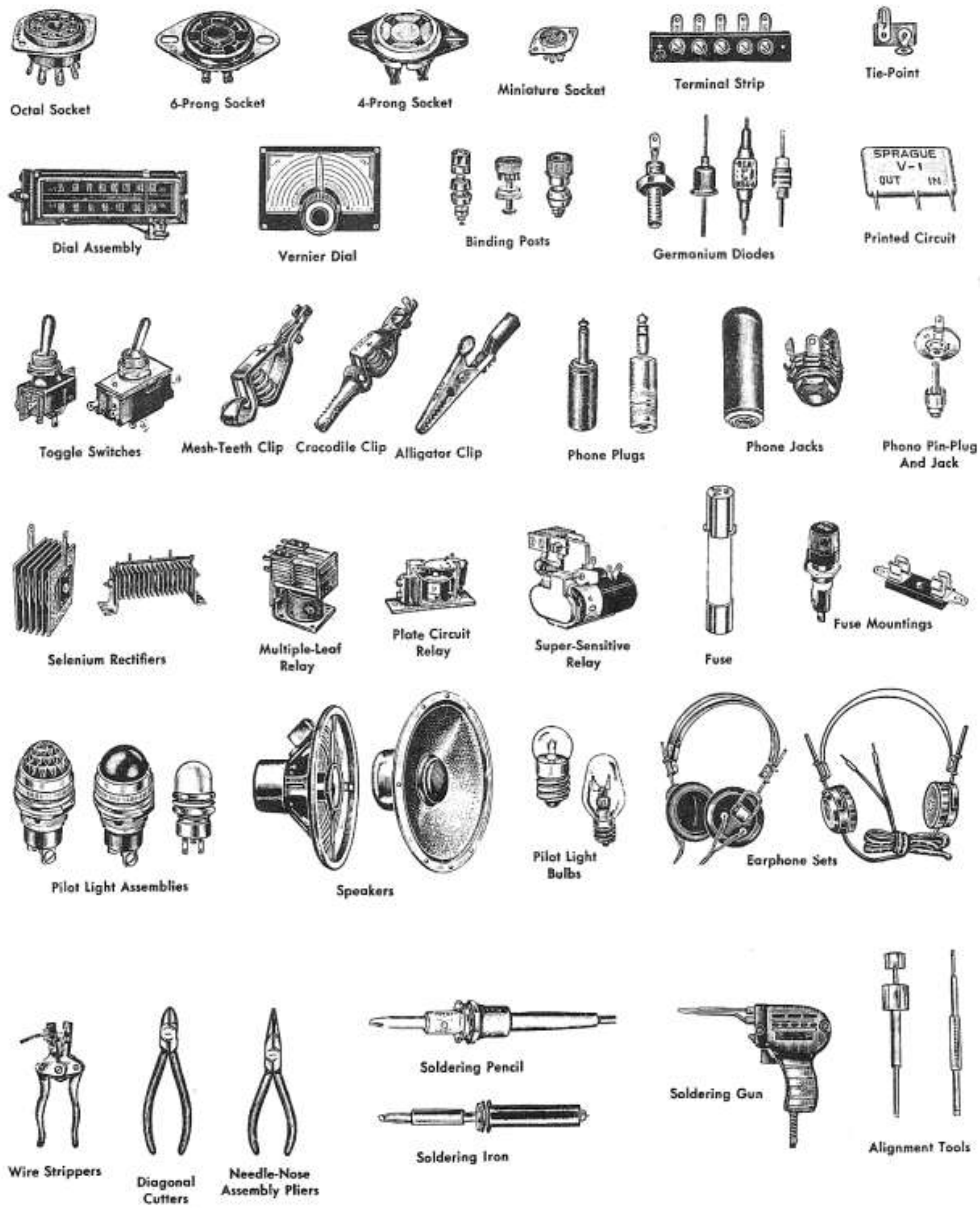
In the construction of a radio set, or practically any other electronic equipment, wire connections to sockets, coils, terminals, and to printed circuits are made by means of soldering. Since this equipment cannot perform properly, or may not operate at all if solder connections are poor, it is important that your iron or gun be kept in good working condition. The soldering iron or gun is the most frequently used and most important tool in electronic assembly — with proper care it will do a fast, efficient job and should give you years of dependable service.

When you buy a soldering iron, it will have a clean, shiny copper tip. Before using the iron, be sure to melt solder over the entire exposed surface of the tip, until it is covered completely with a coating of solder. This process is called "tinning." Tinning not only protects the tip from oxidation, but also makes for easier, more efficient soldering.

The tip of a soldering iron should always be cleaned and well tinned. If it gets black and crusty, this means that it is being oxidized and that cleaning is necessary. To clean the iron, wipe the tip with a heavy piece of cloth or felt which you may fasten to your workbench. However, if the tip has been allowed to become badly oxidized, the crusty material, as well as any pit marks which appear, should be removed with either a file or sandpaper. After restoring the tip to a smooth finish be sure to recoat any bare copper surfaces with solder.

Soldering guns require very little care. Since the tip is hot only for very brief periods during actual soldering, tip oxidation seldom presents a problem. However, if the tip does become oxidized, a file or piece of sandpaper may be used to remove the crust, or any pits, which may have developed.

Common Radio Parts And Tools



Getting The Right Chassis Base

If you look into the cabinet of your home radio set you will notice that all of the tubes and other parts are mounted on a metal base. This is known as a chassis base. All commercially built radio receivers use a base of this type. Chassis bases, made of either steel or aluminum, are commonly used in radio work. Aluminum chassis are excellent for most applications and are particularly recommended for beginners, since aluminum is soft and can easily be cut and drilled with hand tools. Though not as rigid as steel chassis, aluminum chassis provide plenty of strength for most uses. Aluminum is, of course, substantially lighter in weight, and this is advantageous when equipment must be as light as possible. Steel chassis bases are excellent where high rigidity is required, such as for circuits where heavy components are used.

Many experimenters prefer using a wood base. A piece of wood, about half an inch thick, sandpapered to a smooth finish and stained, is all that is needed. Parts are mounted on the surface of the board with wood screws and no drilling or punching of the base is necessary. The use of a wood base is a simple, low-cost means of working on experimental circuits, since if any changes in wiring must be made, parts can easily be moved without the necessity of drilling or cutting new holes. Then, after all "bugs" are removed from the circuit, it can be reassembled on a regular metal chassis.

Preparing The Chassis Base

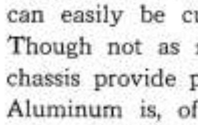


Figure 19. Typical punched and drilled chassis base.

If you use the proper tools you will find that the chassis bases can be rapidly prepared for mounting the necessary radio parts. These tools are low priced and are designed especially to permit ease in use.

The first step is to determine what size chassis base will be needed. If the construction article or parts list from which you are working does not tell you this, it is advisable to lay out the parts to be used in the set on a table and experiment with placement until you have a neat layout permitting short leads. Then estimate what size the surface of the base must be.

