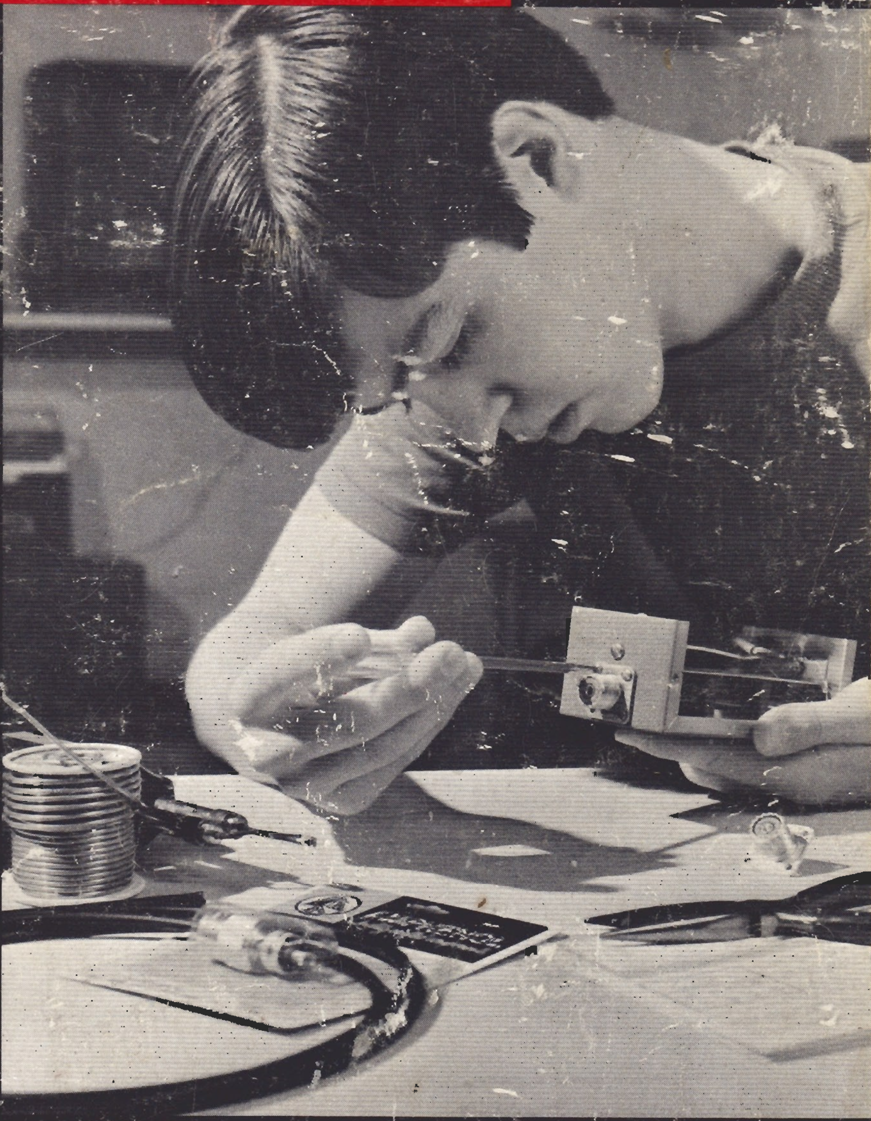
How to BECOME A RADIO AMATEUR

$1.00

FULL INFORMATION ON SETTING UP YOUR OWN AMATEUR RADIO STATION



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How to Become A RADIO AMATEUR

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Chapter 1

The Lure of Amateur Radio

You are interested in radio and in the magic of radio communication. The thrill of direct two-way radio conversation with persons in foreign countries, of participating in emergency communications in time of disaster, of exploring the frontiers of radio development with equipment you build yourself—all these and more may be yours through the medium of amateur radio.

You probably know that there are people called "radio amateurs" who talk amongst themselves at all hours of the day and night. You may have read of them in your daily newspaper after some flood or emergency in which they rendered great public service.

Who are radio amateurs?

What *is* amateur radio?

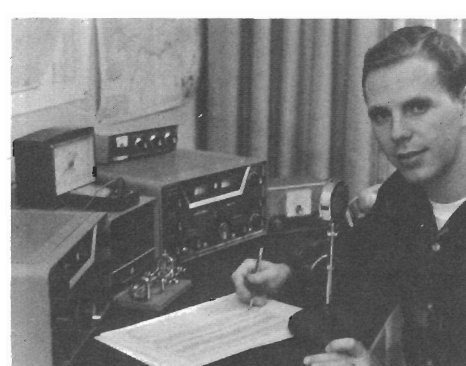
Amateur radio is direct private experimental communication, from your own home, on apparatus you have built or assembled yourself, with other amateurs similarly equipped.

Anyone can become an amateur—boy or girl, man or woman—almost regardless of previous training and experience. All that is required is a sincere desire to learn and a little effort acquiring the necessary knowledge. Boys and girls of 8 and 10 have become amateurs—as have men of 80. They come from all walks of life, their sole bond the fascination that the amateur game affords.

You may have already tuned in some distant station in a foreign land on an all-wave receiver. But that is only a small part of the thrill that comes only to the radio amateur—not only hearing foreign countries but also throwing the switch on your own transmitter and talking with the stations you hear.

You would like to know how these people came to be amateurs, how they acquired the ability and the equipment to get on the air and talk with each other. You might like to become an amateur yourself—at least you would like to know how to go about becoming one.

The purpose of this booklet is to tell you, as simply and straightforwardly as possible, what amateur radio is, how one can become an amateur, how to build a simple receiver and transmitter, and how to get on the air. But first let us explore some of the many possibilities amateur radio offers.



This modest amateur station, assembled from commercially-available units, requires very little space yet under favorable conditions can easily communicate to the other side of the world.

The operator of every amateur station takes pride in a neat logbook showing dates, times and frequency bands for other stations he has "worked."

Adventure!

Each night's operation is a new adventure into space. An amateur's station—sometimes an elaborate affair that rivals the equipment of a big broadcasting station, more often an inexpensive outfit assembled at home in spare moments—becomes a modern Aladdin's lamp. You never know, when you sit down to your transmitter and receiver for a few hours' operation at the end of the day's work, what those hours will bring. Perhaps, to start, a few friendly chats with neighboring amateurs in near-by states. Some of these may be contacted for the first time that particular night; others may be amateurs who have been "worked" before and with whom regular schedules have been arranged once or twice a week. Following this there may be an opportunity to pass the time of day with a Virgin Islander or, later, a missionary afar in Africa or a weather observer on some remote U. S. island in the Pacific. You may suddenly be asked to relay a message for assistance for a town even then being devastated by a hurricane, or have the experience, as many amateurs have, of exchanging signals with some Arctic or Antarctic expedition.

A housewife or "XYL" ham takes time out from ironing to operate her amateur station.

Would you like to talk direct with the owner of this fine station in Japan, or other amateurs in all parts of the world? It is one of the most interesting facets of becoming a ham.

Endless Variety

These are but a very few of the things that you, as an amateur, may do. The reason that amateur radio is often called the most satisfying and thrilling of all hobbies is that it offers something for everyone. It is, to use a familiar phrase, "all things to all men."

For example: You may be a "tinkerer"—you may like to play around with gadgets, build them up, make them work. Amateur radio is the ideal hobby for the tinkerer who likes to go into the "why" of the things he builds. It offers endless

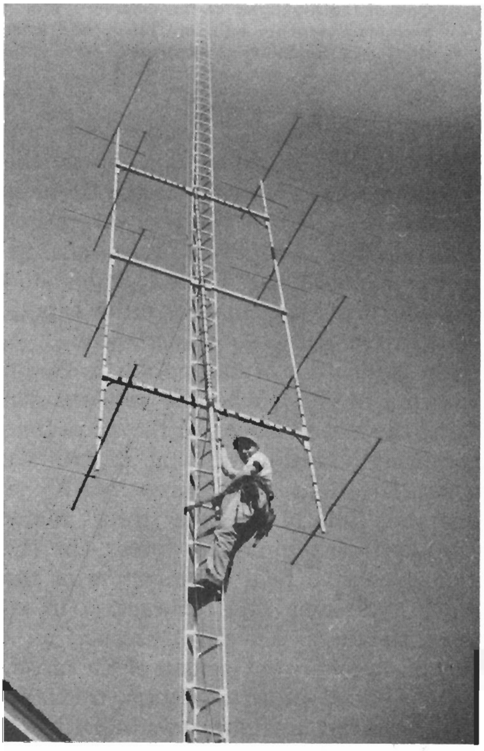
Many amateurs find their greatest interest in the hobby to be experimentation with new circuits and gadgets.

room for experiment, an infinite variety of problems to overcome. You may be a "rag-chewer." The most enjoyment you know may come from getting together with a crowd of good fellows and talking over everything under the sun. Amateur radio is full of confirmed addicts of the conversational art; indeed, there is even a "Rag-Chewer's Club," with a membership certificate signed by "The Old Sock," himself, for those who can qualify.

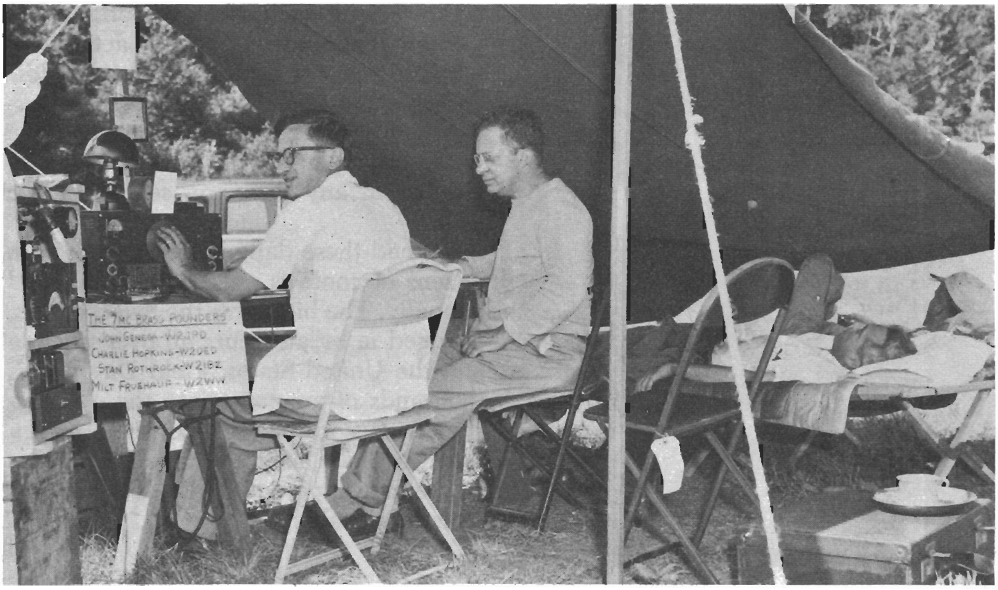
Competition

You may have the competitive urge. If your biggest kick in life comes from putting everything you've got into some sport or game that requires a high order of intelligence and skill, amateur radio will provide plenty of activities to test your mettle. Every day in the year thousands of amateurs compete to see who can relay the most messages; elaborate traffic nets, with trunk lines, field officials and comprehensive organization have been established by the Communications Department of the American Radio Relay League. Hundreds of other amateurs compete with each other in working DX (distant) stations. DXing is actually a glorified form of fishing; it takes endless patience and skill, but to the true "fisherman" it has a zest nothing else in the world can equal—and it's a sport you can indulge in any day, any season of the year.

Beyond these daily activities there are dozens of contests of various kinds held annually. The biggest is the Sweepstakes, engaged in by amateurs all over Canada and the United States. Field Day brings thousands of amateurs into the countryside with portable self-powered equipment. In these, as in the smaller contests, amateurs compete not only on a national scale but locally.



Another field of experimental interest by amateurs is the very-high-frequency bands, where simpler antenna systems will perform adequately, but where elaborate beams such as this will provide communications over distances unheard-of until a few years ago.



One of the highlights of the amateur's year is participation in ARRL Field Day each June, when portable-emergency units are set up and teams of operators work around the clock as a demonstration of the ability of amateurs to serve in times of disaster.

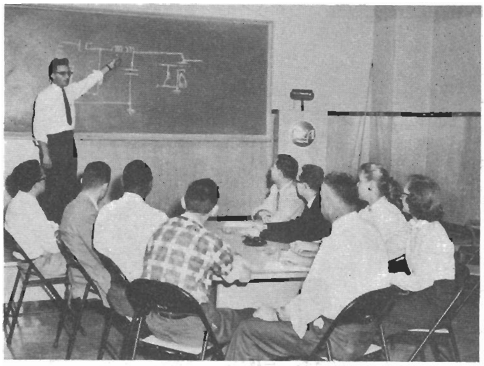
Group Activities

But all this still does not convey the whole picture of amateur radio. If one is interested in Army, Navy or Air Force activity, there are communications reserves in both the United States and Canada in which amateur radio experience can be put to good use. In the U. S., there is also the Military Affiliate Radio System (MARS), whereby civilians can assist the armed forces, at the same time acquiring valuable training in military communications procedures. MARS is operated jointly by the three major branches of the armed forces. In the comprehensive field organization of the ARRL you may find satisfaction in an appointment as Official Observer, as a sort of voluntary policeman of the air, or as an Official Bulletin Station, transmitting the latest amateur news bulletins on regular schedules, or as an Official Experimental Station, helping plumb the mysteries of the ultra-high frequencies.

Nor is all of amateur radio confined to contacts over the air or solitary experimentation. There are more than 1200 active community radio clubs in the country affiliated with the ARRL, and they offer programs of wide general interest. Each year several divisional conventions and some dozens of "hamfests" are held. Hundreds of amateurs attend these fraternal get-togethers, which last from an afternoon or evening to as much as three days. Not only are they instructive, not only do they permit amateurs to meet in person those they have talked with over the air, but they are mighty good fun, as well.

Public Service

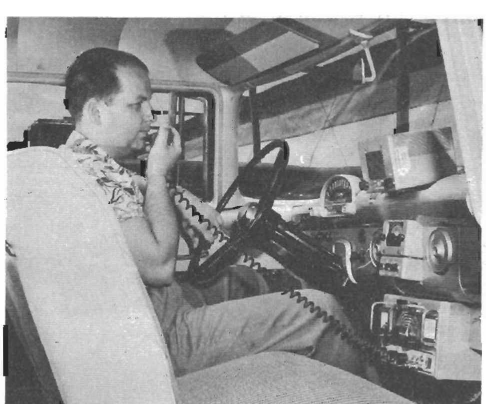
It is one of the finest aspects of amateur radio as a hobby that it is not only a source of delightful fun and pleasant recreation, but it is also an outstanding opportunity for voluntary public service. The communicating experience an amateur acquires, and the organized networks in which many hams participate, in time of disaster become of untold value to the community and the nation.



Many of the 1200 or more local amateur radio clubs around the nation conduct free courses of code and theory instruction to help newcomers obtain ham tickets.

Let a hurricane or an earthquake or a flood destroy normal lines of communication, and hundreds of amateurs are ready to step in and provide emergency circuits for the Red Cross, civil defense, military, and municipal agencies.

Perhaps as many as one amateur out of every three has, in addition to his station at home, a complete communications set-up in his car. Driving back and forth to work, or on a longer weekend trip, an amateur can be in constant touch with other hams to while away the time in pleasant conversation—or to ask local highway directions of local hams at their



Another field of intense interest for amateurs is mobile — a simple but complete two-way installation in an automobile. Besides a great deal of fun, such units are invaluable in time of communications emergency.

home stations. Here again, in the event of communications emergency an amateur mobile unit becomes invaluable because it not only has its own power supply but can be dispatched to key points to furnish vital communications for relief work.

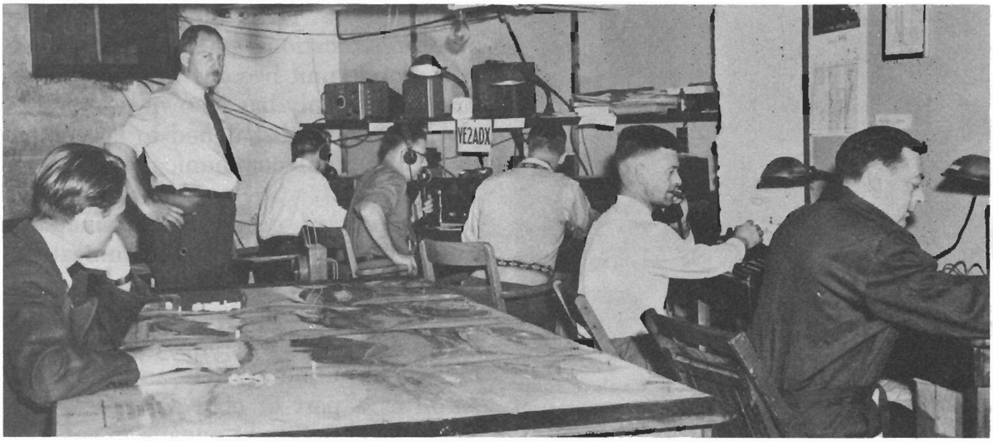
So important, in fact, is the amateur's work in emergency communications that the Federal Communications Commission has set up special rules for a Radio Amateur Civil Emergency Service, in which public-spirited amateurs can enroll as a part of civil defense efforts. These local networks engage in practice drills regularly, hoping that disaster will never strike their community but determined to be fully prepared for any catastrophe that might come.