Whenever holes are to be drilled in metal, always use a center punch first to locate the exact center of the hole. A valuable guide in this job is a heavy sheet of paper on which an outline of the components, in their exact locations, has been plainly traced. This sketch may easily be fastened to the metal chassis by using gummed paper or adhesive tape. The holes may then be punched through the paper and you will thus avoid marring or scratching the metal surface.

Some care should be taken to get the measurements of the holes as accurate as possible. If the holes are too large, the parts will not fit properly.

To cut out the holes you can use either a drill or a hole-punch. Holes smaller than $\frac{3}{16}$ of an inch can easily be made with a drill. Larger holes should first be made with a small drill, after which larger drills are used to enlarge the hole until the proper size is reached. A circle-cutter or a radio chassis punch is also useful for this work. When cutting holes for tube sockets, a socket punch is the fastest, most convenient tool. Socket punches are available in various diameters to permit cutting holes for the different types of tube sockets used.

Figure 20. A circle cutter is handy for cutting round holes from $\frac{5}{8}$ inches up to 8 inches.

When all holes have been drilled, file or ream off the burrs. You can also give your panels and chassis a professional appearance by painting them with one of the air-drying crackle varnishes or lacquers which are now available in many popular colors.

Mounting The Parts

One aspect of radio building which sometimes puzzles beginners unduly is that of actually mounting the parts on the chassis base. To clear up any vagueness you may have on this subject, we shall talk about this problem now.

In the first place, the chief idea to keep in mind when mounting parts on a chassis is this: Always arrange the layout so that all leads will be as short and direct as possible. Above all, the grid and plate leads must be very short. The reason for this is to assure best operating results, because long leads will result in excessive coupling and stray pick-up, which may prevent the set from performing as it should.

Another point to remember is this: When placing parts tentatively for mounting, see that all controls are at the front panel. For example, the tuning capacitor and its associated dial should be mounted so that stations can be tuned from the front panel. In the same way the volume control, tone control (if any) and other controls such as a rheostat or potentiometer should always be placed so that the control shaft will protrude from the front panel. You can easily see why this is necessary—otherwise, you would have a good deal of inconvenience in operating the receiver.

If the set you are building is described in a magazine construction article, you will usually find an illustration showing how the parts are laid out. It is best to follow such a layout because the author of the article has undoubtedly spent some time in experimentation to assure best results. If you are working from a diagram of the pictorial type, you will also be given definite data as to how parts should be laid out. But remember—always try for the shortest possible leads.

In your first tentative layout of parts, you may find that better wiring facilities can be obtained by changing the position of two or three parts. Accordingly, juggle the parts around until you are sure you have the best possible plan. Then, but not before, go ahead with the final drilling and punching.

Place all mounted parts such as sockets, upright capacitors, transformers, etc., on the chassis in accordance with the holes you have previously drilled. Set in any screws or terminals which hold these parts in place. After all these parts are mounted, you can proceed with wiring.

Making Solder Connections

The performance and dependability of radio equipment depends, to a very great extent, upon the quality of solder connections. Faulty solder connections may result in complete circuit failure, intermittent operation, or poor performance. Therefore, it is of the great importance that you follow good soldering techniques when wiring your set.

As already mentioned, the purpose of soldering is to provide secure, dependable wire connections to sockets, coils, or to other wires. However, do not depend upon soldering alone to provide the correct connections. It is always necessary to hook the wire around the terminals first. Then, after a secure mechanical joint is provided, solder should be applied to seal the joint. Always hold the heated iron or gun to the joint (point of connection) until it becomes hot enough so that the solder, when applied, will melt when it comes in contact with the joint. When the solder runs freely over the joint, the iron or gun must be removed at once, without moving the wire. The connection will then be secure. Be sure to use only enough solder to cover the joint. If too much solder is used, and if it spreads over nearby insulation, it can result in either breakdown of the insulation or excessive electrical leakage between adjacent terminals.

Rosin-core solder should be used for radio connections. When this type of solder is heated, the rosin flux in its core spreads over the joint and removes any oxidation which might otherwise prevent the solder from adhering properly. Never use acid-core solder, since it will corrode the wire to cause a faulty, high-resistance connection.

Checking Your Work

As you proceed with the circuit wiring, use a colored pencil to check off on the diagram each step that you have finished. Unless you do this, you may find that you have omitted some essential bit of wiring and your set will not work. Every part and wire indicated on a circuit diagram is essential if the set is to operate correctly. Make it a habit to check your work as you go along. This will save time in the long run and will assure you of best performance from your radio set.

When you have at last finished mounting all parts, connected all leads, and checked your work, you are ready for the final test. Plug into the electrical outlet (or connect batteries if a battery set), turn on the switch, allow the tubes a few moments to heat up, and then operate the tuning control until you hear a station. If your work has been satisfactory, you will experience quite a thrill in listening to your first program coming in on a set you have built yourself.

Printed Circuits

Until a few years ago, the universal method of wiring a circuit was to use regular hook-up wire between the various components. In the interests of speed in production and in reliability, this method does have certain short-comings. During the war, however, a method was developed by the National

Bureau of Standards whereby the wiring for a specific circuit could be printed directly on the supporting board. Thereafter, the various components could be added easily, often by automatic machinery and then the entire assembly soldered in one dipping operation.

The use of this technique has a number of desirable features. It lowers the cost of manufacture because printed circuit boards can be prepared by automatic means. Furthermore, since all printed boards in a production run are identical, any wiring errors can be totally eliminated. With hand wiring, even using the most skilled workers, this is seldom possible.

Printed circuits are basically an electrical conducting pattern which has been laid down on an insulating support. The conductor is usually copper and the insulator is usually laminated plastic. The sheet of insulation is covered first with a thin layer or foil of copper bonded to one side. To form the necessary wiring, some of the copper foil is removed by a photographic or etching process. That is, the pattern of the wiring is first laid out on the copper foil by applying a chemical "resist" either a silk-screening process or photographically. Then the copper is bathed in an acid bath which removes all of the foil except those portions containing the "resist". The board is then washed to remove the acid, the "resist" is removed, and the result is the printed wiring. Holes are then punched in the board through which component leads are inserted. The component leads are soldered directly to the wiring pattern. The finished product is a circuit with uniform wiring, compact size and entirely without wiring errors.

The excellent operational qualities of printed circuits have led to their widespread use in Knight kits. Not only do they assure uniform quality, but they also shorten construction time considerably. However, since you are dealing with a finely-engineered product, precautions should be taken. Do not overheat the component terminals or the foil. Excessive heat, by applying the soldering iron longer than necessary, may cause the bond between the board and the foil to break. Too much solder may cause a short-circuit to develop between the point being soldered and an adjacent conductor, particularly since many of the printed wires are quite close together.

The Antenna And Ground

To obtain the best results from any radio set—whether a crystal set with earphones or big, deluxe superhet with loudspeaker—you must have a satisfactory antenna and ground connection.

It is impossible to state positively just what type of antenna is best. To determine which is best for any specific installation, you must consider such variable factors as the sensitivity, selectivity, and power of the radio receiver itself; the distance from the nearest broadcasting stations; the number of stations within the local area; the kinds and intensity of interfering devices such as electric flashing signs, trolley-cars, high power lines; the physical conditions which limit space for antenna installation, and so on. We can say, however, that in general for the smaller home-built sets in which good broadcast band reception is the goal, a suitable antenna is a single wire about 50 feet long, installed as high off the ground as possible. That figure—50 feet—should not be taken too literally. We suggest it only because it is about the correct length for a good many installations. If it is found that too many stations interfere and prevent good reception when a 50-foot antenna is used, it is advisable to shorten the antenna. On the other hand, after some experimentation, it may be found that a longer antenna offers better reception. So we say, the length of the antenna required for best reception can be determined only by "trial-and-error" methods.

The ordinary antenna for the beginners' sets may be a length of No. 14 or No. 12 (B. and S. gauge) enameled copper wire. The lead-in (the wire connecting the antenna to the radio receiver) should be a rubber-covered wire. The rubber covering prevents any possibility of grounding if the lead-in

Figure 21. Typical Antenna Installation.

comes in contact with a foreign surface. All contacts should be solid and secure. Loose contacts at lead-in or joint may cause noisy, intermittent reception. Solder the lead-in securely to one end of the antenna, and drop it down directly to the receiver where connection is to be made.

Antennas running in different directions do not have the same pickup patterns, especially on the higher short wave bands. Therefore, if you have plenty of space available, you may wish to install two or more antennas running in different directions to be sure of best possible reception. You will find that each antenna will favor signals coming from different directions. This will permit you to select the antenna which gives strongest reception for the specific station to which you are listening.

There are a number of points concerning which some specific cautions may be advisable:

1—Since the antenna is exposed to the elements, your installation should be strong and secure so that the first high wind which comes along does not blow the wires down. Poles affixed to buildings should be carefully set up and secured.

2—Not too much sway of antenna and lead-in wires should be permitted. If the antenna is installed during warm weather, however allow enough slack so that cold weather will not contract the wires so much that they will snap.

3—Try to prevent aerial or lead-in from touching anything: tree, building, etc. Such contacts cause signal leakage which will result in reduced volume.

4—If there is a high-power line or similar source of interference near your house, run the antenna at a right angle to the source of interference to minimize undesirable effects. Never install an antenna parallel to a high-power line if you want quiet reception from your radio.

Something too, should be said about insulators which are needed for a good antenna installation. There are several types of insulators, the best of which are of glass or glazed porcelain. One insulator should be used at each end of the antenna, and another (of the porcelain nail-knob type) should be used at the window where lead-in enters your house.

We have said the antenna should be installed as high off the ground as possible; a minimum of twenty or thirty feet is usually satisfactory. In the city this is easily done by installing the aerial on the roof of your building. In rural areas, one end may be strung from the roof of your house, and the other from a barn or outlying structure, or a pole.

Indoor aerials, in general, should not be used unless physical conditions are such that the alternative is either an indoor aerial or else none at all. Indoor aerials can never be as efficient as outdoor aerials and at their best are only a compromise. "Aerial eliminators" are not particularly useful if long distance reception is one of your aims, although they are frequently suitable for local-area reception.

A good ground connection is sometimes helpful in improving long-distance reception. Its purpose is to form the second plate of a capacitor, the antenna acting as the first plate. The capacitor is part of the open oscillatory circuit in which the signals flow. The ground wire makes the connection between the "Ground" post of your set and a metal pipe or rod, which is driven into or connected to the earth. Use a ground clamp which will assure a good solid connection. Suitable grounds are: a radiator pipe, a water pipe, or a rod of iron driven into the earth. The ground clamp should touch bare metal; paint or gilt should be scraped off of the pipe used for a ground at the point where the clamp is attached.

In addition to improving reception, a good ground connection should be used for another extremely important reason. Every outdoor aerial should be equipped with a lightning arrestor—and the proper operation of this arrestor is dependent upon the ground connection. Make it a must to install a lightning arrestor as part of your aerial. When properly installed, it will drain off static electricity in the region of your aerial and, thereby, prevent lightning from striking.

To conclude, we might mention the fact that people may tell you of the "marvelous" reception they got without using an aerial at all. That may be —but for consistently good reception, you cannot dispense with an aerial.

NOTE: Receivers of the AC-DC type—that is, sets which are designed to operate from either Alternating or Direct Current rated at 110 or 220 volts—do not have a power transformer in the circuit. Voltages from the power line are obtained directly. Accordingly, no ground connection should be used with an AC-DC receiver unless called for in the circuit.

Radio Tubes: Some Basic Information

Vacuum tubes are the heart of modern radio sets. Ordinarily a receiving tube consists simply of two or more electrodes within an evacuated glass or metal shell (Fig. 22). This glass or metal envelope is needed to maintain the vacuum inside the tube. The vacuum itself is necessary so that the electronic action in the tube can be regulated according to certain specified requirements and so that filaments will not burn out. Only in a vacuum can the flow of electrons to the electrodes be regulated.

As we have already explained (page 9), electrons, essentially, are tiny invisible charges of negative electricity which are capable of traveling at a speed of thousands of miles per second. These electrons make modern tubes possible. Without the constant, regulated flow of these tiny bits of electricity, a tube could not be operated.

Tubes contain several components. The cathode is the element in the tube which supplies the electrons. A directly heated cathode consists of nickel alloy wire coated with a special substance which gives off electrons when heated, The necessary heat is furnished by passing an electric current through the filament wire. (This is one reason for the fact that some kind of electric current—whether from batteries or from an electric outlet—is required to operate any radio set which employs radio tubes.) Examples of directly heated cathode tubes are these types. 1L4, 1R5, 1U5, 3V4 and 1LC6.

An indirect or "heater" cathode tube has a heater or filament inside a metal sleeve. This sleeve is coated with a special substance which emits the electrons. Most present-day A.C. tubes have heater cathodes.

A diode is a two-element tube with a cathode to supply the electrons and a plate to attract and receive the flow of electrons. This plate has a positive voltage applied to it. (Remember that, as we said before, electrons are negative charges; you can see, then, why the plate, which is charged positively, will attract these electrons.) Types 80, 5U4G, and 35Z5 are examples of rectifier diode tubes. Diodes are used most frequently as rectifiers or as special detectors.

A triode is a three element tube. The third element, called a "control grid", is located between the cathode and plate, close to the cathode. Its function is to control the flow of electrons to the plate. As electrons are negative electrical charges, they are repelled and prevented from passing to the plate when a negative potential is applied to the grid. When the potential to the grid is made less negative (or more positive) it permits electrons to reach the plate. A change of just a few volts to the grid is enough to permit or prevent passage of electrons. Thus, a small change in grid voltage is sufficient to control the large current passing through a tube and results in a high degree of amplification. Almost any desired level of amplification can be achieved by adding additional tubes. Commonly used types are the 6C4, 6C5, 6J5 and 7B4.

In actual operation the grid voltage is kept slightly negative to limit the flow of electrons. When you tune in a program from a radio station you are actually picking up a small electrical charge and adding it to the grid voltage now on your tube, thus making it sufficiently positive or negative to increase or decrease passage of electrons. This picked-up signal is not constant. It varies in accordance with the speech or music being fed into the broadcaster's microphone, and so permits a varying flow of electrons (duplicating the program) to flow from cathode, through the grid, to the plate. The varying electron flow is an electrical picture of the program, and is changed to sound by your speaker.