From Champions to Newsboys

This, then, is amateur radio. That its appeal is universal is demonstrated by the type of people that pursue it. A cross-section of amateur radio is a cross-section of any community. The popular myth that all amateurs are "attic experimenters" has no basis in fact. It is true, of course, that a considerable number of boys and girls under 20 do become amateurs, for it is one of the advantages of amateur radio that it is not too intricate or abstruse for young people of high school age to master. But if you, as an amateur, get on the air tonight or tomorrow night and contact other amateur stations you may find yourself talking with the son of a former President or a popular band leader or a famous radio comedian—or your newsboy or filling-station owner. . . . The list could go on endlessly, but the point is that amateur radio is indeed a universal hobby, having an appeal to professional worker and artisan alike, to young as well as old.

Careers in Electronics

With the intense personal interest a young amateur develops in his hobby, it is not surprising to find that many radio



The public-service record of amateur radio operators has drawn many words of praise from government and municipal agencies, and from the military. But one example is this city communications control center, organized and manned entirely by hams.

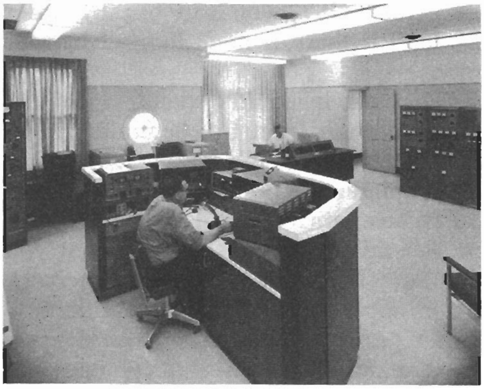
industry executives, and electronics engineers high in the profession today, were first drawn to radio as a career through a ham station of their own. Nearly one-half of all amateurs are employed in communications electronics or allied fields. Some are owners and presidents of their own manufacturing companies; others are engineers or laboratory technicians, or sales engineers, or maintenance men, or broadcast station attendants, or government research workers on classified projects. The rapid advances in the art of electronics and its daily expansion into new phases of American industry make it apparent that the field is a continually-growing one which offers unparalleled opportunities to the young man of today who is faced with selecting his life's work. And experience as an amateur is the ideal stepping-stone to a professional career, offering not only an easy method of early self-training, but equally as important, the development of a personal interest that makes one's working hours pleasant and rewarding instead of drudgery.

National Organization

Amateur radio is not a spontaneous development. It is the result of five decades of evolution. For more than 50 years it has been guided in technical and operating progress, and defended against legislative threat, by its national organization in the U. S. and Canada, the American Radio Relay League.

The League, which was founded in 1914, is the traditional spokesman for amateur radio. Numbering in its ranks a majority of the active licensed amateurs, it is operated as a mutual non-stock corporation, entirely amateur-owned and directed. Through a representative system of government, it makes the amateur

Headquarters activities of the League include a well-equipped laboratory, pictured above, in which new designs of amateur gear are developed and tested.



The Headquarters station, W1AW, maintains extensive operating schedules, dedicated to sending code practice for beginners, transmission of news bulletins for all amateurs, and general contact with other amateur stations.

body articulate in representation domestically and at international radio conferences. Scores of times it has averted the threatened abolition of amateur work. From its headquarters at Newington, Conn.—where visitors are always welcome—where some seventy people are employed—it publishes the monthly journal of amateur radio, *QST*, as well as many amateur handbooks and booklets, all available at low cost to help amateurs obtain the greatest enjoyment from their hobby.

Licenses Essential

It is the law that no one can operate a radio transmitter without a license. In the United States, all forms of radio are administered by a government agency at Washington called the Federal Communications Commission. The Commission assigns radio facilities to all types of radio stations—and often certain services feel that they require more space on the air. This competition, the necessity for every class of radio station to demonstrate that it is operated in the maximum of public interest, convenience and necessity, forces amateur radio—through the ARRL—to maintain a united front in order to preserve its rights.

Governments require that every amateur station and operator be licensed. There are heavy penalties for operation of an unlicensed station—a maximum of two years in jail and a fine of $10,000. In Canada, the Department of Transport is the regulatory agency. As you read on in this booklet you will learn how the necessary licenses can be easily acquired and the other requirements met.

Build or Buy?

Sooner or later you will have to decide whether to construct your own radio equipment or buy it ready-made. There are advantages to either choice. Strictly from the standpoint of cost, buying ready-made is cheaper in the long run, principally because the manufactured equipment will have a much higher trade-in or resale value if and when you decide to change your station's apparatus (for higher power, or some other reason). In many instances the beginner can get better performance from manufactured gear, since it is the result of design by skilled engineers, and of mechanical production by techniques often impractical to duplicate in the home workshop. It is also true that you can buy a receiver and have it home in operating condition the same day, while constructing your own would require a number of evenings or other spare-time work.

The principal advantage to home construction is that it can furnish half the pleasure and satisfaction in the hobby of amateur radio. In building your own, you learn far more about radio theory and technique than the buyer of ready-made gear ever possibly can. You can thus become a much more skilled amateur. Furthermore, when a new technical development comes along, you can take advantage of it by modifying your home-built equipment accordingly; the purchaser of a manufactured unit may hesitate to make any modifications since alterations might adversely affect its resale value.

A number of manufacturers today make amateur equipment available in "kit" form; this is one compromise between the two choices. Much of the mechanical work difficult to accomplish in the home workshop—such as chassis-punching and dial mechanisms—is already done for you. But in assembling and wiring the components you can acquire a certain amount of knowledge of the innards of radio equipment and of construction techniques generally. You are thus more easily able to grasp technical knowledge required for your license examination.

Ready-made amateur radio equipment and kits are sold by numerous radio stores or distributors in various parts of the country (and, in a few instances, direct by the manufacturer). Check the yellow pages of your local telephone directory, or the advertisements in this publication or the League's monthly magazine, *QST;* you can usually order by mail if there is none located in your city.

"How much should I spend?" is a common question from the beginning amateur. That is largely a personal decision. The amateur equipment market is a fairly competitive one, however, so that in general you get just about what you pay for. The more expensive receivers, for example, generally give considerably better performance under adverse operating conditions than cheaper ones, although under good radio conditions an inexpensive receiver and low-power transmitter will do nearly as well. A second-hand receiver (there are many on the market) is often a good investment.

But we recommend that, at the start, you build at least one major item for your amateur station—receiver or transmitter—for the experience and training it will afford, not to mention the satisfaction of personal accomplishment.

Fundamentals of Radio

You are going to run into some new words in ham radio. Don't let them bother you. In any new hobby you have to learn the language. We'll explain the new words as they come up, and after a while you'll be handling ham radio talk like a veteran.

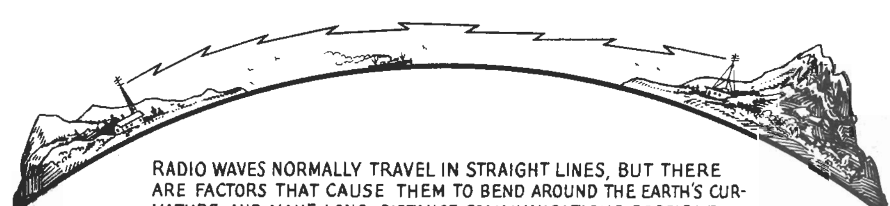
Amateurs learn how radio works because a modest understanding is required for the written part of the license examination. Further, the more one knows about radio, the easier it is to get the most out of it, in the way a good mechanic gets top performance from his car. And, of course, you have to know a little about radio to be able to "shoot trouble" in equipment that goes bad.

An Amateur Station

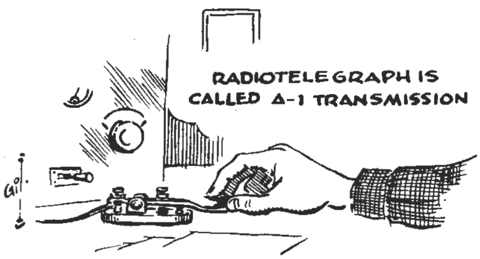
Your amateur station, be it simple or elaborate, will consist of three basic parts: the transmitter, the antenna and the receiver. You may use one antenna with the transmitter and another with the receiver, or you may use a single antenna for both transmitting and receiving, switching the antenna from receiver to transmitter and back again. Regardless of these details, the three basic parts are the transmitter, the antenna and the receiver.

The transmitter is the unit that takes electrical power from a battery or, more commonly, from the electrical power line in the home and converts it into **radio frequency** power. When this radio frequency power is fed properly to the antenna, the power is radiated in many directions. Although the r.f. (radio frequency) power is electrical power somewhat similar to that in the house power line, the house power will not leave the wires and travel great distances through space the way r.f. power will. The directions in which the power leaves the antenna depends upon the form of the antenna, and this is a study all by itself. It is sufficient for now to remember that the radiation from an antenna is not equal in all directions.

The power leaving the antenna travels through air and space in straight lines away from the antenna at the speed of light (186,000 miles per second). It continues in these straight lines unless it is

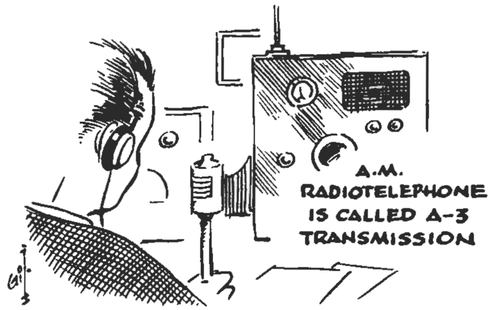


RADIO WAVES NORMALLY TRAVEL IN STRAIGHT LINES, BUT THERE ARE FACTORS THAT CAUSE THEM TO BEND AROUND THE EARTH'S CURVATURE AND MAKE LONG-DISTANCE COMMUNICATIONS POSSIBLE diverted or reflected. Fortunately for long-distance communication on a spherical earth, there are conditions above the surface of the earth (up to about 250 miles) that cause radio energy to be bent back toward the earth, and consequently it is possible for the energy leaving an antenna to be returned to earth at points beyond the horizon. (These conditions vary with the amateur band in which you are operating, and the time of day and year, and they constitute a study of their own, called "propagation.")



The r.f. power radiated from the antenna will generate tiny electrical currents in any wire or antenna past which it travels. If this wire is connected to a suitable radio receiver, the tiny currents can be amplified to a large signal in the receiver. The signal disappears when the transmitter is turned off. If the transmitter power is increased, the received signal increases in the same proportion. When the transmitter is turned on and off rapidly with a telegraph key to form the characters of the radiotelegraph code, the identical characters can be heard at the receiver from headphones or a loudspeaker, and the operator at the key can "talk" to the operator at the receiver. Radiotelegraph communication like this is called "**A1** transmission" by FCC definition or, in amateur language, **c.w.** (for "continuous waves") or **code.**

With suitable equipment, the power output of the transmitter can be varied by the sound waves in the voice of the transmitting operator, working through a microphone. When the transmitter output is varied, or **modulated,** in this way, the output in the distant receiver varies in the same way. If the receiver output



is fed to headphones or a loudspeaker, new sound waves are generated that duplicate the voice waves of the transmitting operator. This is called "**A3** transmission" by FCC definition or, in amateur language, **a.m.** (for **amplitude modulation**).

As mentioned earlier, there are several factors affecting any radio path, so it is not possible to communicate with all parts of the world at any one time. However, by recognizing the factors one can, over a period of time, communicate with most of the regions of the world where there are amateur stations. And, of course, one can communicate over short paths within the horizon limit without worrying about the long-distance factors.

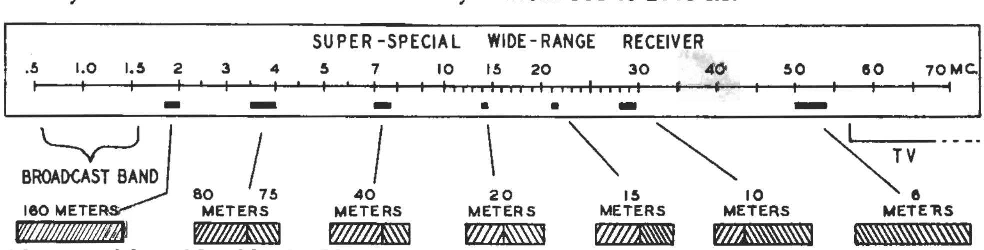
The Receiver

The first part of your amateur station to acquire is the receiver. It will enable you to listen to amateurs and other services, you will gain first-hand knowledge of the receiver's operation, and you will be able to copy signals that will help you to improve your code speed, as outlined later. You will not need a special antenna until you have your license and transmitter, and even a 15- or 20-foot length of wire in the room or attic will be sufficient with most receivers. The receiver can be one you build from plans given later in this booklet, or you may select a design from *The Radio Amateur's Handbook* or a copy of *QST* magazine. You may elect to assemble one of the receivers offered in kit form on the market, or you may decide to invest in a new or second-hand communications receiver. Don't hesitate to investigate second-hand receivers offered by reliable dealers; these receivers will be in good working condition and are excellent values. Don't expect any "bargains," however; receivers are realistically priced and you will get what you pay for. The only bargains are receivers that can be reworked into better performance, and this requires technical know-how that you won't acquire overnight. Usually the market value of a commercial receiver does not depreciate rapidly. Be sure to save the shipping carton and the instruction book; it helps when you turn in the receiver on another one.

There are two general classes of receivers that are useful for amateur work: "general coverage" and "amateur-bands only." As the names indicate, the general-coverage receiver will tune over a wide range, while the other covers only the amateur bands, with a little to spare in some cases. The general-coverage receivers usually include the regular broadcast band (not f.m.) as well, so they can be used by the other members of the family for the reception of news and entertainment. This is a good argument for the potential amateur to use in a budget-conscious family.

Amateur Bands

Right here is a good place to get acquainted with the amateur bands mentioned above. If your only experience with radio is tuning a broadcast or TV receiver, you will have noticed that your local stations come in at certain points on the tuning dial. For example, your local stations might appear at 6, 11 and 15 on your broadcast receiver dial. These numbers represent 600, 1100 and 1500 **kilocycles per second or kilohertz.** ("Kilocycles per second"—usually shortened to plain "kilocycles", since the "per second" is always understood—is the older term. The unit "Hertz", meaning cycles per second, has also been adopted internationally and is now in general use. The prefix kilo means 1000, so a kilocycle is 1000 cycles–per second understood–and a kilohertz is 1000 Hertz, or 1000 cycles per second. The abbreviation "kc." is used for the former, and "kHz." for the latter). The different *frequencies* of transmission that these stations have permits tuning to one or the other without mutual interference. The broadcast band, or group of frequencies, extends from 535 to 1605 kc.



The dial of a super-special wide-range receiver might look something like this. As we tune away from the broadcast band (left-hand end) we run into many different radio services and an occasional amateur band (solid dashes), and we end up in Channels 2 and 3 of the TV bands. The amateur bands are expanded below the scale, to show their frequency limits. The cross-hatching indicates subdivisions allocated between phone and code. The ARRL License **Manual** gives the latest FCC regulations on these subdivisions.
This dial scale represents only a portion of the radio spectrum, and still more space would be required to show the 2-meter (144-148 Mc.) and other amateur bands.

If the broadcast receiver were a very special one that could continue to tune higher in frequency (there are technical reasons why this is impractical without switching), you would find many different groups, or bands, of frequencies, used by many different services. Some of these include ship-to-shore communications, transoceanic code, voice and teletypewriter links; military radio, aeronautical radio, and overseas propaganda broadcasting. And, what you are most interested in right now, the amateur bands. Unlike other services, we amateurs are permitted to operate on any frequency within these amateur bands, in accordance with the terms of the particular license we hold.

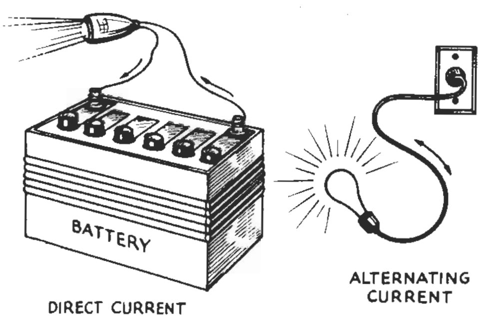
To indicate the amateur bands and the sequence in which they would be encountered on this hypothetical receiver, the dial scale is shown on p. 15. Because the kilocycle or kilohertz designation starts to become clumsy at these high frequencies, we show the scale in "Mc.", for "megacycles." It also could have been designated "MHz.", for "Megahertz: A **Megacycle** is 1,000,000 cycles; 1,000 kc. = 1 Mc. Similarly, a Megahertz is 1,000,000 cycles per second; 1000 kHz. = 1 MHz. In amateur work you will often hear the amateur bands referred to as the "40-meter band" (7.0 – 7.3 Mc.), the "20-meter band" (14.0 – 14.35 Mc.), etc. This is a carry-over from past years when a signal was identified by its "wavelength" rather than by its frequency.

Frequency and Wavelength

This business of frequency and wavelength is often a stumbling block for a newcomer to radio, but it is so basic and you will be working with it so often that right now is a good time to discuss it.