The 3 elements in the triode—grid, plate, and

Structure Of Miniature Pentode-Type Tube

1. Glass Envelope
2. Internal Shield
3. Plate
4. Grid No. 3 (Suppressor)
5. Grid No. 2 (Screen)
6. Grid No. 1 (Control)
7. Cathode
8. Heater
9. Exhaust Tip
10. Getter
11. Space Shield Header
12. Insulating Spacer
13. Spacer Shield
14. Inter-Pin Shield
15. Glass Button-Stem Shield
16. Lead Wire
17. Base Pin
18. Glass-to-Metal Shield

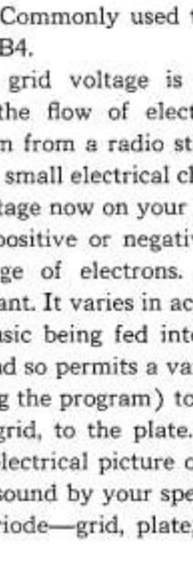


Figure 22. Cross-section of a typical RCA Miniature Tube. This diagram illustrates in detail the construction of a modern radio tube. All elements are clearly indicated. The complexity of the modern tube is here readily apparent. A good basic understanding of tube design and function is essential to good radio building.

cathode—have existing capacities among themselves which are detrimental to perfect operation. The capacity between grid and plate limits the possible gain (or increase in amplification).

Accordingly, while a triode represents an advance over the diode tube, a still greater advantage was made possible with the invention of the tetrode. (The names given to these tubes can easily be explained when you remember that diode means two elements; triode means three elements; tetrode means four elements and pentode means five elements.)

A tetrode is similar to a triode but has an additional screen grid to eliminate the undesirable inter-electrode capacity which is found in triode tubes. This screen is mounted between the grid and the plate, connected to a positive potential, and by-passed to ground. Representative types of tetrodes are the 1A4GT and 7G8.

A phenomenon known as "secondary emission" —the only limitation of the tetrode tube—is eliminated by adding a suppressor grid between the plate and screen grid. This suppressor is connected to the center tap of the filament or cathode (as in the 6SG7 and 6F6) or is brought out externally in some types such as 6AU6, 6BA6 and 12SJ7GT.

For the purpose of the beginner this information on tubes is sufficient. However, as you advance in your radio work you will want to know more about tube theory and function; you can acquire this advanced knowledge from any one of a dozen tube manuals or radio theory books (see page 30).

The various tube manufacturers make available without charge, characteristic tube charts which set forth the average characteristics of all types of tubes under a given set of applied voltages. These charts show the recommended grid and plate voltages and in practice may be deviated from within narrow limits without affecting the operation of a tube. Filament voltages as shown by the charts are maximum values, however, and cannot be exceeded without seriously shortening the life of the tube or even causing a failure of the filament through burn-out.

Coils

We have previously mentioned the fact that coils are used in the tuned circuit or circuits of a radio receiver, but we have said nothing about these coils. Essentially, they are used to permit reception of radio signals on specific frequencies as desired. For example, a set of Short-Wave coils is required to cover Short-Wave frequencies, and Broadcast coils are needed to cover the Broadcast band.

As we have already stated, a magnetic field is set up around a coil of wire through which current is flowing. This field follows in intensity the strength of the exciting current. The number of turns of wire on a coil determines the portion of the radio spectrum which can be covered with a given tuning capacitor.

Coils are wound with magnet wire on forms usually made of bakelite or similar composition material. For convenience in changing bands, some coil forms have prongs at the base such as radio tubes have. Thus, to change bands, you remove one coil from its socket and replace it with another coil that covers the desired band.

In many receivers all the coils for the various bands are permanently installed and are wired to a selector switch. By merely turning the switch, the proper coils for any desired band can be selected. This arrangement makes it unnecessary to use the plug-in arrangement.

Coils must be made specifically for particular receivers because the physical size of the coil, wire size and number of turns on the coil may be different for each receiver. In most cases coils for specific receivers will be purchased completely constructed. For this reason, no winding details for coils are given here. If for some reason the experimenter finds it necessary to wind some coils for a particular receiver that he is building, winding details will be given together with other constructional details for that receiver.

Transistors

The transistor, first introduced at Bell Telephone Labs in June, 1948, is considered one of the electronic marvels of the age. Its invention promises to have as far reaching effects as the invention of the triode vacuum tube. Transistors have already widely replaced vacuum tubes in hearing aids, radios, and such advanced equipment as computers and electronic "brains". Transistors not only can do most of the things that vacuum tubes do, but they can be used in applications where use of the vacuum tube would be impractical.

The general acceptance of transistors is credited to their extreme versatility and the many advantages they offer. Transistors can be operated from extremely low voltages, thus cutting the cost of power supplies. They are very small (see illustration), permitting the design of much more compact equipment. Their light weight, only a fraction of a tube's weight, makes them ideal for portable equipment. They are highly efficient as practically no heat is generated in operation. Their rugged construction makes them especially suitable for use in aircraft, missiles, industrial applications, or anywhere severe vibration may be encountered. In addition to these advantages, modern production methods are reducing the cost of transistors to a point where their extremely long life makes them potentially less expensive than vacuum tubes.

Since, from all indications it appears that transistors will play an ever more important role in electronics it is important that the beginner in radio have some understanding of what transistors are and how they are made. To begin with, transistors are made of crystalline materials called "semi-conductors." These materials are so called because they act like conductors under some conditions and like insulators under others. The galena crystals used in crystal radio sets are one example of "semi-conductors". Other examples include selenium rectifiers, photocells, and silicon and germanium diodes. As previously stated, a diode is a two element device. In a broad sense, the transistor is simply a "semi-conductor" that incorporates three elements; namely, the emitter, base, and collector. These elements correspond to a certain extent with the cathode, grid, and plate of a triode vacuum tube. Germanium is the material most widely used in the manufacture of transistors. It was found that by adding a trace of a specific foreign material to pure germanium, either positive (P), or negative (N) material can be formed. Transistors are made of three layers or sections of these P and N materials combined in either N-P-N or P-N-P sequence. Leads are connected to each layer or section in the transistor to permit making external connections.

The two most popular types of transistors currently available are the "junction" and the "point-contact" transistors. These names indicate the manner in which the P and N sections of the transistor were formed and also, to a certain extent, the application for which the transistor was designed. Most junction type transistors are designed to operate as oscillators, AC or DC amplifiers, buffers, mixers, etc., at frequencies up to about 30 mc. Point-contact transistors are particularly suitable for switching circuits as in computers, and for high frequency applications.

New types of transistors for higher power and higher frequency applications are appearing all the time and these promise an ever expanding field of application in electronics.

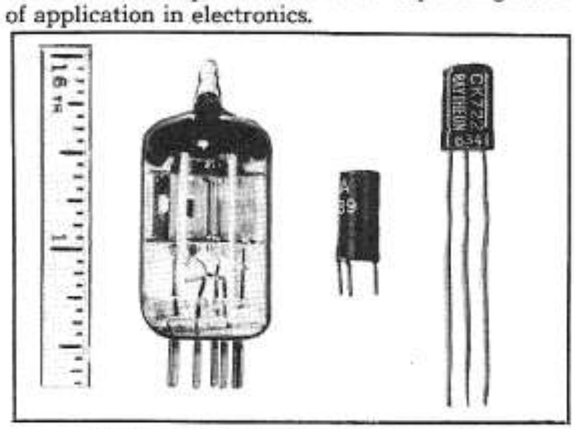


Figure 23. Size comparison between a 6AL5 miniature tube and transistors.

Originally, two types of transistors were developed, junction and point-contact transistors. These names indicate the manner in which the P and N sections were formed in the manufacturing process. At first, point-contact transistors were employed for high-frequency circuits (above 5 mc) whereas junction transistors were best applied in low-frequency circuits (below 5 mc). However, with improvements in fabrication techniques, junction transistors are now able to operate well into the hundreds of megacycles. For this reason they have largely replaced point-contact transistors in all but a few applications such as the switching circuits of computers.

Additional transistor types are also available, such as the tetrode, PNPN, field-effect and thyristor transistors. Undoubtedly others will appear as the state of the art progresses. This applies particularly to high power transistors which are now in considerable demand in all types of electronic equipment.

In dealing with transistors physically and electrically, there are a number of precautions that must be observed in order to prevent their destruction. Physically, there are two ways to mount a transistor in a circuit: by plugging the leads into a special socket, if they are stiff enough, or by soldering the leads directly to the circuit components. For the latter operation, a low-wattage (35-

40 watts) soldering iron is required. This is because transistors are exceedingly sensitive to heat and the heat generated by a normal soldering iron (100 to 200 watts) could cause the transistor terminal leads to become hot enough to damage the transistor internally.

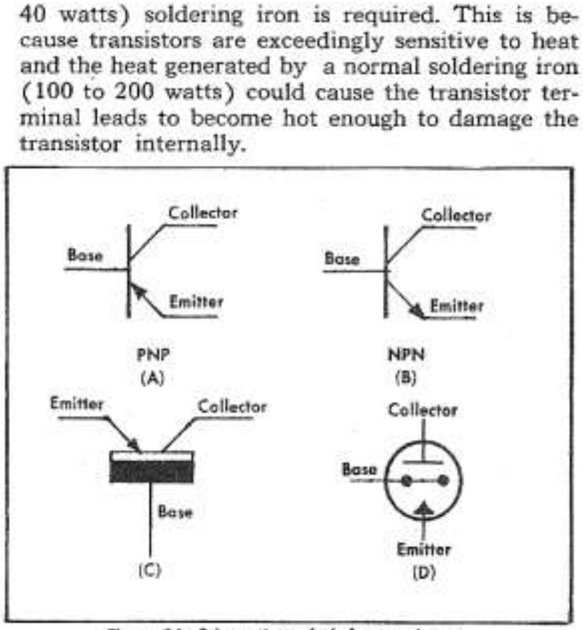


Figure 24. Schematic symbols for transistors.
(A). Symbol for a PNP transistor. (B). Symbol for an NPN transistor. (C)-(D). Two alternate transistor symbols.

To provide the transistor with the maximum protection while it is being soldered or unsoldered, it is good practice to grasp the terminal lead tightly with long-nose pliers positioned between the transistor body and the lead end. With this arrangement, any heat travelling along the wire will be shunted away from the transistor housing. It is desirable to retain the pliers on the wire for a short time after the iron has been removed to make certain that all of the heat has been dissipated. It is also good practice to provide such a heat shield when other wires are being soldered to any terminal lugs to which a transistor lead is attached. Two helpful rules to follow are to keep the transistor leads as long as possible, consistent with the space available and the application, and to get whatever soldering has to be done over with as quickly as possible. Helpful in this respect is 60/40 low-temperature rosin-core solder.

When transistors are plugged into sockets, make certain the unit is out of the socket when the soldering iron is brought into contact with any of the socket terminal lugs.

As a final word concerning the use of any tools on transistors and their associated miniaturized components, always remember that because these units are small, their connecting wires are quite fragile. Handle these wires carefully and gently, both when the part is being installed and when it is being removed.

Electrically, there are also some precautions that must be observed when dealing with transistors. Scrutinize carefully the value and polarity of any voltages (from batteries or other power sources) that are being applied to a transistor circuit. Make certain first that you have the voltage called for, then check polarity before final connection is made to the circuit. If you are at all in doubt about the latter point, check the type of transistor being employed. PNP units require negative collector voltages and positive emitter voltages, both taken with respect to the base. In NPN transistors, the reverse situation holds.

Before the battery is connected in the circuit, the various transistors should be firmly in place. Never insert or remove a transistor when voltages are present. This is designed to prevent the appearance of surge currents which, if they are powerful enough, can permanently damage a transistor. Always remove the voltage first. If you are experimenting with a new circuit or building a kit, double check all wiring before applying bias voltages.

One final word about the precautions to observe when positioning transistors in electronic equipment. Keep transistors clear of any component, be it tube, resistor, or transformer which passes enough current to develop a noticeable amount of heat. The ratings specified for transistors are always given at a certain surrounding temperature, generally 25°C. For every degree above this figure, a corresponding lowering of the transistor ratings must be made, thereby effectively reducing the operating range of the unit. It might be useful to remember this when you find that transistor equipment is not operating as it should and there is no component that is apparently at fault. Check the temperature near the transistor (with a thermometer) with the equipment in operation. If it is higher than it should be, then try to get it back to normal and see if proper operation is obtained.

High Fidelity

High fidelity is a term that is applied to audio equipment capable of reproducing music in your own home with the range, vitality and naturalness you hear and enjoy when you are actually present at the original performance. There are many factors that make this concept of musical enjoyment possible, but three characteristics stand out above all others. These are Minimum Distortion, Wide Frequency Range, and a Balance of Tone.

Minimum Distortion: If you have ever looked at a photograph or motion picture that was not in focus, you know the meaning of distortion. The image is fuzzy, blurred, and undefined—completely disturbing to the eye. Sound can be similarly distorted and equally offensive to your ears. Distorted sound is fuzzy, and you hear it as a blur of noise rather than as a clear distinct musical note. You get this kind of distortion in most commercial instruments of low or average quality. In high fidelity, however, all of the components are specially designed to keep distortion at an absolute minimum.

Wide Frequency Range: High fidelity components have the ability to reproduce the entire range of musical sound with equal realism, from the lowest note of the organ to the highest note of the triangle. It is this ability to reproduce not only the fundamental tones, but the overtones as well, which enables you to enjoy the true character and full beauty of the musical presentation.

Balance of Tone: Balance of tone is as vitally important to musical enjoyment as is the balance of color in a picture. For true musical enjoyment, the musical performance must be balanced properly with the high notes and low notes maintained in the same relationship as in the original performance. High fidelity components are designed to assure this proper tonal balance.