The electricity from a battery (or other **direct current** source) flows in one direction through a circuit. In other words, every time you turn on your flashlight, or the headlights of your car, the electrical current that flows through the lamp or lamps flows only in one direction. (The direction can be reversed by reversing the two connections at the battery.) The current in the electric lights in your home (and in all of the other appliances) is called **alternating current.** In most parts of the country it is 60-cycle or 60-Hz. alternating current or, to abbreviate it, 60-cycle **a.c.** This means that the current goes first in one direction and then the other, to complete a cycle, and its goes through 60 of these cycles each second. It has a frequency of 60 cycles per second. (All frequencies should specify the time unit, but in electrical work the "per second" is understood and usually omitted.) Alternating current is used instead of direct current in homes and industry because it has certain advantages over d.c. in convenience of use and in long-distance transmission of power.

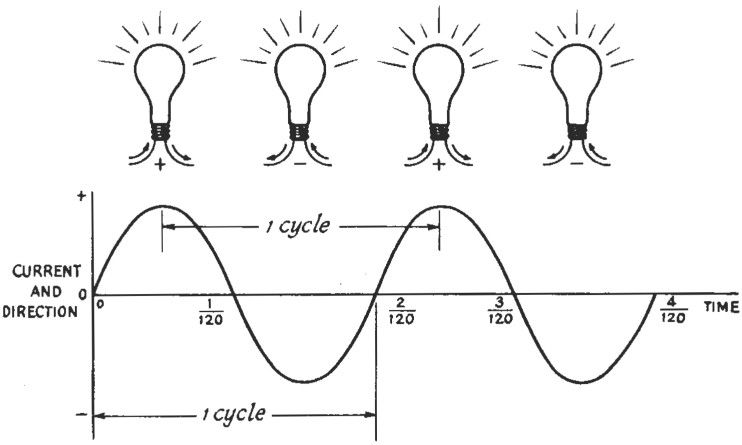
Audio frequencies are those in the normal hearing range of 30 to 15,000 cycles and, of course, include the speech frequencies.



The storage battery in an automobile is a common source of direct current. The current always travels in one direction from the battery to the headlamp or other load and back to the battery.

Electricity in the home is the most common example of alternating current. The direction of current flow reverses every 1/120th of a second. A complete cycle requires two reversals or alternations, hence "60-cycle alternating current."

As mentioned earlier, radio frequency power is basically the same as your house power, but the frequency is different. When the frequency of an alternating current is higher than 15,000 or 20,000 cycles, some of the energy will escape



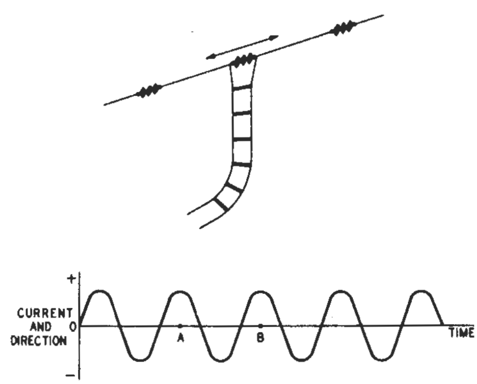
Current flow from left to right through the lamp can be called "+," and "−" from right to left through the lamp. A 60-cycle alternating current would flow in one direction for 1/120th of a second and in the other for 1/120th of a second, as shown by the wavy line being above or below the 0 line. The current rises to a maximum and falls to 0, and then rises to maximum in the apposite direction and falls to 0, as indicated by the wavy line. For an instant there is no current flowing in the lamp, and for a considerable part of the time there is relatively little current flowing. The light doesn't show this by flickering because the changes are too rapid (the lamp can't go on and off that fast and our eyes have persistence of vision), and we see a steody light.

A single cycle is completed when an operation starts to repeat itself. Here you see that there is one cycle from crest to crest, or from zero value to similar zero value.

into space from the conductor carrying the current. Frequencies that do this are called **radio frequencies** and the effect is called **radiation.** As mentioned earlier, the radio frequency (r.f.) energy leaving the conductor (wire) travels with the speed of light.

An alternating current does not flow at maximum value in one direction for half of the cycle and at maximum value in the other direction for the remaining half of the cycle. Instead, it rises gradually to a maximum in one direction, falls to zero in that direction, rises to maximum in the opposite direction and falls to zero in that direction. This can be illustrated by the sketch above, which shows how the magnitude of the current and its direction varies with time. As you can see, it repeats this operation over and over; each complete operation is one **cycle** or **Hertz.** (If you are familiar with trigonometry, the shape of the cycle is that of a **sine wave.**)

Try to visualize a radio-frequency current flowing in an antenna. It will vary in amplitude and direction of flow as shown below. At time A some radio energy is just leaving the antenna, with the speed of light. One cycle later (B) the energy that left at instant A will be a certain distance from the antenna. This distance can be easily computed by



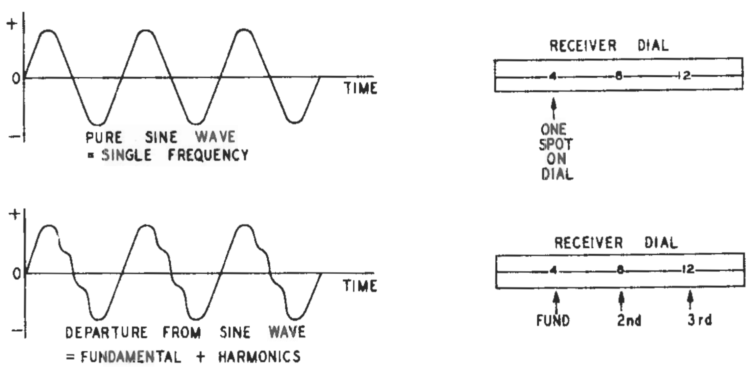
The alternating current in an antenna is changing very rapidly, but it can be represented in exactly the same way that the house current was, by a sine-wave curve. The time scale (horizontal) will be much different, since it will involve millionths of a second instead of hundredths.

multiplying the speed of travel by the time interval. The speed of travel is 186,000 miles per second (300,000,000 meters per second). If the frequency is, say, 4.0 MHz. (4,000,000 Hz.), then it takes 1/4,000,000 second to complete one cycle. In that time the energy will have traveled 300,000,000 × 1/4,000,000 = 75 meters. Thus we say a "frequency of 4.0 MHz.," or a "wavelength of 75 meters," to identify the same bit of radio energy. The wavelength designation comes from an early concept of radio and how it worked, based on early technical methods that actually measured the wavelength. But direct measurement of frequency is more accurate, particularly in the ranges used by amateurs, and now the wavelength concept is useful primarily in discussing antenna lengths and heights. It isn't necessary to spell out the arithmetic as was done above, and the simple formula is

$$Wavelength\ (meters) = \frac{300}{Mc.\ (or\ MHz.)}$$

This relation holds only for conditions where the speed of travel is 300,000,000 meters per second, as in free space. You will learn later that radio energy traveling in material substances (such as in cables) will not travel as fast, and the 300 in the above formula would then become a smaller number. Thus the wavelength of a radio frequency signal can be changed by the substance or medium through which it travels; the *frequency* cannot change in the medium through which radio waves travel, except in a few special cases that involve reflections from moving objects, or movement of the transmitting or receiving station.

A pure radio signal would follow the sine wave variations of amplitude *vs.* time exactly, as indicated in previous sketches. This type of wave has a single frequency. If through some defect in its generation, or through some deliberate or accidental means *distortion* is introduced in passing through a portion of a transmitter or receiver, its shape could no longer be that of a pure sine wave. When this happens, or is caused to happen, it will be found that radio energy exists not only at the original frequency, but some can be found at certain multiples of this frequency. For example, if we start out with a pure signal at 4.0 MHz., distorting it will cause energy to appear at 8.0 MHz., 12.0 MHz., 16.0 MHz., etc. The proportionate amounts of energy found at these frequencies will depend upon the mechanism of distortion; with intentional distortion it is quite possible, for example, to emphasize either the



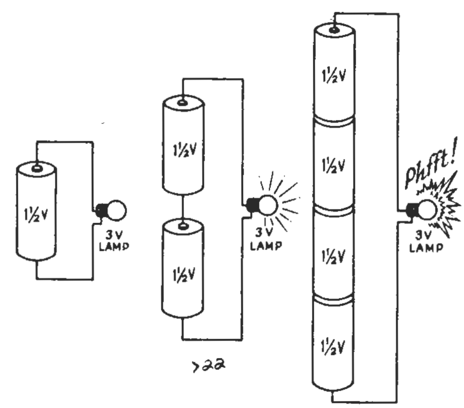
A single-frequency signal would be tuned in at only one spot on a perfect wide-range receiver. A distorted signal (departure from sine wave) could be tuned in at the fundamental and at the harmonic frequencies. The strength of the harmonic signals would depend upon the degree of distortion and consequent departure from a pure sine wave.

8.0-MHz. energy, or the 12.0-MHz. signal and minimize the others. This process is called **frequency multiplication,** and it is an important function of some internal portions of a transmitter. The 8.0-MHz. signal is called the **second harmonic** of the 4.0-MHz. signal ($2 \times 4.0 = 8.0$), the 12.0-MHz. signal is called the **third harmonic** ($3 \times 4.0 = 12.0$), and so on. In some special circuits, it is possible to detect energy at harmonic frequencies as high as the 300th and beyond. Harmonics in the *output* of a radio transmitter are undesirable and should be avoided, since they may fall on frequencies intended for other than amateur use and, if they are of sufficient strength, may interfere with another of the radio services, which is a violation of our government regulations. Normally you can only obtain integral (2nd, 3rd, 4th, etc.) harmonics; it takes specialized circuitry and techniques to generate sub-harmonics (½-frequency, ⅓-frequency, etc.). As you have guessed, there is no "first harmonic"; 1 times the frequency is the frequency itself, or the **fundamental frequency.**

Measurement of Electrical Power

Earlier we mentioned the electric current that flows in a flashlight lamp when the lamp is connected to a battery. Most flashlights use a 3-volt battery. The **volt** is a unit of electrical force, or potential, and a 3-volt battery has 3 times the force of a 1-volt battery and ½ the force of a 6-volt battery. The lamp has a property called **resistance,** and this property is measured in **ohms.** Resistance is a property all substances have, to impede or resist the flow of electrical current. Substances with little or no resistance are called **conductors,** while those with considerable resistance are called high-resistance materials. The highest-resistance materials are called **insulators,** because they prevent, or insulate against, the flow of current.

Getting back to the flashlight, the 3-volt lamp has been designed so that its resistance permits the flow of just enough current to heat its filament (the fine wire in the lamp) to incandescence. A 1½-volt battery wouldn't have the potential to push enough current through the filament to heat it sufficiently, and a 6-volt battery would push so much current through that the filament would burn out quickly, although it would give a nice bright light for an instant! Current is measured **in amperes,** and by definition, 1 volt will force a current of 1 ampere



A 1½-volt battery doesn't have the potential to force enough current through a 3-volt lamp, but a 6-volt battery has more than enough! Notice that the voltages of the flashlight cells add when they are connected properly. One connection of a cell is called + or positive (the small electrodes when not marked) and the other is called — or negative. Voltages add when connected in series (+ to —).

through 1 ohm. The relationship, as you may have sensed when the flashlight bulb burned out, is that through a given resistance, the current is proportional to the voltage. Thus

$$\textit{Current in amperes} = \frac{\textit{Potential in volts}}{\textit{Resistance in ohms}}$$

The traditional symbols for current, potential and resistance are *I, E* and *R* respectively, so the formula is usually written

$$I=\frac{E}{R}$$

From this and the simplest algebra,

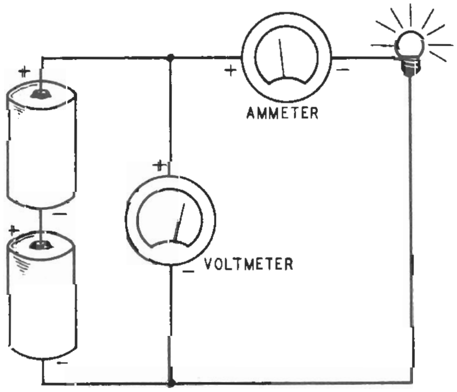
$$E=IR, \text{ and } R=\frac{E}{I}$$

It is a good idea to familiarize yourself with these simple relations, because they are essential to many of the problems you will encounter in your practical radio work, as well as in the technical portion of any license examination. The relationship is called Ohm's Law, in honor of the man who first formulated it.

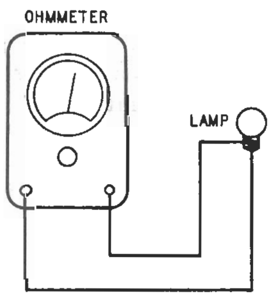
Much of the time in radio work the currents involved are very much smaller than an ampere. Consequently the units milliampere and microampere are often used. A **milliampere** is one-thousandth (.001) ampere and is abbreviated ma.; a current of .005 amperes is written 5 ma. and spoken of as 5 milliamps or 5 mils. A **microampere** is one one-millionth (.000001) of an ampere and, of course, 1 ma. equals 1000 microamperes. While you probably won't run into microamperes very often, when you do the microamperes may be abbreviated μa. Meters are available for measuring current; depending upon their scales they will be called ammeters, milliammeters and microammeters. Different types of meters must be used for measuring d.c., low-frequency a.c. and r.f.

The unit of resistance is the ohm, as mentioned earlier, and normally any fraction of an ohm that you encounter will be given as a fraction or decimal. In the high resistances, running into the millions of ohms, the term megohm is used. One **megohm** is equal to a resistance of one million ohms. On the wiring diagrams of radio equipment, and sometimes in a list of parts, you may run into a cryptic designation like "10K." This represents 10 kilohms, or 10,000 ohms, and all you have to remember is that the "K" stands for "thousand ohms." The word kilohm is practically never used, but you may hear amateurs speak of "a 10-kay resistor." And in speech or on wiring diagrams, a 2-megohm resistor usually becomes a "2-meg resistor." Resistance is measured with an ohmmeter.

But a volt is a volt. While you may occasionally hear about kilovolts (thousands of volts), millivolts (thousandths of a volt) and microvolts (millionths of a volt), most of your practical work will revolve around volts. Your flashlight battery is 3 volts, your car battery is 6 or 12 volts, and your house wiring is 115 volts



A voltmeter and an ammeter can be connected in the lamp circuit to read current and voltage. Note that direct-current (d.c.) meters have polarity (+ and −) and that it was observed when these meters were connected in the circuit. In other words, the + side of the meter goes to the + side of the voltage source.



An ohmmeter is used to measure resistance, but the voltage and current readings of the preceding picture would allow the resistance to be computed from $R=E/I$. (An ohmmeter works on the same principle; it measures the current flowing for a given applied voltage, but instead of indicating the current it indicates the resistance.)

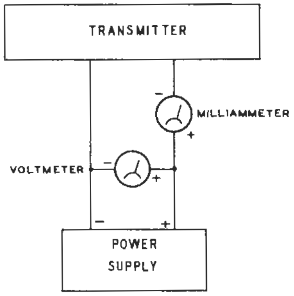
to a light fixture and 230 volts to the electric range. Your amateur transmitter will probably use a maximum voltage of 500 or 600, unless you use high power and voltages of several thousand. Voltages are measured by voltmeters, and they will be of different types depending upon the frequency. Like the ammeters, a d.c. meter is required for d.c. measurements, and an a.c. meter is required for a.c. measurements. These latter often have an upper frequency limit beyond which they are no longer accurate, so when you acquire current- or voltage-measuring equipment of any kind, it is wise to read the instructions and acquaint yourself with the proper use—and the limitations—of the instrument.

There is one more basic term and unit in this family that you should know. The term has been used often in this discussion so far, but with no mention of the unit. The term is **power,** and it is measured in **watts.** In an electrical circuit, the power in watts is defined as the product of volts times amperes in the circuit. Hence if 1.0 ampere of current passes through the electric light bulb in your reading lamp, connected to the 115-volt line as it is the power being used by the lamp is 1.0×115, or 115 watts. Obviously the 60-watt lamp on the other side of the room, which is also connected to the 115-volt line, has a smaller value of current passing through it. Since P (*power in watts*) equals E (*voltage*) times I (*current in amperes*) or $P = EI$, your algebra tells you that $E = P/I$ and $I = P/E$. From the last formula, you can compute that the 60-watt lamp has a current of 60/115 or 0.52 amperes (520 milliamperes, if you want some practice in converting.)

Later on, when you get your transmitter, you will want to be able to compute the **power input** to certain parts of it. To do this you just recall that the power $P = EI$, read the meters and do the simple multiplication. In the case of your transmitter, the current will probably be indicated by a milliammeter, so don't forget to convert to amperes before you do the multiplication. For example, if the transmitter input is 150 ma. (150 milliamperes) at 500 volts, you change the 150 ma. to 0.15 ampere and multiply by 500, to give the correct answer of 75 watts.

You may be wondering about the meter that the man from the power company reads each month. This is a **watt-hour** meter and, as the name implies, it records the product of the number of watts your house uses times the number of hours it used them. It is a clock and counter; the more power you draw the faster the clock goes and the faster the counter changes. Watch it sometime when there are few electrical appliances running in the house and then a few more switched on; you'll see. You pay the company for the watt-hours you use; 100 watts for 2 hours or 200 watts for 1 hour will add the same amount to your bill.

There is one more point in connection with electrical power that you should be familiar with, and then we will get back to that ham station you're going to have. Since power $P = EI$, and you know from an earlier paragraph that $I = \frac{E}{R}$, the relations for power can also be written



To measure the power input to any part of a transmitter, it is necessary to know the voltage and the current. These are measured by a voltmeter and a milliammeter (or ammeter), and the power input is equal to volts times amperes. If the meters shown here read 500 volts and 80 ma. (.080 amperes), the power input would be $500 \times .08 = 40$ watts.

$$P = I^2 R \text{ and } P = \frac{E^2}{R}$$

(The small figure 2 above the *I* and *E* means that the quantity is squared, or multiplied by itself. For example, 4^2 is read "4 squared" and means 4 × 4, or 16.) If you know algebra you can have a little fun deriving these relations from those given earlier; if you don't know algebra just try and remember these formulas for future use, because they will come in handy. With them you can compute the power being used in a circuit if you know the current and the resistance or if you know the voltage and the resistance. And one last thing: remember that *power can only be used up, or dissipated, in a resistance.* And now we are going to talk about some important components that will be found in most radio circuits which, because they have little or no resistance, dissipate little or no power.

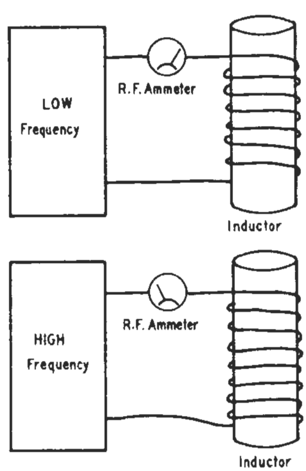
Inductance and Capacitance

When you start digging into a piece of radio gear you will continually run into two types of components that have the properties of **inductance** and **capacitance.** Don't let these words frighten you; you will be at home with them presently, and much of the successful operation of radio equipment depends upon them.

The components that have the property of inductance are called **inductors,** but if you are like most other amateurs you will call them coils. And coils describes them because coils they are, except in some special cases. Inductors are usually coils of wire wound in a single layer on an insulating cylindrical form or self-supporting with a minimum of insulating material, although to conserve space they may be made with many layers of turns. The wire must be so insulated or supported that adjacent turns don't make electrical contact.

When you apply an alternating voltage to an inductor, you will find that the current through the coil doesn't follow a simple law like the earlier one involving resistance. Instead, the current becomes less as you increase the frequency, even though the voltage remains the same. If, for example, you measure 1 ampere flowing through the coil when you apply 100 volts at 4.0 MHz., you will find that only ½ ampere is indicated at 8.0 Mc. If you applied a direct voltage, as from a storage battery, the current would depend only upon the resistance of the windings, but any given inductor will tend to hold back the flow of alternating current to a degree that depends upon the frequency. This property is called **reactance.** Inductors used at low frequencies will usually have laminated iron cores in them to increase the inductance for a given number of turns, and at high frequencies powdered-iron cores are sometimes used for the same reason. For a given diameter and core material, increasing the number of turns increases the inductance.

The basic unit of inductance is the **henry,** and you will run into it in power



The current flowing through a given coil, or inductor, decreases as the frequency is increased. A direct current passes to a degree limited only by the resistance of the winding. The core is the form on which the inductor is wound.

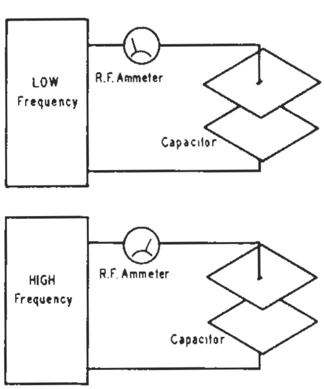
supplies and audio-frequency equipment. At r.f. the smaller units of the **millihenry** (thousandth of a henry) and **microhenry** (millionth of a henry) are usual. These two are abbreviated mh. and μh., respectively and, of course, 1000 μh. = 1 mh.

You will often hear or read about a "10-henry choke" or a "2½ millihenry choke," and you will probably wonder what inductance has to do with strangulation. The word choke is a carry-over from days gone by, when the action of an inductance in holding back the flow of high-frequency current was thought of as a choking process. You will also read about filter chokes and r.f. chokes; the first expression we will take up later. An **r.f. choke** is an inductor used in a circuit to permit the passage of direct currents and audio frequencies while preventing the flow of radio-frequency currents. Similarly, an **audio-frequency choke** is an inductor used to pass d.c. and hold back audio frequencies.

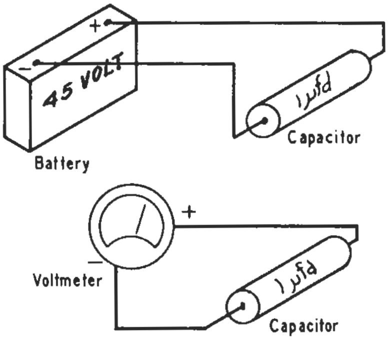
A **capacitor** is basically two parallel plates of conducting material (sheet metal, metal foil) separated by an insulator (air, mica, ceramic, plastic). To conserve space, the plates are often stacked alternately, and the insulating material is made as thin as possible for the voltage at which the capacitor will be used. (High voltages can break through insulators that are quite adequate for lower voltages.) Or, the plates may be two pieces of metal foil rolled with insulating material to form a tubular capacitor. The insulator prevents the flow of any direct current through the capacitor, but a.c. can flow through the capacitor, to a degree dependent upon the frequency of the a.c. and the capacitance.

It isn't strictly true to say that no d.c. can flow through a capacitor. If you connect a capacitor to a source of d.c. (a battery, for example), current will flow from the d.c. source for an instant. This energy is flowing into the capacitor to "charge" it; if the capacitor is removed from across the d.c. source, a voltmeter connected across the capacitor will show that a voltage appeared there equal to that of the d.c. supply. We say "appeared" because the voltmeter might draw enough current to "discharge" the capacitor, and the voltmeter would only indicate the voltage for a short time.

The ease with which a capacitor passes a given frequency of a.c. and the amount of charge that it will hold at a given voltage depends on its property of **capacitance.** This is measured in **farads,**



The current flowing through a given capacitor increases as the frequency is increased. A direct current cannot flow through a capacitor.



Current flows from a d.c. source into a capacitor until the capacitor is "charged" (has a voltage equal to the source). The capacitor retains its charge until it is discharged by an external or internal resistance. Good capacitors will hold a charge for minutes; "leaky" ones have low internal resistance and discharge in a few seconds.

an electrical quantity that is too big for any practical use and only comes about to make the arithmetic work out in certain formulas. The capacitors you will encounter will be measured in **microfarads** (millionths of a farad) and **picofarads** (million millionths of a farad). These are abbreviated μf. and pf. respectively. When you hear an amateur talking about "10 mikes," you will know he means a 10-μf. capacitor and not an Irish invasion. Capacitance increases with the plate area and decreases with the spacing, for any given insulating material between the plates.

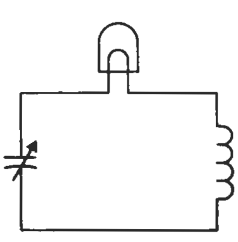
You will encounter the expression "bypass capacitor" or, simply, "bypass." A **bypass** capacitor is used to permit the passage of a.c. or r.f. while preventing any flow of direct current. When you become familiar with radio circuits you will see why chokes and bypasses are useful devices.

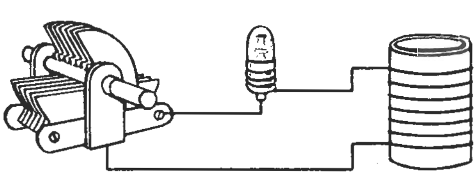
Inductors and capacitors are not used solely for choke and bypass applications. Probably their greatest use is in combination to form a tuned circuit. A **tuned circuit** has the ability to accept signals of one frequency, or a narrow band of frequencies, and not others. When you tune a receiver you are changing inductor-and-capacitor circuits within the receiver, to select the signal or signals you want to listen to.

Circuits

And speaking of circuits, it is about time you were introduced to some of the symbols that are used in radio work to show how the various components are connected together. You have probably seen them in radio books or magazines and wondered how anyone could follow all that stuff. Actually, it is easy. Symbols are the "words" of circuit language. The "sentences" describe the way in which the components are connected together electrically. These are formed by drawing lines, representing wires or other kinds of conductors, between the appropriate connection points on the symbols. This is a much more compact form of representation than a picture diagram or "pictorial," as the accompanying illustration shows. Here we have the same circuit drawn in both styles. The "schematic" at the left can be understood at a glance by anyone having a little familiarity with the sign language of circuit diagrams. The "pictorial" at the right would require some study before one could be sure just what the collection of parts is supposed to do, even when the reader is fairly experienced. Its only virtue is that someone with no electrical background whatsoever could assemble and wire it. Unfortunately, blind copying of this kind adds nothing to one's fund of knowledge.

The schematic circuit diagram sacrifices any attempt at pictorial representation. *It does not show where parts are physically located in the equipment, nor does it try to show which leads must be short and which may be long.* This information must be obtained from supplementary material, such as photographs and the written text of an article. Together, these will give a reasonably-experienced reader all he needs to know to produce a workable piece of equipment.

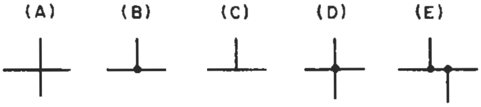




Wiring

A line between two symbols, or parts of symbols, represents an electrical connection. If it is a simple line, no particular type of wire or other conductor is implied. In the actual piece of equipment, one terminal of one component might be soldered directly to a terminal on the other component. Or the two might be separated by several inches, or feet, and connected by wire, metal strip, or tubing. In most actual construction, of course, the wiring will be done either with the wires or "leads" furnished on the component or with "hook-up" wire which may range in size from No. 12 to No. 22 gauge, depending on the current to be carried.

There are times when it is impossible to avoid having one connection line cross over another in the drawing. When it must be done it is simply done as shown at A below. Although in nearly all other



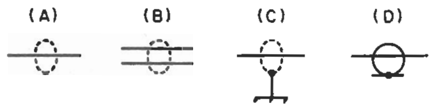
cases a line touching a symbol means that there is electrical contact, here *no* contact is indicated. If a connection is to be made between two wires in a diagram it is usually shown by a dot, as at B. (However, the dot is not actually *required* in such a case; the connection can be shown as at C.) A "four-way" connection preferably should *not* be drawn as in D, because of the similarity to a plain cross-over; confusion is avoided by showing such a connection as in E.

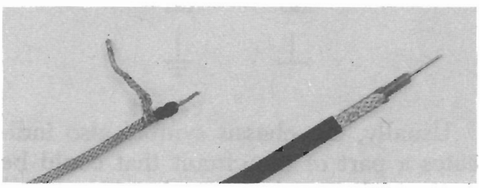
Nearly every circuit has an array of "common" connections; examples are the connections to one side (usually the negative side) of the plate-supply source used for the various vacuum-tube circuits in a multitube arrangement. These common connections usually are made to the metal chassis, as a matter of convenience and sometimes as a matter of specific design. In drawing circuits it is customary to show such "chassis ground" connections by the chassis symbol shown at A below. When you see a collection of such symbols in a diagram you appreciate immediately that all of them are actually one multiple electrical connection. Using the chassis symbol in this way invariably makes the diagram easier to read, because without the symbol it would be necessary to show line connections between all those same points.

Usually, the chassis symbol also indicates a part of the circuit that could be connected directly to earth without any effect on the circuit's operation. If an actual earth connection is called for, the "ground" symbol shown at B will be used. In some older diagrams you will find this symbol used in place of the chassis symbol, to indicate a connection to chassis without reference to an actual earth connection.

Special cases in wiring occasionally come up. Sometimes a shielded wire or cable is called for. Such wire consists of one or more insulated conductors inside a metal tube usually made by braiding fine bare wire so the whole assembly will be flexible. When grounded, this tube shields the conductors from electrical fields which otherwise might induce unwanted currents in them. The presence of the shield is indicated by a broken, somewhat-elliptical symbol around the wire, as in A and B on the next page. Usually the shield will be grounded or connected to the chassis, in which case the symbol for this is added as in C. Coaxial cable, which is basically shielded wire but is used where r.f. current is to be carried, has a special symbol of its own, shown at D. Here, too, the shield symbol usually will be shown grounded.

Finally, although it is not a part of the actual wiring, you should recognize the symbol for a shield or shielding. It is simply a dashed line, often formed in the shape of a rectangle, around the symbol for a component, or set of components, which actually are enclosed in a shielding container.





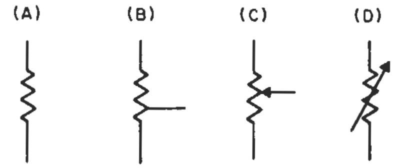
Examples of shielded wire and coaxial cable. The wire (left) is the type with a single inner conductor. Multi-wire cable of similar construction is often used. The coaxial cable shown (right) is a small type (RG-58/U). Cable of this general construction is available in several different diameters, for handling various power levels.

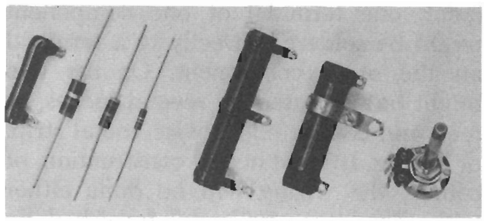
With the "hooking up" out of the way, we can new get down to the component symbols themselves.

Resistors

You rarely meet a circuit that doesn't have at least one resistor in it. While resistors come in a wide variety of sizes and shapes, the same basic symbol, shown below at A, is used for all of them. In its plain form, this symbol represents a "fixed" resistor—one having just a single value. If the resistor is "tapped," having a connection made somewhere in its body that permits another value of resistance to be secured from the same resistor, the presence of the tap is indicated as shown in B. More than one tap, when needed, may be added to the basic symbol.

The solid arrowhead in the symbol at C indicates that the resistance is adjustable in value. Other than this, it does not





Commonly used types of resistors. The resistors grouped at the left have fixed values. In general, the larger the resistor the higher its power rating. The four types shown in this group include a 10-watt wire-wound, and 2-watt, 1-watt, and ½-watt composition resistors. A tapped wire-wound resistor is in the center, with a slider-type (adjustable) wire-wound at its right. On the far right is a composition "control," or variable resistor.

give any indication of the physical construction of the resistor. The adjustment might be by means of a slider on a wire-wound resistor, for example. Or it might mean the moving contact on a wire-wound or composition "control." Note that with this symbol there are three terminals, the adjustable tap and the two outside ends of the resistor, so this symbol can be used for an adjustable voltage divider or "potentiometer." On the other hand, the symbol at D, with the arrow drawn through the basic resistor symbol, simply indicates that the total resistance is continuously variable. This symbol has only two terminals, although the actual component frequently will have three; one end connection is left unused in that case.

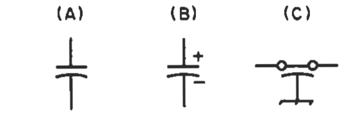
Capacitors

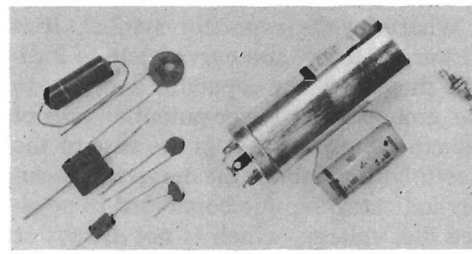
The basic capacitor symbol is shown at A at the top of the next page, and just as in the case of the resistor, this symbol as it stands implies that the capacitor is "fixed" — that is, it has just a single value of capacitance. Again, the symbol stands for all sorts of fixed capacitors, from tiny ceramic disks to bulky potted high-voltage types, with dielectrics ranging from vacuum to oil-filled paper.

Electrolytic capacitors are "polarized" — that is, in d.c. circuits one terminal must be connected to the positive side of the voltage source and the other to the negative side. The proper polarity is frequently shown on the circuit diagram by putting a + sign near the side of the capacitor that should be connected to positive. Frequently, also, the other side is labeled — .

A special type of fixed-capacitor symbol is shown at C. This is the "feed-through" capacitor, used particularly in high-frequency radio circuits for bypassing. In this type the circuit being bypassed goes into one terminal, indicated by one of the small circles, and out the second terminal. The r.f. bypassing takes place internally to the curved capacitor "plate," which is always grounded to the chassis. This type of capacitor is especially useful where the circuit goes through the chassis, or other metallic sheet, from one side to the other.

Two common types of continuously-adjustable or "variable" capacitors used for tuning r.f. circuits are shown symbolically at A and B below. The first symbol may stand for any of several physically-different types. One of these is the "air" type, which has a set of metal plates on a rotatable shaft, interleaving with a similar set of stationary or fixed plates. A second is the "compression" type, in which the spacing between two sets of leaf-spring plates is changed by screw adjustment. The two sets of plates are insulated from each other by thin mica wafers. A third is the "piston" type, in which a metal cylinder is moved in or out of a conducting tube by screw adjustment. The cylinder and tube are insulated from each other. Small capacitors are often used as "trimmers"—that is, set to a desired capacitance value experimentally in the equipment and thereafter left alone. A capacitor used for this purpose may be (but does not *have* to be) so indicated by putting a small T alongside the straight line representing the fixed plate.

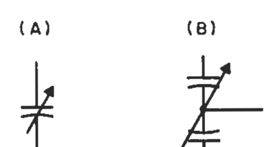




Fixed capacitors come in various shapes, sizes, and types of construction. At the left are a paper tubular capacitor, two sizes of molded mica capacitors, and three types of ceramic capacitors (two sizes of disks, and a tubular with axial leads). The large metal can is an electrolytic filter capacitor (in this case, several capacitors in one can, which is a common connection for all units). Beside it is a small electrolytic with wire leads. The small capacitor at the far right is a feed-through type useful at v.h.f.