A hi-fi system consists of four basic units:

1. The record changer and cartridge.
   The record changer revolves the record. The pick-up arm contains a cartridge in which the needle is installed. The needle follows or "tracks" the record grooves, and with the cartridge, changes the vibrating paths in the grooves into small electrical voltage impulses.
2. Amplifier.
   This unit amplifies and builds up the final voltages produced by the cartridge into an amount of electrical energy capable of operating the loudspeaker or reproducer.
3. The Loudspeaker.
   This is the actual sound-reproducing unit. It converts the electrical energy delivered by the amplifier into sound waves.
4. Housing.
   This is the cabinet or cabinets that contain the record changer, amplifier, and loudspeaker. The loudspeaker should be in its own enclosure.

Stereophonic Sound: Stereo is a revolutionary new development in high fidelity. In stereo reproduction the sound takes on direction and depth to achieve remarkable realism. Stereo records and tapes have become extremely popular among those who want the ultimate in lifelike sound. A stereo system employs essentially the same components as any other high-fidelity system, but requires an additional amplifier (or dual-section stereo amplifier), an additional loudspeaker, and either a stereo phono cartridge or stereo tape player.

Radio Operating Hints

Tuning a Short-Wave set or an All-Wave set that covers the Short-Wave bands requires a procedure different from that of simply twirling the dial for Broadcast reception. It is necessary to keep in mind such factors as time difference between your own region and foreign countries, atmospheric conditions, and time of transmission schedules. Foreign Short-Wave stations frequently have available a number of different frequencies for transmission—and they shift from one frequency to another at different times of the day or in different seasons of the year. Some foreign stations transmit simultaneously on several frequencies; for example, the British Broadcasting Corporation transmits the identical program over stations GSB, GSC, GSD, and so on—each station being on a different frequency. Thus, if at any particular time conditions are such that you cannot pick up GSB, you may find that your set will bring in GSC because conditions are favorable for reception on its particular frequency. British stations—or other foreign stations transmitting in English—are easiest for the newcomer to identify. But you will soon learn to recognize foreign language stations, like "Ici Paris Radio Coloniale," which means "This is Paris." And other stations, too, have easily recognizable catch-phrases.

Since stations are crowded closely together on the Short-Wave portions of the dial, you must learn to tune very slowly and patiently in order to "pull in" the signals you want. This is a point which cannot be too strongly emphasized. Unless your Short-Wave set has provisions for bandspread (an arrangement making it possible to spread out stations over a larger dial scale area), you must not expect to tune in foreign stations as you would local stations. Tune very slowly in the area on the dial covering the frequency of the station you want.

If, after careful tuning, it appears to be impossible to tune in a specific station at one time, try again on another occasion—because when atmospheric conditions change, the station may "come in like a local." Remember that even the big commercial radio networks—with all of their costly and elaborate equipment (much of which is specially built and runs up into enormous sums of money)—sometimes cannot pick up programs from abroad scheduled for rebroadcast simply because atmospheric conditions are unfavorable.

Static—which simply means disturbance caused by atmospheric electricity—is a matter over which we have no control. This, of course, applies only to "true" static. "Man-made" static—disturbances caused by electric motors like those used in electric shavers, vacuum cleaners, elevators, mixers, etc.,—can be nearly eliminated by efficient filter devices attached to the source of the interference, although these filters are also sometimes useful when used between the electric outlet and the radio set. Battery operated sets are not usually affected by "man-made" static caused by the devices mentioned since such sets do not get their power from the electric line.

Amateur Radio

We now come to a subject which could be treated adequately only in far more space than we have available. This is the subject of Amateur Radio. Strictly speaking, an Amateur is a person who holds a Federal license to operate a transmitter on the radio bands restricted to non-commercial use. In order to obtain this license (issued by authority of the Federal Communications Commission) the prospective Amateur must meet a number of requirements which have been set up by the government.

There are five Amateur license classifications: Novice, Technician, General, Conditional and Extra Class. The Novice and Technician license exams make it particularly easy to get started in Amateur Radio. To obtain a Novice license it is only necessary to pass a simplified written exam covering theory and regulations and a code sending and receiving test of only five words per minute. The Novice license is good for one year; to retain Amateur privileges after that period it is necessary to pass the General Class exam. All Amateur licenses except the Novice license are good for five years and renewable without examination. The Technician exam consists of the same theory and regulation test as the General Class License, but a code sending and receiving speed of only five words per minute is required. The General Class exam consists of a written test on theory and regulations, as well as a code sending and receiving test at 13 words per minute. Those living 75 miles airline, or more, from an F. C. C. examining point may take the Conditional Class license exam. This exam is the same as the General Class exam, but is conducted at the residence of the applicant by two volunteer examiners. The Extra Class license requirements are comparable to that of commercial licenses. The exam consists of a written test on advanced theory and a code sending and receiving test of 20 words per minute. Novices and Technicians are permitted to operate on only a limited number of frequencies, while holders of the General, Conditional and Extra Class licenses have full privileges. At present, holders of the Extra Class license do not have any extra privileges, but this very advanced license is a mark of distinction and certainly something of which one can be very proud.

In all cases, the Amateur operator must be a citizen of the United States and the Amateur station must be operated on premises not owned or controlled by an alien. There is no age limitation—and so Amateurs range in age from 8 to 80.

Full details of the license requirements and the addresses of your nearest F.C.C. office can be obtained by consulting one of the many Amateur books or by writing to Allied. (In Canada, details of requirements may be obtained from the Canadian Radio Commission, Ottawa, Ontario.)

For purposes of radio administration, the continental United States is separated into ten districts. Amateur station call letters are based on this separation. In the first place the prefixes W and K were assigned to the United States by International radio convention. To one of these prefixes is added the number corresponding to the district number. W9 or K9, for example, are the prefixes for the district comprising the states of Illinois, Indiana and Wisconsin. Added to this prefix are two or three letters, identifying the individual station.

The U. S. districts are:

K1, W1—Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.

K2, W2—New Jersey, New York.

K3, W3—Delaware, District of Columbia, Maryland, Pennsylvania.

K4, W4—Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia.

K5, W5—Arkansas, Louisiana, Mississippi, New Mexico, Oklahoma, Texas.

K6, W6—California.

K7, W7—Arizona, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming.

K8, W8—Michigan, Ohio, West Virginia.

K9, W9—Illinois, Indiana, Wisconsin.

K0, W0—Colorado, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota.

Code

Learning to transmit and receive the code should be an early step in the procedure of every one who intends to become an Amateur. The Continental International Code used in radio consists of short signals (called dots) and long signals (called dashes) which are about three times as long in duration as the short signals. The following table shows the code for letters of the alphabet, for numbers, and for common punctuation marks.

While the long and short signals are called dashes and dots, when heard over the air they sound like "dit" for the dots and "dah" for the dashes. The letter P, for example, sounds like "dit-dah-dah-dit." In learning the code, the letters should be memorized with the "dit-dah" sounds, not as "dot-dash."

We lack the space to say very much about the process involved in learning the code. Furthermore, it is adequately covered in several books for the Amateur. However, we can suggest that a "code-learning" device or "code practice set" of some kind

Letters

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

Numbers

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

Punctuation

• — • — • —	Period
— — • • — —	Comma
• • — — • •	Question Mark

be used. (An excellent, low-cost code practice oscillator is described on page **44**. Pressing the key of a code practice oscillator produces a high-pitched tone very similar to the sound of code as it is transmitted. The beginner can thus associate the "dit-dah" combination of sound with each letter and fix the sound-combination firmly in mind. If two persons work the set together, they can learn to send and receive code in a short time.