When the arrow is added to the basic capacitor symbol to show that the capacitor is variable the curved line represents the movable plates.

The "split-stator" capacitor symbol is shown at B. This is an "air"-type capacitor having two sets of rotor plates and two sets of stator plates. The former are



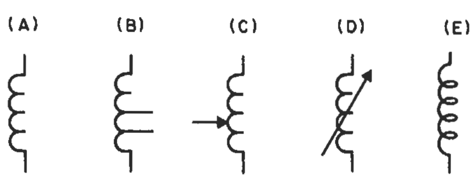
A few samples of variable capacitors; there are innumerable styles of these, and only a few are shown here. From left to right, a mica compression trimmer, a tubular trimmer, a single-section variable, and a dual-section or "split-stator" variable. The latter can be used either as a balanced capacitor or as two separate sections driven by a single central shaft.

mounted on the same shaft; in effect, there are two identical variable capacitors operating together. Capacitors of this type are used in "balanced" or "push-pull" circuits.

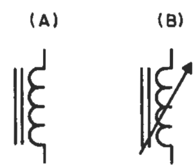
Whatever the capacitor symbol, it is customary to use the curved line to indicate the side of the capacitor that goes to the grounded or lower-potential side of the circuit, except that in the case of the electrolytic capacitor the curved line usually indicates the side connected to negative d.c. voltage, which is not always at ground potential.

Inductors and Transformers

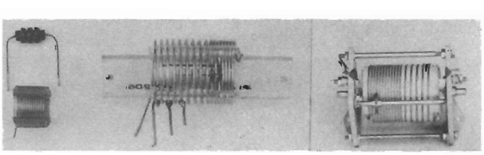
The basic inductor symbol, like the ones for resistors and capacitors, gives no information about the *type* of inductor. It is shown at A below. It represents an inductance of fixed value, and it can stand for a simple r.f. coil wound on a form, for a multi-layer coil, a universal-wound coil, or even for one wound on an iron core. Like the resistor symbol, it can be shown tapped (B), or adjustable (C and D). C is used for inductors having a moving contact; an example is the "roller" type which has a traveling contact on a bare-wire coil, the contact position being changed as the coil is rotated. This symbol also would be used for a coil having a movable spring clip to make contact with any part of the bare-wire winding. Incidentally, there are two fundamental types of inductor symbol, one having open loops as shown at A, B, C and D, and one having closed loops as shown at E. The open loop type is the preferred one. However, most older diagrams used the closed-loop inductor symbol, and you may run across it now and then in books and periodicals.



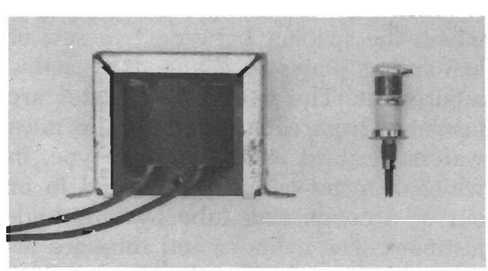
If the inductor has an iron core or slug it may be indicated by two straight lines placed alongside the inductor symbol, as in A below. This particular symbol



would be used for an iron-core choke in a power-supply filter, for example. B shows a continuously-variable iron-core inductor such as a slug-tuned r.f. coil. The iron-core symbol is not a *required* part of the inductance symbol. It simply represents a little additional information about the inductor when the person who draws the circuit wishes to supply it.



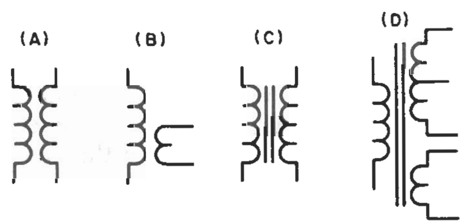
Typical inductances used at radio frequencies. Left, a multisection "pie-wound r.f. choke, and a small "air-wound" coil. Next to these is a tapped coil such as is used in small transmitters. The inductor at the right is continuously variable; a roller makes contact with the wire as the form is rotated by the control knob.

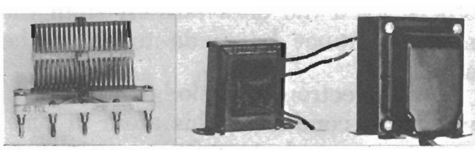


Iron-core inductances. Left, an inductor of the type used in power-supply filters (filter choke). Right, an adjustable inductor for radio frequencies. Adjustment of inductance is made by moving a small cylindrical powdered-iron core or "slug" in and out of the coil, which is wound on the form.

A transformer is essentially two (or more) inductors magnetically coupled, and the basic symbol for it is shown at A below. If the transformer has an iron core it can be shown as at C.

In this book the iron-core symbol is used only for inductors and transformers working at power-supply and audio frequencies. The core is omitted from the symbols for inductors and transformers operating at radio frequencies even though the actual transformer may have an iron core. This helps make it easier to differentiate between the two classes of transformers in glancing over a diagram.

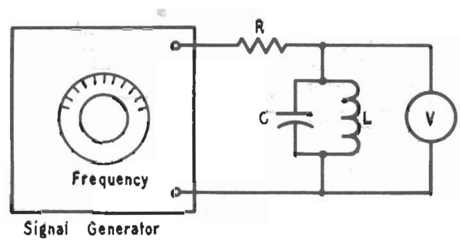




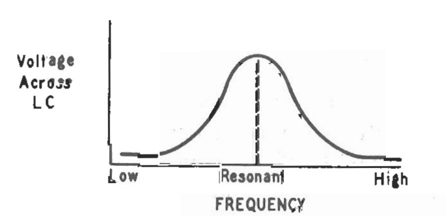
Transformers. The r.f. coil at the left is typical of the tank coils used in transmitters, and has a low-impedance output winding or "link." Such a winding is usually drawn with fewer loops than regular windings (B). A transformer for audio-frequency amplifiers (two windings-C) is shown in the center. The unit at the right is representative of power-supply transformer construction.

Resonance

Earlier it was mentioned that perhaps the greatest use of inductors and capacitors is in combination to form tuned circuits. To form a tuned circuit, the inductor and capacitor can be connected either in series or in parallel; the more common in radio work is the parallel connection. Connected in parallel the combination behaves like ("looks like") a high resistance at one frequency, called its resonant frequency or frequency of resonance, except that it does not dissipate power. (You will recall that power can only be dissipated in a resistance.) To clarify this a little, let us suppose we have a source of variable frequency r.f. energy, and we connect its output to a parallel-connected tuned circuit through a resistor, so:

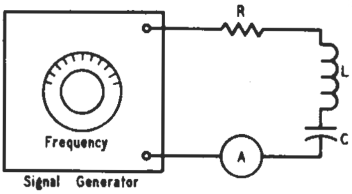


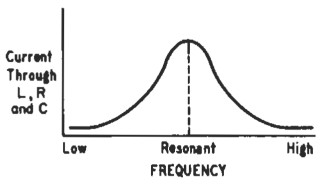
The box represents the source of r.f. energy, with a dial for setting the frequency, and the output runs to the parallel-connected tuned circuit (*C* and *L*) through the resistor *R*. An r.f. voltmeter, *V*, is connected across the tuned circuit, to make some voltage measurements. We will assume that the source of r.f., or signal generator, has constant output at all frequencies, the frequency being determined by the setting of the dial. If we turn the dial to change the frequency from the signal generator, we will find that the voltage measured across the tuned circuit (*L* and *C*) would follow a curve like this:



It would be low at low frequencies, then build up to a maximum at the resonant frequency, and then become low again at higher frequencies. The resonant frequency depends upon the *product* of *L* and *C* (*i.e.;* *L* multiplied by *C*), so a circuit with a 10-mh. inductance and 50-pf. capacitor would resonate at the same frequency as a 10-pf. capacitor and a 50-mh. inductance (or 20 mh. and 25 pf., or 25 mh. and 20 pf., etc.).

A series-connected circuit behaves in somewhat the same way, except that it behaves like a very low resistance at the resonant frequency:





The basic points to remember are (1) a parallel-tuned circuit acts like a high resistance at its resonant frequency (without consuming power), and a series-tuned circuit acts like a low-resistance connection at its resonant frequency. (2) The resonant frequency depends upon the *LC* product (*L* times *C*).

By the way, did you notice that you're reading the schematic symbols? It isn't too difficult, is it?

Vacuum Tubes

Up to now we have talked about electric currents without any detailed description of what they really are. This is sufficient when you're dealing with currents in wires, but not when you get into vacuum tubes. To understand vacuum tubes you have to know something about these currents and to know about currents you have to be on speaking terms with the **electron.**

Now electrons can get to be pretty complicated, as any physicist will testify, but for our purpose it is sufficient to know that they are elementary particles having the smallest known electrical charge. Together with **protons** and **neutrons,** electrons are part of the **atom,** and its reasonable to assume you know that word and the fact that all matter is made up of atoms. The atoms of the various basic elements are different because they contain different numbers of electrons and the other ingredients.

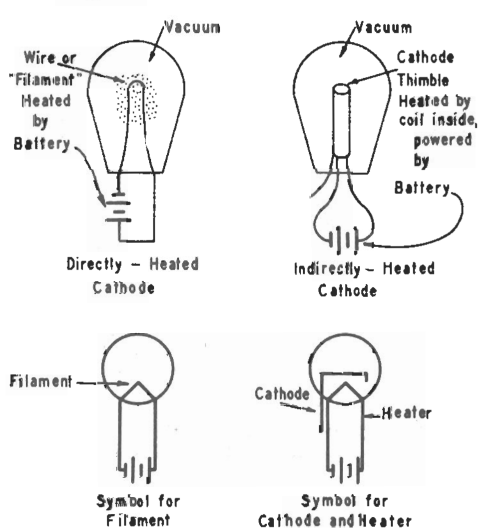
As mentioned above, the electrons have an electric charge (called **negative** to tell it apart from the opposite kind of charge, called **positive,** that protons have). A basic rule in electricity is that *opposite charges attract* and *like charges repel.* Each atom contains a number of electrons, together with a **nucleus** (protons and neutrons); the electrons are believed to rotate about the nucleus in "shells" at varying distances from the nucleus. The positively-charged nucleus attracts the negatively-charged electrons and holds them in their orbits around the nucleus. However, in some substances, such as metals, an electron in the outermost shell is not tightly bound to the atom and can readily be dislodged. In others, even the ones farthest from the nucleus cannot be made to leave the atom.

If an electron is dislodged from an atom in a conductor, this atom in turn attracts a new electron from a neighbor, and the neighbor from *its* neighbor down the line, and so a regular chain of motion is set up. This motion of the electrons along the line is called *electric current.*

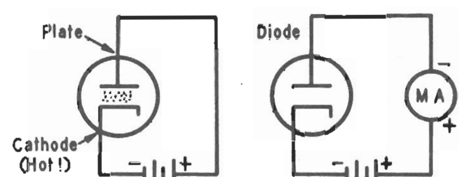
When a strong source of difference in potential, like a battery, is connected to a length of wire a large current flows through the wire, and the electrons work overtime trying to equalize the large difference in charges that exists at the two ends of the wire. But it must be remembered that the current through a wire is only a balancing of charges maintained by the movement of electrons from atom to atom, a relatively short hop. In other words, any single electron doesn't flow the length of the wire or anything like it.

The substances in which it is easy to dislodge an electron are the **conductors,** because they conduct electricity easily. They include most of the metals, with silver being the best, followed by copper and aluminum among the common metals. Substances that conduct little or no current are called **insulators**; dry air, ceramics, some plastics, mica and quartz are among the better insulators.

Getting back to the vacuum tube, it was found some time ago that some materials when heated in a vacuum will emit electrons. The emitting material is called a **cathode.** Two methods are generally used to heat the cathode: a current can be passed through the material to raise its temperature, in which case it is called a **filament or directly-heated cathode**: or a "thimble" of cathode material can be heated by a coil inside the thimble, in which case it is called an **indirectly-heated cathode.** Simple pictures of these are shown here, together with the symbols used to represent them in schematic diagrams. It should be apparent, of course, that it isn't necessary to use a battery to heat the cathode; a.c. is commonly used in radio equipment, and the batteries are shown here for simplicity. In many schematics the heater connections may not even be shown, since any radio man worthy of the name will know that the cathode must be heated, and the heater-connection details only clutter up the diagram.



If nothing else is put in the vacuum except the hot cathode, the first few million or billion electrons set free will cloud around the cathode and, having negative charges, repel any other electrons that are trying to escape from the cathode. However, if another element, called the **plate,** or **anode,** is installed in the vacuum, and if this element has a positive charge, some of the electrons will be attracted, in proportion to the magnitude of the positive charge. You can think of it like this:



The electrons flow from cathode to plate to equalize the charge; this constitutes an electric current. The difference between this current flow, and the current flow in the wires in the external circuit, lies only in the distances the electrons travel; it is still the same basic business of the electrons trying to equalize the charge around the circuit, and not being able to do it until the battery runs out of current and can't produce the difference in charges, or until the cathode runs out of emission or becomes cold because the heater is turned off or burns out. A **milliammeter** connected in the circuit will indicate the current flowing around the circuit.

A tube like this with two elements (plate and cathode) is called a **diode.** Current can be made to pass through it in only one direction; no current would flow through the diode if the negative (−) terminal of the battery were connected to the plate, because a negative charge on the plate would repel the electrons coming from the cathode.

Diodes and Power Supplies

So far we have shown batteries as the sources of direct currents, but in most of your work you will probably use an a.c. power supply. This is a device that takes the 60-Hertz a.c. from your house wiring and eventually delivers d.c. that is almost as good as you would get from a battery. (Later on you will see why we said "almost as good.")

An a.c. power supply consists of three basic sections: the transformer, the diode rectifier, and the filter. Let's start with the transformer. Earlier we mentioned inductors, or coils, and said that they were used with laminated iron cores at low-frequency a.c. The sketch shown here illustrates the practical form such an inductor might take. The laminated iron core is usually built up from L- or U-shaped stampings, to facilitate winding the coil first and then assembling the unit. An actual unit might have hundreds or even thousands of turns of wire in it; the sketch is greatly simplified.

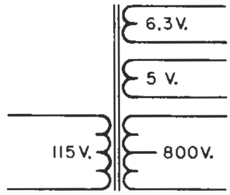
The second drawing shows the physical construction of a transformer. As you can see, two separate coils of wire are wound on the same core, and, like the simple inductor, it may have hundreds or thousands of turns in the windings, although in some transformers one of the windings may have only a few turns.

Transformers are designed for specific frequencies or frequency ranges, like 60 Hertz, 300 Hertz, and the audio-frequency range. The latter are called audio transformers and the former come under the heading of power transformers. A 400-Hertz transformer will get very hot when used at 60 Hertz, but a 60-Hertz transformer will work at 400 Hertz, for reasons beyond the scope of this discussion. (But we did want to warn you not to buy surplus 400-Hertz transformers and expect to use them at 60 Hertz.)

The input, or primary, winding of a transformer connects to the power source. Let's say we have a 60-Hertz power transformer designed to work with 115 volts on the primary. (Some are designed for 230 and other voltages.) We connect this primary to the 115-volt line by means of a plug and length of lamp cord. Measuring the voltage across the secondary (the other) winding with an a.c. voltmeter, we find that the voltage is something other than 115 volts. We could predict what this voltage would be if we knew the number of turns on both primary and secondary, because the *voltage transformation depends upon the turns ratio of the transformer.* Take a specific case. The primary has 300 turns and the secondary has 900 turns. This is a ratio of 1 to 3, and the secondary will measure 3 × 115, or 345, volts. If the secondary had only 30 turns, the ratio would be 10 to 1 and the secondary voltage would be 115 ÷ 10, or 11.5 volts.

You can see what a useful device a transformer can be, because it permits us to start with an a.c. power source at 115 volts and go up or down in voltage level very conveniently, which isn't true of a d.c. power source. The *power* level remains the same, however; the transformer that delivers 345 volts at 0.1 ampere ($P = EI$; $345 \times 0.1 = 34.5$ watts) draws 0.3 ampere at 115 volts ($I = P \div E$; $34.5 \div 115 = 0.3$ amp) from the line (plus a little bit more because there are some slight losses in the transformer itself). Similarly, the transformer that delivers 11.5 volts at 3 amperes draws 0.3 ampere from the 115-volt line. In other words, the power drawn by the primary must equal the power in watts delivered by the secondary (neglecting the slight losses in the transformer).

Many power transformers will have several secondary windings, to give several different voltages. For example, the power transformer in a receiver or small transmitter might have three secondaries: one delivering 6.3 volts, one 5 volts, and one delivering 800 volts. This would be shown in a schematic diagram like this:



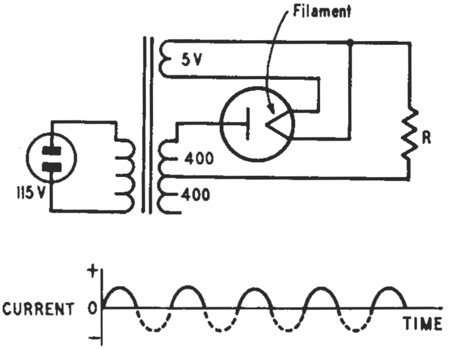
POWER TRANSFORMER

The symbol for a transformer with several windings, such as a power transformer. The numbers on the right-hand side (secondaries) represent the voltages that will be obtained when 115 volts is applied to the primary (left-hand) winding. Notice that a lead is shown from the center of the 800-volt winding; this is usually a center tap that divides the winding into two equal parts.

The 6.3 volts is used to heat the cathodes of the many vacuum tubes in the receiver or transmitter, the 5-volt winding heats the filament or cathode of the diode rectifier, and the 800-volt winding will supply the power that is to be converted to d.c. by the rectifier and filter. Power transformers are usually completely enclosed in a case, so they won't look like the earlier sketch unless the case is removed.

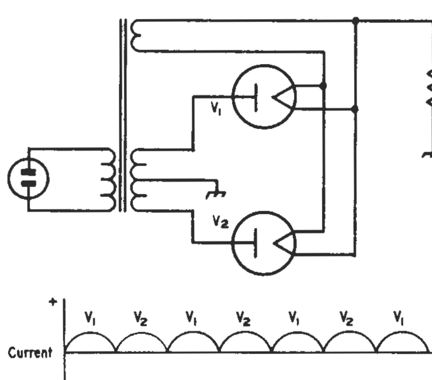
To understand diode rectifier action, let's connect a diode to the 800-volt secondary of our transformer, using the 5-volt winding to heat the filament. This is shown in the sketch below. (A plug has been connected to the primary, and the 6.3-volt secondary was omitted because we aren't considering it right now.) You will notice that we have added a resistor *R* and that only half of the 800-volt secondary is being used. The resistor is necessary to complete the circuit, and we are going to see what the current flow through *R* looks like. Since only half of the turns of the 800-volt secondary are being used, we know that 400 volts a.c. appears between the transformer center tap and the diode plate.

During the half of the a.c. cycle that the applied voltage makes the plate positive with respect to the cathode, the diode rectifier will conduct and current will pass through *R*. During the other half of the cycle, no current can pass



Schematic diagram of a power transformer connected to a diode. In this case the cathode of the diode is a filament of wire heated by the current from the 5-volt winding of the transformer. Diodes used in power supplies often use directly-heated filaments instead of the indirectly-heated cathodes common to receiving tubes, but the action of emitting electrons and the performance of the tube is the same as described earlier.
Since the diode can conduct current in only one direction, the current through *R* is alternate half cycles of the a.c., as shown by the solid lines in the bottom sketch. The dotted lines represent the half cycles when no conduction takes place.

through the diode and consequently no current can pass through *R*. The current passing through *R* varies with time as shown in the sketch. The action of the diode in permitting the current to flow in one direction only is called **rectification.**



When diodes are used to conduct on both halves of the a.c. cycle, a full-wave rectifier circuit is obtained. The bottom sketch shows the current flow through *R*. (Note the use of the chassis symbol for the return path in this schematic, and compare it with the preceding circuit where no chassis connection was shown.)

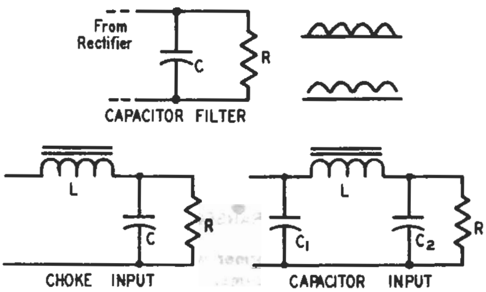
If now another diode is connected to the unused portion of the secondary winding, this second diode will conduct during the portions of the a.c. cycle that the first diode cannot. The current through R varies as shown. The rectifier circuit with diodes working on both halves of the cycle is called a full-wave rectifier, as opposed to the single diode half-wave rectifier that only uses half of the cycle.

The vacuum diode is not the only device that can rectify alternating current—that is, conduct current in only one direction. There are many others that possess this same property. Some have long since dropped out of use. In fact, the vacuum diode, too, is becoming obsolescent, and is now almost superceded (except in older equipment) by the semiconductor rectifiers discussed later. The operation of the vacuum diode is easy to understand, however, and serves very well to illustrate the phenomenon of rectification.

The Filter

The output from the rectifier, as represented by the current flowing through the resistor R, is not d.c. like that you would get from a battery. Actually it is what is known as *pulsating* d.c.; it flows in only one direction but not at a steady value. If you were to use this to replace a battery supply in a transmitter or receiver, it would introduce a strong hum on all signals, of the type you sometimes hear from small a.c. broadcast receivers. To smooth out the pulsations and eliminate the hum and its effects, a filter is used between the rectifier and the load R.

The simplest type of filter is a large capacitor across the load R. If the capacitance is high enough and the resistance of R is not too low, the capacitor will charge during the time the diodes conduct but it will not completely discharge during the times the diodes aren't passing much current. As a result, the current through R will never go down to zero. This is shown by comparing the two



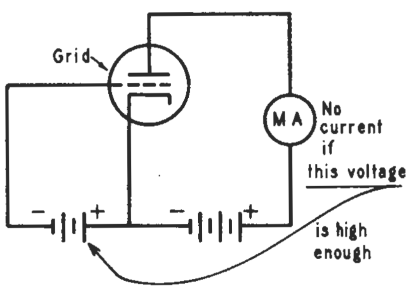
wave forms in the sketch above. With the capacitor C installed, there is less hum, or ripple, in the current passing through R than there would be without the capacitor.

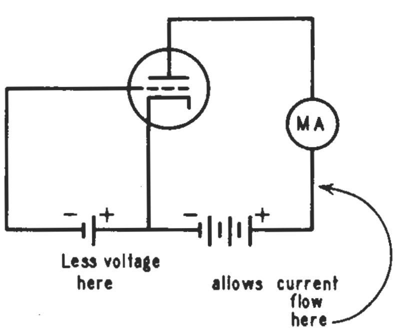
A further improvement in filtering action can be obtained by using an inductor, or **filter choke,** in series with the load. The basic filter sections can be cascaded (connected one after the other) to improve the filtering action still further. The two basic filters are called choke-input and capacitor-input filters. Generally speaking, the more inductance and capacitance used in the filter, the greater the ripple reduction will be. In the filter drawings shown here, it should be understood that the resistance R represents the load for the power supply, which might be a transmitter or receiver.

Good practice calls for connecting a high-resistance resistor across the output of a power supply, to discharge the capacitors when the power-supply primary voltage is turned off. Such a resistor, called a **bleeder resistor,** bleeds the charge from the capacitors and decreases the chances for accidental electrical shock.

The Triode Vacuum Tube

Now that we've learned a little about transformers and power supplies, let's get back to the vacuum tube. The diode is a one-way street for current flow, but by adding a policeman with authority we can do a lot more than the diode can do. The policeman, or authority, is called the **grid;** it is a mesh of wires between cathode and plate. By putting a negative charge on the grid (policeman holding up his hand), the current flow can be stopped, because the grid is nearer the cathode than the plate and a relatively small negative charge on it can overcome the attraction of the positive charge on the plate that must be felt over a greater distance. A smaller negative charge on the grid (policeman waving traffic on) permits the plate's positive charge to be felt in the vicinity of the cathode and attract the electrons. Since the grid is a mesh and not solid, the electrons can pass through to the plate and current flows through the vacuum tube. The action is something like this:





It should be realized that the action in the vacuum tube is not a stop-and-go operation like much automobile traffic is. It is a smooth and continuous operation, in which the current flow through the tube increases in proportion to the reduction in negative charge at the grid. The action of the grid is often likened to the control ability of a valve in a water line and, as a matter of interest, the British call vacuum tubes "valves."

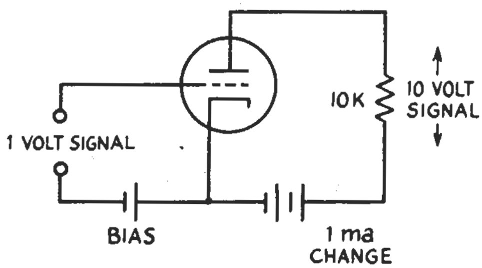
If the grid is made positive with respect to the cathode, some current flows from the cathode to the grid (the grid acts like a small plate) but most of the current flows to the plate unless the grid is made quite positive.

It is important to realize that no *power* is taken from the battery shown connected in the grid circuit (between grid and cathode) unless the positive terminal is connected to the grid, yet power is being taken from the plate battery (as evidenced by the plate current flow). This means that the vacuum tube gives us a tool with which a relatively large current flow can be controlled by a voltage source that doesn't have to furnish any power. It's like the one-way street, where the wave of the policeman's hand controls the tons of automobiles in the street. By using a vacuum tube in an electrical circuit, a small electrical signal can be **amplified** into a large one, through the magic of the action of the grid. In a radio receiver, almost infinitesimal signals in the antenna circuit can be amplified by vacuum tubes up to similar signals measured in watts. It should be mentioned that proper operation of vacuum-tube amplifiers permits the output signal to duplicate the input in frequency and changes in amplitude. The action of the grid in controlling the plate current can be considered instantaneous in most applications.

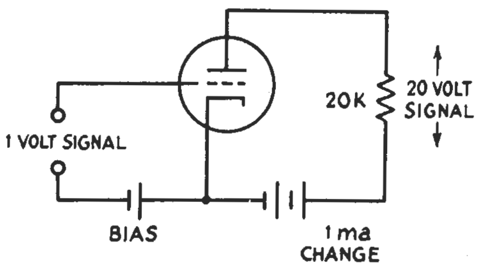
A vacuum tube with a cathode, plate and grid is called a **triode** (three-element tube). In many instances tubes with more grids are more suitable, and you will find **tetrodes** (four-element tubes with two grids) and **pentodes** (five-element tubes with three grids) in many spots in your radio equipment. But the grid to which the signal is applied, the **control grid**, is the policeman in the one-way street.

The actual amplification through a vacuum tube depends upon the construction of the tube and what is connected in the plate circuit. This is easy to see in an example:

Suppose we have a vacuum tube that,



AMPLIFICATION $= \frac{10}{1} = 10$



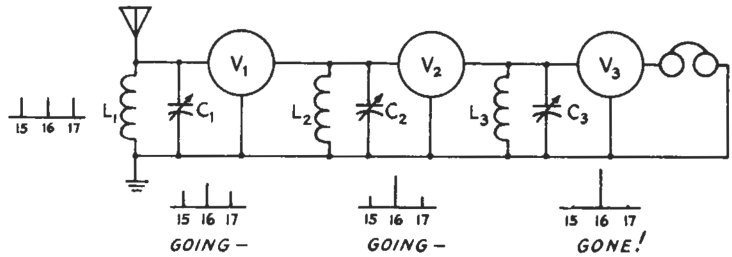
AMPLIFICATION $= \frac{20}{1} = 20$

by the nature of its construction, gives a change of 1 ma. in plate current for a 1-volt signal at its grid. If we connect a 10,000-ohm resistor in the plate circuit, a 1-ma. change in plate current develops a 10-volt signal across the resistor $(0.001 \times 10{,}000 = 10)$. If we use a 20,000-ohm resistor instead of 10,000 ohms, a 1-ma. change in plate current develops 20 volts. Thus by simply using a higher value of resistance for the plate "load," we increased the amplification of the stage from 10 to 20. The process can be carried further, until it eventually becomes limited by certain practical considerations. The important thing to remember is that, for a given vacuum tube and set of operating conditions (grid bias, plate voltage) the voltage amplification will depend upon the "load" in the plate circuit.

Selectivity

If we wish to build an amplifier that will amplify a wide range of frequencies equally, as in an amplifier for audio frequencies, we choose something for a plate load that has as nearly as possible a constant value of resistance over this frequency range. A resistor is, of course, a good example of such a load, although a good audio-frequency transformer will also satisfy the requirement. However, if it is desirable to amplify only a single frequency or a very narrow band of frequencies, we can use a load that has a high resistance only at the desired frequency. This is our friend the parallel-tuned circuit, described some pages back. You will recall that a parallel-tuned circuit behaves like a high resistance at the resonant frequency and increasingly like a low resistance as you move away from the resonant frequency. It's just what we want. Unfortunately, it is usually difficult to build a single tuned circuit that is capable of rejecting unwanted signals to the degree we would like, and we are forced to use several circuits, all tuned to the desired frequency. Their cumulative effect is illustrated by the following example:

Let us suppose that three signals are coming down the antenna lead; they are represented by the three vertical lines marked *15*, *16* and *17* (which could mean signals at 7.15, 7.16 and 7.17 MHz.). The strength of each signal is proportional to the height of the line representing it, so we see that these three signals have the same strength as they come down the antenna lead. We tune L_1C_1 to the frequency of signal *16*, and thus when the three signals are presented to vacuum tube V_1 the signal *16* is slightly stronger. We also tune L_2C_2 to frequency *16;* tube V_1 amplifies this signal more than the others, and thus a proportionately-larger signal is fed to V_2. At the same time the selectivity of L_2C_2 has cut down the amplitudes of *15* and *17*. By tuning L_3C_3 to frequency *16* the process is carried still further, and only signal *16* is presented to V_3. If the operator wishes to listen to signal *15*, he must tune the circuits to frequency *15*. (In practice, the

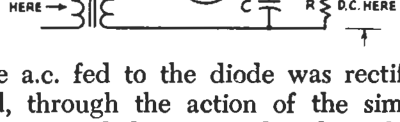


three variable capacitors would be linked mechanically so that a single control tunes the three circuits simultaneously.)

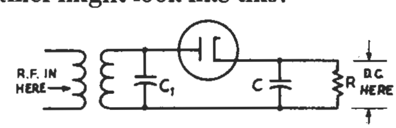
Detection

In the receiver just outlined, the tubes V_1 and V_2 would be used as, and be called, **radio-frequency amplifiers** (or, more usually, "r.f. amplifiers"). But notice that V_3 has a pair of headphones connected to it, and you can guess that r.f. doesn't operate a headphone set. Yes, V_3 has a different function; it represents a vacuum tube operated as a **detector.** A detector is so connected and operated that it will recover the intelligence from the received r.f. signal. That last statement sounds pretty fancy, doesn't it? But it isn't, really; let's see how simple it is.

One of the most common forms of detector is a diode rectifier, connected as a half-wave rectifier. Here's an old friend, talked about back in the section about power supplies. You recall that a diode rectifier will take an a.c. signal and transform it into d.c., like this:



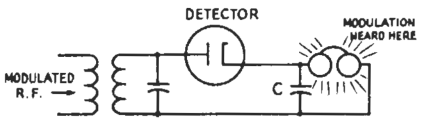
The a.c. fed to the diode was rectified and, through the action of the simple filter *C*, ended up as a d.c. through *R*, which of course developed a voltage across *R*. But we didn't say a thing about *frequency;* the diode works at any old frequency, for all practical purposes. We could have used an r.f. signal instead of the 60-Hertz signal, and the diode would work just as well. (The transformer wouldn't require iron in it at r.f., and we could use a much smaller capacitance at *C* for the same degree of filtering, but everything else is the same.) Our r.f. rectifier might look like this:



There's a mighty close resemblance.

Now think back to the early talk about a phone (A3) signal. We said that the output was modulated, or varied, in accordance with the sound waves of the voice of the operator. Even if this operator is a coloratura soprano his voice vibrations aren't going to occur faster than 6000 to 7000 times a second, so we know that the r.f. signal he is modulating doesn't change its level faster than that. But let's say that during a short "Ah" or "Oh" in his speech his voice is close to a pure 800-Hertz tone. During the time it takes to say the "Oh" or "Ah" the transmitter output is being varied at a rate of 800 cycles per second. If the voice tones were at other rates, the transmitter output would be varying at those other rates.

Reconsider the detector. It develops a voltage across *R* that is proportional to the signal fed to the input. The filter *C* can smooth out the rapid (millions per second) changes at r.f., but if we make the capacitance small enough it can't smooth out an 800-Hertz change. Consequently, if the strength, or amplitude, of the r.f. is varying at 800 Hertz, the current through *R* is varying in a like manner. Put a pair of headphones in the circuit in the place of R and the headphone output varies at 800 cycles per second. That's the 800-Hertz "Oh" or "Ah" the transmitting operator was speaking at that instant; we have transmitted voice



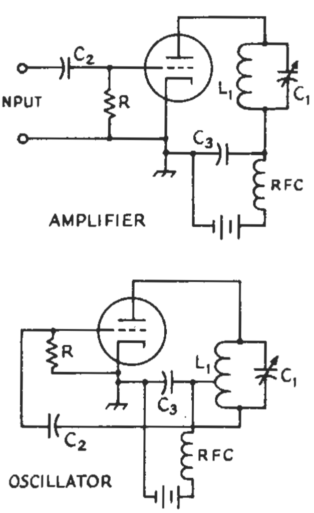
by radio. But make no mistake: we transmitted voice (intelligence, even if it was only an "Oh") by changing the transmitter output in accordance with the voice frequencies, and then used a device called a detector to reclaim the modulating frequency (or frequencies, because voice is usually more complex than a single tone). The voice itself doesn't pass through the air from transmitter to receiver, even though you will hear references to a "carrier" when you start talking with other hams about amplitude modulation. (The preceding explanation of modulation and detection is a classical one and is quite valid, but as soon as you can you should learn more about side bands and other factors involved.)

So far we have only talked about vacuum tubes used as voltage amplifiers and detectors. The prime purpose of a voltage amplifier is to build up weak signals, in the microvolt or millivolt range, into signals that would be measured in volts. Voltage amplifiers generally will have high gain (ratio of output to input signal voltage), low distortion and poor efficiency. To get the maximum power from any given tube the grid must be driven positive during a portion of the signal cycle. Tubes operated this way are usually found only in transmitters.