The listing below shows frequency allocations assigned exclusively for Amateur use. C.W. (code) signals are permitted in all of these bands. Phone transmission is permitted in portions of them.

The Amateur bands are as follows:

3500-4000	KC (80 meter band)
7000-7300	KC (40 meter band)
14000-14350	KC (20 meter band)
21000-21450	KC (15 meter band)
28000-29700	KC (10 meter band)
50-54	MC (6 meter band)
144-148	MC (2 meter band)
220-225	MC (¾ meter band)

(There are also many Amateur micro-wave bands.)

The Amateurs of the world maintain several organizations, the most noted of which is the American Radio Relay League (A.R.R.L.). A full description of this group, its aims, and its operation is included in the A.R.R.L. Handbook (see List of Books, page 30). Amateurs have, on hundreds of occasions, particularly during times of disaster, rendered immeasurable service. The 1936 Ohio Valley flood, the Long Island and New England hurricanes of 1938, the Florida and Gulf Coast hurricanes in 1947, Louisiana's 1957 hurricane, and the 1958 Wisconsin tornado, are but a few of the times that Amateurs have maintained contact with the rest of the country when almost all other facilities have failed. The newspapers frequently tell of how lives of persons in isolated localities are saved by Amateur radio communications.

But even aside from times of disaster and heroism, Amateurs are constantly active to improve the art of radio and to further fellowship and good will. The radio-builder and experimenter who passes beyond the beginning stages can well set as his goal the operation of his own Amateur station.

Amateurs played a very important role in our country's victory in World War II. At the beginning of the war Amateurs were an immediate source of highly trained urgently needed radio operators. In addition, they rendered great service in emergency civilian work.

As mentioned before, there are several handbooks and manuals available which give complete information on how to become a licensed amateur radio operator. An excellent education in radio may be obtained from them, as they adequately cover theory, operation, and actual construction of many "rigs"—from small low-cost sets to very elaborate ones. They are revised periodically, bringing up to date many circuits on transmitters and receivers which it would be impossible to cover within the pages of this booklet.

The American Radio Relay League also publishes the popular monthly periodical, QST. Another popular Amateur magazine is CQ. While most of the articles are for the more advanced Amateur, a good many are of special interest to the beginner.

The following books are suggested as reference works for the student of radio, and as sources of further information for the advanced radio builder. All of these books and many more may be purchased from Allied Radio.

Allied's Dictionary of Radio Terms. Over 3500 concise, easy-to-understand definitions of commonly used words in Radio, Electronics and Television. Fully illustrated. 80 pages.

Allied's Radio Circuit Handbook. Ideal for the student and experimenter. Shows typical radio circuits with explanation of their functions. In addition there are 16 extra diagrams of basic radio circuits with explanation of their use in complex radio design.

Allied's Electronics Data Handbook. Edited by Nelson M. Cooke, Lieutenant Commander, U. S. Navy. Handbook of formulas, data, standards, tables and charts used in the solution of everyday problems in radio and electronics.

AMATEUR RADIO RELAY LEAGUE: *The Radio Amateur's Handbook.* The official handbook of the A. R. R. L., covering every aspect of Amateur radio.

AMATEUR RADIO RELAY LEAGUE: *Radio Amateur's License Manual.* Standard reference for the radio enthusiast in preparation for FCC license. Covers all classes of Amateur licenses currently available. Includes rules and regulations and typical examination questions with answers.

AMATEUR RADIO RELAY LEAGUE: *How to Become a Radio Amateur.* Outlines steps required to become a radio Amateur. Elementary theory instruction plus instructions for simple station equipment.

WILEY PUBLICATIONS: *Principles of Radio.* By Henney and Richardson. This well-illustrated 655-page book provides an excellent theoretical background. Thoroughly covers electrical fundamentals and radio theory. Includes laboratory experiments.

EDITORS AND ENGINEERS: *The Radio Handbook.* Covers radio building and operating. An Amateur essential. Diagrams and instructions for building everything from a 1-tube receiver to a 1 K.W. transmitter.

RADIO CORPORATION OF AMERICA: *R.C.A. Tube Manual.* Complete technical specifications on all R.C.A. receiving type tubes.

For prices of above, and for lists of other useful books, consult your current Allied catalog.

List Of Symbols and Abbreviations

As you read circuit diagrams or radio magazines and books, you will frequently run across a good many abbreviations or symbols for radio terms. We believe that even the radio beginner ought to know the meanings of some of the more common abbreviations in general use. The list below covers those most commonly used.

AC	—Alternating current
AF	—Audio frequency
AFC	—Automatic frequency control
AM	—Amplitude modulation
amp	—Ampere
Ant.	—Antenna
AVC	—Automatic volume control
BC	—Broadcast
BFO	—Beat frequency oscillator
C	—Capacity
CW	—Continuous wave (refers to *code* transmission)
db	—Decibel
DC	—Direct current
DX	—Long distance
E	—Symbol for volts
E_p	—Average plate voltage (D.C.) of a tube
E_f	—Filament or heater voltage of a tube
FM	—Frequency modulation
EMF	—Electromotive force (voltage)
Gnd.	—Ground
Ham	—Licensed Amateur
HF	—High frequency
Hy	—Henry (unit of measurement for inductance)
I	—Symbol of current in amperes
I_p	—Average plate current (D.C.) of a tube
IF	—Intermediate frequency
kc	—Kilocycle (1000 cycles)
KW	—Kilowatt (1000 watts)
Meg	—Megohm (1,000,000 ohms)
Ma	—Milliampere (1/1000 amperes)
mc	—Megacycle
Mil	—One-thousandth
Mhy	—Millihenry
Mike	—Microphone
mfd	—Microfarad (1/1,000,000 of a farad)
mmf	—Micro-microfarad (1/1,000,000 of a microfarad)
MU	—Amplification factor of a tube
Ω	—Ohm
PA	—Public Address
'phone	—Radiotelephone (voice transmission)
R	—Resistance
RF	—Radio frequency
R_L	—Plate load resistance of a tube
RMS	—Root Mean Square
SG	—Screen grid
Super	—Superheterodyne (a type of radio circuit)
SW	—Short wave
SWL	—Short wave listener
TRF	—Tuned radio frequency (a type of radio circuit)
UHF	—Ultra high frequency
VHF	—Very high frequency
W	—Watt
Xmitter	—Transmitter
Xtal	—Crystal
Z	—Symbol for impedance

Conversion Table

1 Ampere = 1,000,000 microamperes
1 Ampere = 1,000 milliamperes
1 Cycle = .000001 megacycles
1 Cycle = .001 kilocycles
1 Farad = 1,000,000,000,000 micromicrofarads
1 Farad = 1,000,000 microfarads
1 Henry = 1,000,000 microhenrys
1 Henry = 1,000 millihenrys
1 Kilocycle = 1,000 cycles
1 Megacycle = 1,000 kilocycles
1 Megohm = 1,000,000 ohms
1 Microampere = .000001 amperes
1 Microfarad = .000001 farads
1 Microhenry = .000001 henrys
1 Micromicrofarad = .000000000001 farads
1 Microvolt = .000001 volts
1 Milliampere = .001 amperes
1 Millihenry = .001 henrys
1 Milliohm = .001 ohms
1 Millivolt = .001 volts
1 Ohm = .000001 megohm
1 Volt = 1,000,000 microvolts
1 Volt = 1,000 millivolts

Test Equipment

In addition to the mechanical tools needed for radio construction and the soldering gun or iron to fasten wires securely together, the radio builder will find that electrical test instruments will also prove extremely helpful. Such instruments will enable the radioman to measure the voltages in the circuit, to check resistances and circuit continuity, to test tubes and transistors and, in general, to reveal whether or not a circuit is functioning properly. After the necessary background and experience have been acquired, a radioman will be able to use test instruments to repair radios, television receivers, motors and the many other electrically-powered devices that are found in the modern home.