Transmitters

If you have managed to stay with us up to here, we're ready to talk transmitters. Although the antenna is actually the most important factor in the strength of one's signal at a distance, most amateurs take the greatest pride in their transmitters. There is a good reason, of course. A good transmitter puts out a signal that leaves little room for improvement, from the standpoint of its voice quality or its clean, crisp keying, and it is admired by all that hear it.

The simplest type of transmitter is an oscillator working directly into the antenna. The oscillator is the frequency-determining portion of a transmitter, and it is simply an amplifier connected in a manner that will feed back some of the output voltage to control the grid. You can see that, in a sense, this is like a dog chasing its tail, and it is this kind of action that sustains the oscillations. The frequency of the oscillations depends upon the tuned circuit in the oscillator and a few factors beyond the scope of this book. But it isn't too difficult to picture the operation of an oscillator by starting out with an amplifier circuit and then modifying the circuit slightly:

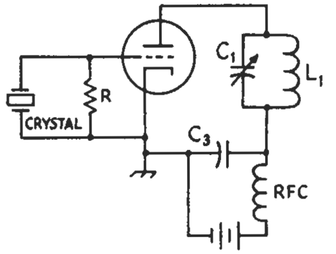


The circuit at the top is that of an r.f. amplifier drawn in more detail than before. You will recognize the tuned circuit L_1C_1 in the plate circuit; a plate bypass capacitor C_3 and an r.f. choke RFC are shown because most practical circuits include them. C_3 furnishes an easy path for the r.f. to complete its flow around the plate circuit and *RFC* discourages any r.f. from trying to flow in the power supply. Together, *RFC* and C_3 form an r.f. filter. You will notice that no grid-bias battery is shown in this circuit. Instead, the grid of the tube acts as the plate of a diode rectifier; when a signal is applied at the input the grid rectifies some of this signal. The rectified current flows through *R* and is called **grid current**; the voltage drop of this current flowing through *R* supplies the grid bias. Obviously in a circuit like this the tube is biased only when there is an incoming signal, so we have to remember never to apply full plate voltage without a proper signal at the grid. The capacitor C_2 prevents any possible short circuit across *R*. Incidentally, you will find the resistor *R* called a "grid leak"; this term dates back to the early days of radio and has nothing to do with a need for plumbing repairs (Don't let anyone sell you a drip pan for a grid leak!)

To make an oscillator out of the circuit, it is necessary to derive our input signal from the output. This we do by connecting the plate-return circuit up on the coil, as shown below, and then running the lead to the grid around to the end of the tuned circuit. If the tap is made at a proper point on the coil (it isn't highly critical but it varies with tube characteristics) the oscillator will run along merrily when power is applied. The frequency of its output will be determined by L_1C_1. There are several basic oscillator circuits, varying in the way the feedback is obtained, but the operation is always based on the same principle: using some of the output signal as the input signal for an amplifier. The one shown above uses "inductive feedback" (feedback of a portion of the voltage across L_1) but capacitive coupling is used in some other circuits.

One difficulty with oscillators like the one just discussed is that they are not always as stable as we would like them to be. Since the frequency of the output is determined by L_1C_1, it is obvious that if the inductance or capacitance, or both, change with temperature or humidity or mechanical vibration then the output frequency likewise will change. Oscillators are also sensitive to changes in plate voltage and to how much power we try to take from them. Although excellent "self-controlled oscillators" can be built by exercising sufficient care, the easiest way to stabilize an oscillator is to use a quartz crystal as the frequency-determining element. This quartz crystal, when properly cut and used, has the interesting ability to vibrate mechanically and develop an alternating electrical potential at radio frequencies; the exact frequency depends upon the thickness of the quartz wafer among other things. The crystals used by amateurs are usually smaller than a postage stamp. Thin crystals operate at high frequencies, thick ones at low frequencies.

A crystal oscillator circuit might look like this:



As you can see, it looks just like the amplifier circuit, except that the quartz crystal is used where the input signal was formerly applied. No, we didn't forget C_2; it just isn't necessary in this case because the crystal is an insulator and won't short-circuit *R*. In the crystal oscillator circuit shown here, capacitive feedback is used. Don't look for the feedback capacitor because you won't find it drawn in the circuit. The small capacitance between the grid and plate of the tube, amounting to only a few pf. at most, is usually sufficient to furnish the necessary feedback. Oddly enough, this circuit stops oscillating when L_1C_1 is tuned exactly to the crystal frequency; it must be tuned to a higher frequency for the stage to oscillate. When you get farther along in radio theory and understand about phase relationship you will understand why, but we won't burden you with it here.

The power output from a crystal oscillator stage usually cannot be pushed very far without danger of shattering the crystal. For this reason, the usual practice is to use a crystal oscillator stage to control a **power amplifier.** An oscillator stage with an output of a few watts can be used to control an amplifier capable of delivering twenty-five to several hundred watts. If the desired output frequency is higher than the frequency of the oscillator stage, a **frequency multiplier** stage (or stages) is used following the oscillator. Thus oscillator output at 3550 kHz., can be multiplied to 7100 kHz. by a two-times multiplication (doubling) and then by a three-times multiplication to 21,300 kHz. Thus by doubling and tripling one can use a 3550-kHz. oscillator for 21,300-kHz. frequency control. Frequency multipliers are usually called **doublers** or **triplers,** to describe the order of frequency multiplication. The circuit diagram of a frequency multiplier is quite similar to that of a straight amplifier, except that the plate circuit is tuned to two or three times the frequency of the grid signal. Multipliers require a much higher grid bias than straight amplifiers, and they aren't as efficient in operation.

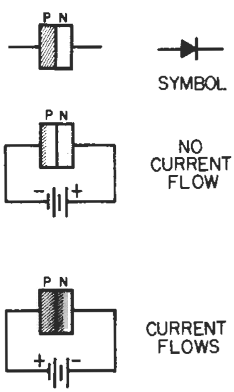
It wasn't exactly accurate to say that the oscillator stage *controls* the amplifier. It would be more correct to say that "the signal from the oscillator (or multiplier) stage is amplified by the power amplifier stage." However, in your amateur work you will hear the oscillator (or multiplier) signal described as the "excitation" or the "drive" for the power or final stage. You will also learn that a triode amplifier with the grid and plate circuits tuned to the same band will require **neutralization** or it will become an oscillator, while a tetrode or pentode amplifier may not require neutralization. This point wasn't brought up before; it was saved until you learned in the crystal-oscillator description that the grid-plate capacitance is a potent feed-back path. The grid-plate capacitance is minimized in tetrodes and pentodes by the presence of the **screen grid,** a grid between control grid and plate.

Semiconductors

You know, of course, that the vacuum tube isn't the only device that can rectify alternating current and amplify signals; the transistor pocket radio will have made you aware of that. The semiconductor diode and the transistor can be thought of—very roughly—as counterparts of the vacuum-tube rectifier and the triode we've just been discussing. But don't try to carry this analogy too far. The internal operation of these devices is quite different. It's also much more complicated, which is why we took up the vacuum tube first.

The heart of the diode and transistor is a special kind of material called a **semiconductor.** As you might guess from the name, it is neither a good conductor nor a good insulator, at least in its undoctored state. The semiconductor materials principally used are the elements silicon and germanium. Pure crystals of these materials will conduct electricity, but their resistance is quite high. However, if a tiny amount of "impurity" in the form of certain other elements is introduced into the germanium or silicon crystal structure, the result is a conductor having fairly reasonable values of resistance.

In itself, this wouldn't accomplish much. We could get still better conductors simply by using ordinary metals. The interesting thing about adding impurities—called "doping" the semiconductor—is that two kinds of effects can be obtained, depending on the impurity material used. With one kind there will be free electrons in the semiconductor, which is then called **n-type.** With another kind there will be a deficiency of electrons, and each missing electron is called a **hole** because the electron-deficient spots (they're subatomic in size, naturally) can move around in the semiconductor just as free electrons can. A semiconductor having an excess of holes is called **p-type.**

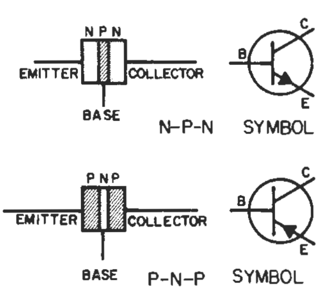


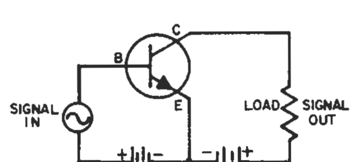
Rectification and amplification become possible when the two types are properly combined in the same structure. As shown in the above drawing, one part of the semiconductor crystal is doped to become p-type and the other part is doped to become n-type. The dividing line between the two types is called the **junction.** A battery connected as in the second sketch would attract electrons in the n-type, pulling them toward the outer edge of the crystal, away from the junction. Similarly, holes would be attracted toward the edge of the p-type material away from the junction. As neither the holes nor electrons cross the junction, there is no current flow. However, if the battery polarity is reversed, holes are "pushed" across the junction to the n-type side, and electrons are pushed across it to the p-type side. Once having crossed, they are free to flow on into the battery leads; the diode passes current with this polarity applied.

In the symbol for the diode the arrowhead corresponds to the plate in the vacuum-tube rectifier. The line corresponds to the tube's filament or cathode. The direction of "easy" current flow is from arrowhead to line, with the applied voltage more positive on the arrowhead than on the line.

The **transistor** consists of two diodes arranged in something like back-to-back fashion. That is, there are two junctions in the semiconductor crystal, as shown in the figure, one on either side of a doped section called the **base.** One of the outside sections is called the **emitter** and the other is the **collector.** Although the emitter and collector both have the same type of doping, they are processed differently during manufacture so that the emitter-base diode is a suitable input circuit for the transistor amplifier and the collector-base diode is suitable for the output circuit.

As you can see, in the drawing below, there are two possible ways of making the transistor, one using a p-type base and the other an n-type base. The first is called an n-p-n transistor and the second is a p-n-p. Both types are widely used. An obvious difference between them is that the voltages applied to a p-n-p have to be oppo-





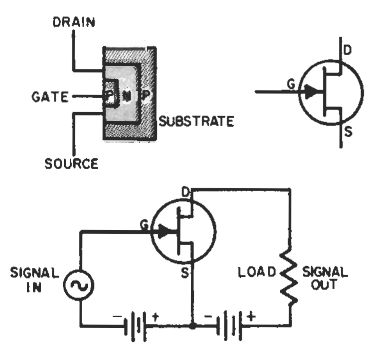
site in polarity to those applied to the n-p-n type; this is readily appreciated when you remember what we said about current flow in the diode.

Diodes alone don't amplify signals, so how can the transistor do it? In the case of the diode, we saw that applying the right polarity to the n- and p-type materials forming the junction forced the holes and electrons to cross the junction and thus caused a current to flow. (Using the right polarity to cause current flow is called **forward biasing,** incidentally.) In operating the transistor, the base-emitter junction is forward-biased, so current flows across this junction. In the little circuit in the figure we have shown an n-p-n transistor with forward bias on the base-emitter junction; consequently, electrons from the n-type emitter cross over to the p-type base.

In the actual transistor the base region is extremely thin, and most of these electrons hardly get into the base before they "feel" the relatively-high collector voltage which, being positive, attracts them across the collector-base junction. Thus most of them flow right straight through from emitter to collector, and don't get a chance to come out through the base lead at all. In other words, the emitter current is also the collector current, except for a small part that manages to flow out the base lead. If there were no voltage on the collector, though, all the current would flow out through the base lead. It is this change in the way the current flows that holds the secret of amplification in the transistor.

Here's why: Imagine that a signal is applied to the base-emitter junction, as shown in the circuit, and that there is no voltage on the collector. Then we have a simple diode formed by the base and emitter, and the entire current flows in the base and emitter leads. This amplitude of this current will follow the amplitude variations in the signal. But if we now apply the collector voltage, most of the current disappears from the base lead, although it still flows in the emitter and collector leads. Nevertheless, its amplitude is still controlled by the variations in signal amplitude, since it is really the emitter-base current, diverted into the collector by the "bias" voltage on the collector. It is "output" current in the collector circuit, though, and since it is much larger than the base current—50 to 100 times larger, usually—we have a much amplified version of the signal (base) current in the output (collector) circuit.

In the circuit shown, the base is the signal-controlling element and the collector is the output element. Thus we can compare the base to the grid and the collector to the plate of a triode vacuum tube. Similarly, the emitter can be compared to the cathode. In fact, we can substitute these for the tube elements in the circuits that we discussed earlier, provided suitable operating conditions and circuit-component values are used. However, don't make the mistake of thinking that the tube and transistor are *equivalent,* even though there may be external similarities.



The type of transistor we've been talking about is by far the most common kind, but there is another that works on quite different principles—the **field-effect transistor.** You'll find this type in the practical receiver described later in this book. Amplification in the field-effect transistor or "FET" doesn't depend on electrons or holes crossing a junction;

in fact, in using the FET precautions are taken to see that they *don't* cross. The structure of an FET is shown in the accompanying drawing, together with its circuit symbol. It is made by forming an n-type "channel" in a crystal of p-type material, and then forming another p-type section on top of the n-type, but not connected to the main body of p-type. The latter is called the **substrate,** and the small p-type section is called the **gate.** Connections are made to both ends of the n-type channel, one end being called the **source** and the other the **drain.** The gate is biased, with respect to the source, so that current cannot flow across the p-n junction at any level of signal to be applied to it. The negative voltage on the gate forces the electrons in the channel away from the gate, thus narrowing the channel and raising its resistance to current flow. When the signal makes the gate instantaneously more negative, the channel is narrowed still more, but when the signal swings in the positive direction the electrons can approach more closely to the gate; that is, the channel becomes wider. Thus the resistance of the channel is varied by the signal, allowing an alternate increase and decrease in the drain-to-source current. Because there is never any current flow across the junction, the gate input circuit takes no power from the signal source (the field-effect transistor is much like a vacuum tube in this respect) and an amplified signal can be produced in a load in the drain circuit.

The drawing shows an n-type channel, but it could be p-type just as well, with n-type gate and substrate. Sometimes a connection is made to the substrate, although none is shown in our drawing. When there is, the substrate is usually connected to the source.

There is still another version of the FET, one not using a p-n junction at all. Instead, the gate is a metal electrode separated from the channel by an extremely thin layer of glass-like insulation. The electric field operates through this just as it does through the junction in the FET shown in the drawing. To distinguish it from the type of FET described above, it is called an "insulated-gate" (or MOS, for metal-oxide-semiconductor) field-effect transistor. The other is known as the "junction type."

There are many other kinds of semiconductor devices, and new ones are being developed right along. They need not concern you at this juncture, although you will run into some of them as you become more experienced in amateur radio.

Right now, if you've grasped what has been discussed so far in this chapter, you know more than enough to pass the technical part of the Novice examination, with the exception of the few definitions treated in the following section.

Keying and Modulation

After you acquire a receiver and listen around in the amateur bands, you will begin to recognize that all of the A1 (radiotelegraph) signals don't sound the same. Ignoring the differences that result from the different sending speeds and (unfortunately) the different interpretations of what good code is, you will notice that some signals change pitch (frequency) during a dot or dash. This is called **chirp.** You will also notice that some signals have a **click** or thump on make (beginning of character) or on break (end of character) or both. The clicks may be combined with chirps. Or the signal may have a low humming sound, indicating that more filter is needed in the power supply.

It would be quite natural to assume that, when a transmitter with good stable output on, for example, 3720 kHz. is turned on and off by means of a telegraph key, the only frequency the output energy could have would be 3720 kHz. Such is not the case, however. If the transmitter output is turned on and off

quite rapidly, energy will appear either side of 3720 kHz. during the instants that the transmitter is turned on and off. If the transmitter output can be made to increase to maximum more slowly (and fall from full output slowly on break), the energy appearing on either side or 3720 kHz. will extend only a few hundreds of Hertz at most, instead of the kiloHertz it will extend when no provision is included for the gradual rise and decay of the output. The equipment used to reduce these key clicks is called a **key click** or **shaping filter.**

Another source of spurious signals from a radiotelegraph transmitter is a **parasitic oscillation.** This is a signal on a frequency entirely different from that of the desired signal and is caused by the power amplifier (or other stage) oscillating by itself. Low-frequency parasitic oscillations are caused by the amplifier oscillating at from 30 to 100 kHz.; their effects will usually be a single signal either side of the normal transmitter frequency, removed from the transmitter frequency by 30 to 100 kHz. (It will be the same either side.) High-frequency parasitics are usually indicated by poor transmitter efficiency and a tendency for the amplifier to operate erratically.

It was just mentioned that one couldn't turn a transmitter on and off (key it) without generating new frequencies either side of the normal output frequency. This is still true when we try to make the slightest change in the output, as to modulate it with voice for A3 transmission. It will be found that new frequencies appear on either side, removed by an amount equal to the modulating frequency. For example, if we modulated a 3860-kHz. transmitter with a 1000-Hertz tone, we would find new energy at 3859 and 3861 kHz. However, if we were to distort the 1000-Hertz tone by some means, and consequently have present the harmonics at 2000, 3000 and 4000 Hertz, modulating with this *distorted* 1000 Hertz would give energy at 3856, 3857, 3858, 3862, 3863, and 3864 kHz., in addition to the normal energy at 3859, 3860 and 3861 kHz. These extra or spurious signals are called **splatter;** they are caused by distortion in the speech amplifiers or by distortion caused by **overmodulation** (more than 100 per cent). The cure for the latter is to turn down the audio volume control or to speak more softly.