For the person who is just starting in the radio field, the most useful test instrument to acquire is a volt-ohm-milliameter. Commonly referred to as a VOM, this instrument will measure a-c and d-c voltages, a wide range of resistances and d-c current. Sometimes, a-c current can be measured, too. No external source of power is required; however, a small dry cell which is mounted inside the instrument case is required for the resistance checks.

The principal governing factor in the cost of a VOM is its sensitivity, expressed in ohms-per-volt. Knight-Kit VOM kits with values of 1,000 and 20,000 ohms-per-volt are available, with the higher value signifying a more sensitive meter movement and consequently costing more. VOM's are also available fully constructed, although kits tend to be considerably lower in cost. Furthermore, they come complete with detailed instructions on how they should be constructed so that anyone who is able to solder wires will have no trouble building the kits.

Closely allied to VOM's are vacuum-tube voltmeters, commonly called VTVM's. These are usually a-c powered, although battery operated VTVM's are also available. A Knight-Kit VTVM kit will permit more extensive and more accurate measurements to be made than a VOM and for that reason is perhaps more widely used by service technicians in their work. However, there is a wide range of measurements which VOM's and VTVM's perform equally well and for the beginner either one will do.

The second basic test instrument is the tube tester or checker. With it, the radioman will be able to test all types of receiving tubes to determine their condition; whether they are good or bad or simply weak. A tube tester is important because tubes are, by far, the most common cause of circuit failure and are the first item to be checked when difficulty is encountered.

A Knight-Kit tube tester kit will not only permit testing conventional receiving tubes but television picture tubes as well. Some testers are devoted solely to tube checking, while others contain such supplementary features as transistor testing, selenium rectifier measurements, continuity checks, etc. In the beginning it is probably best to start off with a good, reliable unit which is relatively inexpensive. After the radio builder has had the experience of working with a number of circuits, he will then be in a better position to select a more expensive instrument, if this is felt necessary.

With the two instruments described above, the radioman will be able to perform 80 percent of all the measurements he will be called upon to make. For the remaining 20 per cent, other test instruments are needed; some of the more important of these are described briefly below.

Oscilloscopes: These are instruments which produce a visual image of the current or voltage waveforms present in a circuit. The picture is developed on the face of a cathode-ray tube which is essentially identical to the picture tube contained in a television receiver. A Knight-Kit oscilloscope is very useful in checking any circuit where the form of the voltage or current is distinctive and where deviations from the normal shape will disrupt operation noticeably. This is particularly true of television receivers.

Signal Generators: A signal generator develops signals of specific frequency. Such signals, when applied to a circuit, reveal whether the circuit is functioning normally or not. A signal generator can be looked upon as a miniature broadcast station which enables the technician to check a circuit (or a receiver) at his convenience and in the manner that he wishes. These instruments also provide stronger signals at the receiver than broadcast stations normally produce.

Generators are available in several different forms, such as the Knight-Kit R.F. signal generator, the Knight-Kit sweep generator and the Knight-Kit audio generator.

Resistance-Capacitance Testers: These instruments measure resistance and capacitance values and, in the case of capacitors, also indicate whether the units are defective or not.

Signal Tracers: Knight-Kit signal tracers are designed primarily for the servicing of radio receivers and audio equipment. They trace the signal through the various stages of a receiver, indicating where the signal level either decreases sharply or is lost completely. They also come equipped with a loudspeaker and several audio stages so that they can serve as a general purpose audio amplifier.

Representative examples of the equipment discussed are shown on the following page. All of these instruments plus many more are available from Allied.

Some Interesting Circuits

On the pages that follow we have included diagrams and construction notes on a number of circuits of special interest to radio builders. The most versatile of these is described on pages 33-35—the Knight-Kit Lab Kit. The circuits were carefully designed so that a minimum of parts is used in a maximum of circuits. The kit is recommended for all beginners. It also makes excellent classroom material for schools. You'll find this complete kit listed in the kit section of Allied's catalog.

Other features of this kit are the use of low voltages and a wired-in power cord as safety factors, separate tubes for each function for a clearer understanding of what each tube does, single control for simplicity, and careful design that makes it possible for anyone to follow the circuit in building these units and enjoy good performance from each.

The circuit of the "Span Master" on pages 36 and 37, provides the best performance obtainable from only a few tubes. It is carefully designed, using modern tubes, and is a real "DX getter."

In addition to the circuits described on these pages, many more—of all types—will be found in construction articles in radio magazines and other handbooks. Also, every Allied catalog devotes a number of pages to listings of "build-your-own" kits. The beginner is certain to find many projects of interest. Construction of test instrument kits provides an excellent means for learning the functions and use of test units, and saves money on the actual cost of the instruments.

The Allied catalog also lists numerous diagrams and blueprints. Each diagram contains complete construction data, schematic and pictorial diagrams and a list of parts required to build the set.

It might be pointed out here that it is not absolutely necessary to use the exact parts as specified in a construction article. As long as parts have the same electrical specifications, good results can be expected.

The construction notes on the following circuits are based on actual laboratory construction of these sets. In each case, the beginner should follow the instructions faithfully. Failure to do so may result in poor operation—or total lack of operation—of the circuits described. In all cases, both pictorial and schematic diagrams have been included to clarify as much as possible the exact procedure to be followed in wiring.

The pictorial diagrams on the following pages show you the actual placement of components in the completed units. Knight-Kits are supplied with the chassis; panels are completely formed, punched and drilled. This simplifies the construction of a kit. All parts are selected, matched components—to insure best performance, maximum dependability, and ease of construction. Few tools are needed at first. In general, the only tools required are a soldering iron, a screwdriver and a pair of pliers. It will probably be easier for the beginner to follow a pictorial rather than a schematic diagram. However, when constructing a kit, both the pictorial and schematic diagrams should be followed. In this way you will become familiar with the various symbols which represent radio components used in a circuit. In following your pictorial or schematic diagram cross off on the diagram the corresponding wire as it is connected in the circuit under construction. This will eliminate omissions in the wiring of the kit. If the foregoing points are kept in mind, the builder will have no difficulty in building the kits which are described on the following pages.