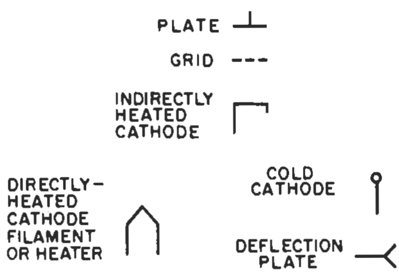
More Circuit Symbols

Earlier we introduced you to the circuit symbols for the basic electrical quantities you'll be dealing with in amateur radio. These sufficed for the discussion of radio circuit principles. Practical circuits, though, have much more in them than inductance, capacitance, and resistance. There will nearly always be switches and connectors of various types, and possibly a relay or two. To round out this section we're showing the symbols for a number of the most commonly used components.

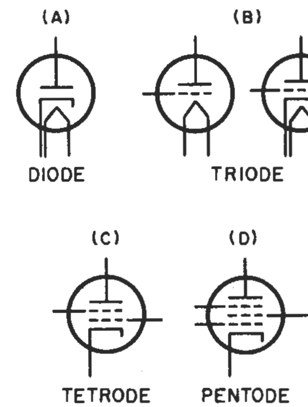
Vacuum Tubes

The simple triode tube that was used in the examples of vacuum-tube circuits can be developed into a great many more complicated structures. This is most frequently done by the addition of extra grids. The **tetrode** (a four-electrode tube) has a second grid between the control grid and plate; this extra grid is usually called the **screen grid** and serves to prevent the plate from "seeing" the control grid, electrically speaking, and thus reduces the grid-plate capacitance we mentioned earlier. Equally important, the screen grid helps draw electrons to the plate and improves the effectiveness of the tube. In the **pentode** (five-element tube) a third grid is added between the screen grid and plate; this improves certain aspects of tetrode behavior that we won't go into here. When there are more than three grids, as in the **hexode** (six-element) and **heptode** (seven-element) tubes, the structure usually is one designed especially for "frequency conversion" as used in the superheterodyne receiver. The principles of such receivers are somewhat outside our scope here, but you'll meet the "superhet" before long in your amateur career.

The circuit symbols for all these types of vacuum tubes are made by combining symbols representing the individual electrodes actually in the tube; the appropriate assembly is then enclosed in a circle or, in the more complicated cases, in an elongated circle. The element symbols most commonly used are shown below.



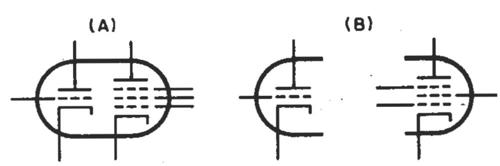
The more basic tube types—diode, triode, tetrode and pentode—are enough to illustrate how the tube symbols are "manufactured." The diode at A (below) consists of a plate, indirectly heated cathode, and heater. The two symbols shown for the triode, B, illustrate the use of two types of cathode; the symbol at the left has a directly-heated cathode or filament while the one at the right is indirectly heated. Either type of cathode may be found in any tube type, whether



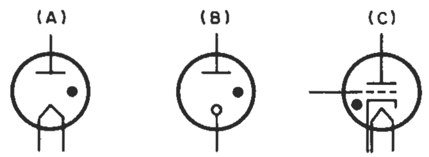
it is a diode, triode, tetrode, pentode, or one with still more elements.

When a tube has an indirectly-heated cathode it is common practice to omit the heaters from the tube symbols, as has been done in the tetrode and pentode symbols, C and D, and group all heaters in the circuit near the source of heater power. This is a legitimate procedure because the heaters have no other function than to make the emitting cathode hot enough to do its job: they take no other part in the operation of the circuit. Grouping them separately avoids cluttering up the diagram with numerous crossovers and makes the circuit easier to follow.

In practice you will often find two—or even more—complete tube structures in a single glass envelope. The most common examples are the dual triode (two triodes in one bulb) and the triode-pentode. The complete symbol in such cases includes the symbols for both tubes in one enclosure. However, it is seldom

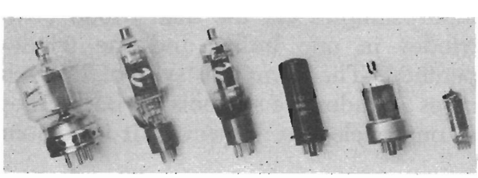


convenient to show multiple tubes all in one piece in the circuit, since the individual structures may be used for completely different purposes and would logically appear in widely-separated parts of the diagram. In such cases the enclosure is shown broken as in B, and the triode and pentode symbols are used in the circuit as though they were separate tubes. The separate sections are usually given a circuit designation (V_{1A}, V_{1B}, etc.) which identifies them as all being in the same envelope.



Some "vacuum" tubes have gas introduced into them intentionally. The ones most often encountered in amateur equipment are mercury-vapor rectifiers and voltage-regulator ("VR") tubes. Both are diodes. The mercury-vapor rectifier usually has a directly-heated cathode, A, while the VR tube has a cold cathode, B. The presence of gas in the tube is indicated by the dot inside the envelope. Another gas type you will meet occasionally is the thyratron, or gas triode, shown at C.

As a help to the constructor, the socket pin number to which each tube element is connected usually is given on the tube symbol close to the appropriate element. (This information, however, is not a *required* part of the symbol.)

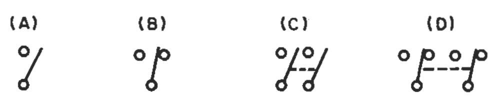


Big or little, glass or metal, based or not based, the symbol is the same for any tube of a given basic type. The big tetrode at the left, capable of handling a full kilowatt, has the same symbol as the low-power tetrode at the right.

Vacuum-tube symbols frequently omit elements, such as suppressor grids, that have only *internal* connections and are not brought out separately to a base pin on the actual tube. This makes the symbol less complicated and avoids internal crossovers in the tube symbols. The actual connections tc the tube are not affected by this omission.

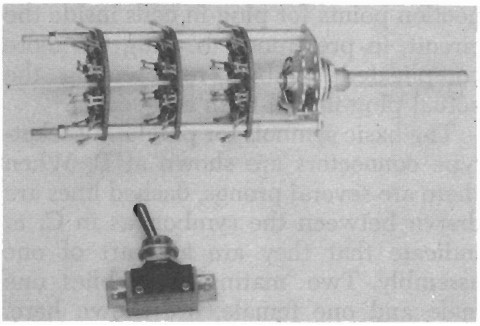
Switches and Relays

Shown below are the symbols for toggle switches. There are four common types—single-pole single-throw (s.p.s.t.) at A, single-pole double-throw (s.p.d.t.) at B, double-pole single-throw (d.p.s.t.) at C, and double-pole double-throw (d.p.d.t.) at D. Note that in the symbols for the double-throw types the switch arm (straight line) always is touching one contact (small circle), since an ordinary toggle switch has no "open" position. The double-pole types are ganged



(that is, operated simultaneously from one control), which is shown by the dashes connecting the movable arms. However, ganged switches, like multiple tubes in one envelope, can have their separate sections placed in different parts of the circuit diagram, in which case the sections have appropriate designations (S_{1A}, S_{1B}, etc.) to show that they are all part of one switch mechanism. The dashed lines can be omitted when this is done, but are sometimes included when it is thought desirable to do so.

Multicontact switches, such as the rotary "wafer" type, can be represented by either of the symbols shown below. The choice is usually a matter of making the wiring diagram as easy as possible to follow. The straight-line arrangement

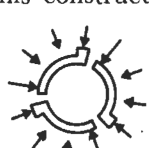


The three-section rotary switch at the top is just one of many styles. The number of wafers may run from one to as many as a half dozen, and both phenolic and ceramic wafers are available. The familiar toggle switch is below.

shown at A is used less frequently than the circular one at B. In either case, it is customary to show only the actual number of contacts *used,* although the switch itself may have more. (The number of contacts on small wafer switches is usually 11 on a wafer having a single arm or pole, 5 per pole on a wafer having 2 poles, and 3 per pole on a wafer having 3 poles.) Those not needed in the circuit are usually ignored in the diagram.

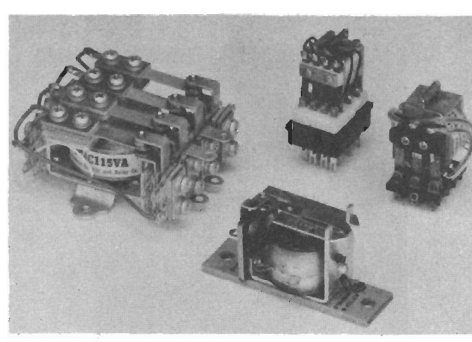
The separate sections of a multiple-pole switch, whether the sections are on the same or different wafers, can be shown to be ganged by using dashed lines as in the case of the toggle switches discussed above. However, it is more common to place the switch sections where they fit best in the diagram; the same circuit designation is used for all, with A, B, C, etc., identification to show that they are all operated from the same control.

A type of rotary-switch symbol frequently used in circuits of commercial equipment is a sort of picture diagram, illustrated by the example below. In switches of this construction the switch "arm" is a metal ring, or segment of a ring, on the wafer. It makes continuous contact with a fixed spring contact, indicated by the longer arrows in the example. The ring has one or more projections that meet the shorter arrows as the wafer is rotated. These short arrows represent the fixed contacts or switch "points."

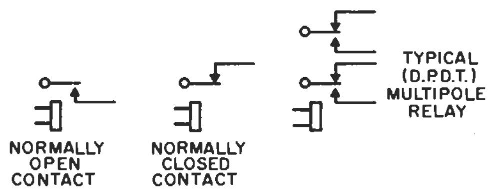


This type of symbol is very useful for indicating actual wiring of a switch wafer, since it shows exactly which contact to use for a particular circuit connection. The disadvantage is that it is difficult to trace out what the switch actually *does* in the circuit. However, there is a fairly simple way to find out what is connected to what at each position of the switch. Make a tracing of the ring or segments on transparent paper and rotate the tracing one switch position at a time (a short arrow, in general, is placed at each switch position) and follow the circuit through the short arrow, projection, ring segment and long arrow. At times the projection will be large enough to make contact with two or more short arrows in one or more positions, so *all* the possibilities for contact must be observed.

The symbols for relays are shown on p. 48. Note that the arm moves *toward* the coil when the coil is energized, and springs away from it when the coil current is cut off. In actual circuit diagrams



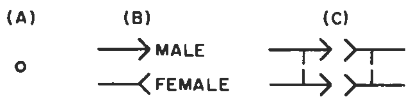
A few of the many varieties of relays are shown here. The large one at the left is for power switching. A miniature type is in the top center.



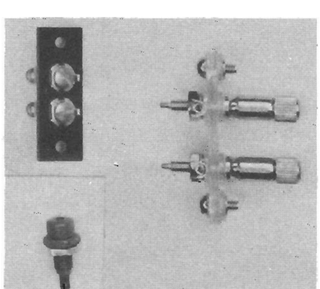
the contacts may be considerably separated from the relay coil as a matter of convenience.

Connectors

A fixed terminal is represented by a small circle as shown at A below. This symbol can stand for a binding post,



screw terminal, or other type of contact to which a wire can be connected. It is also used as a general symbol for an external or internal connection when for some reason—for simplifying the appearance of the diagram, or because the exact type of connector used doesn't matter—no specific type of connector is to be represented. For example, this symbol may be used to indicate external connections to supply voltages. Then, if he wishes, the builder may select any one of several types of plug-and-socket multi-circuit connectors for the actual piece of equipment. The small terminal symbol also is frequently used to indicate con-

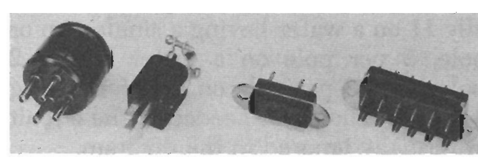


Terminal strips can be obtained with many more screw terminals than the two shown on the sample at the upper left. Below it is a tip jack. A binding-post strip is at the right.

nection points for plug-in coils inside the circuit, in preference to using the more complicated symbols representing the actual plug-in coil form and socket.

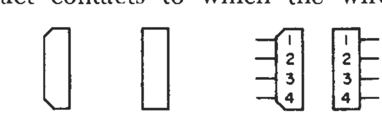
The basic symbols for plug-and-socket-type connectors are shown at B. When there are several prongs, dashed lines are drawn between the symbols as in C, to indicate that they are all part of one assembly. Two "mating" assemblies, one male and one female, are shown here. Note that either could be the fixed connector ("socket" or "receptacle") and either could be the movable one ("plug"), since both sockets and plugs are made with male and female contacts. In fact, both could be plugs if both symbols represented connectors on the ends of lengths of multiwire cable.

An alternative way of showing cable connectors is given in the sketch below. These symbols can be used for any



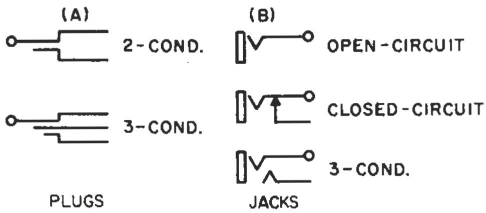
Plugs fitting into ordinary tube sockets (left) are commonly used in amateur equipment. Beside this one is a miniature plug with keyed prongs. Typical multiple-connection chassis-mounting connectors are at the right, one with female and one with male contacts.

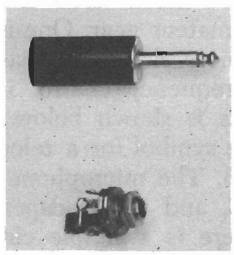
number of wires. They do not show which contacts are male and which female, but this information is usually made available in the data accompanying the circuit. If the contacts in the actual connectors used are numbered, the exact contacts to which the wires are



connected can be indicated by placing the numbers inside the symbol at the appropriate point. They do not have to be in numerical order.

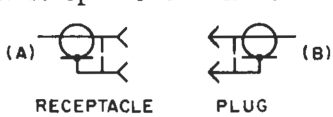
A few special types of connectors are used widely enough to have individual symbols of their own. Among these are the phone plug and jack. The symbols

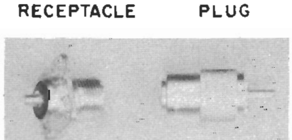



Phone plug and jack. Jack styles include leaf switches which operate when the plug is inserted.

shown at A and B, respectively, are ones you will find frequently used. The rectangular block in the jack symbol represents the jack frame, usually grounded. The open "V" is the contact that connects with the plug tip, and the closed arrowhead represents a contact not touched by the plug tip but which makes or breaks when the plug is inserted. A number of such contacts, either normally open or normally closed, may be incorporated in a single jack, but these more complicated arrangements are not often used in amateur equipment.

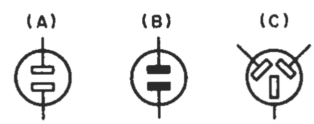
Another type of connector that occurs frequently in r.f. circuit diagrams is the coaxial receptacle shown at A below.




The common type of coaxial receptacle (left) and plug. These belong to the "UHF" series, which does not mean a type preferred for u.h.f. work but is simply an early designation.

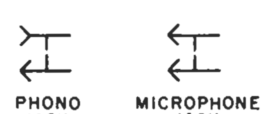
The symbol is that of a basic two-conductor connector with the coaxial symbol added. Note that no attempt is made to show the actual male and female contacts of a conventional coax chassis fitting; in this one case the female symbol is used for both, indicating a receptacle rather than a plug. In the plug symbol, B, which you will see less frequently, the male contact symbol is used throughout, plus the coax indicator.

Still another special group of symbols is used for a.c. power connectors such as 115-volt plugs and sockets. These are drawn with the contacts inside a circle, as shown below. The open rectangles, A,

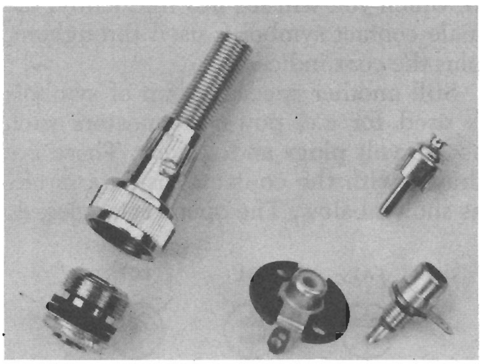


indicate female contacts, used in what are usually called sockets, and the solid ones, B, stand for male contacts, usually in plugs. The system can be extended as shown by the example at C, which is a 3-conductor polarized connector with female contacts.

Aside from these special cases, connector symbols are constructed from the fundamental contact symbols, described earlier, assembled as required to represent the actual connector used. There are times when the choice of a symbol becomes a little puzzling for the circuit designer—for example, is the widely-used phono connector a "real" coaxial connector or not? The question could be argued both ways. In our drawings the phono connector, and also microphone connectors such as the one in the picture, are drawn from the basic contact symbols, omitting the coaxial indicator, thus:



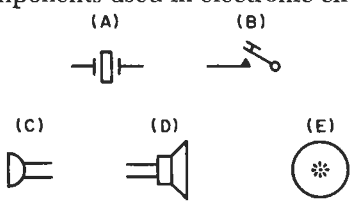
the bottom contact being the grounded one in both cases. The actual center contact (top, in the symbol) in the microphone connector is merely a spot of solder, and does not really qualify as a "male" contact, but neither is it female. There being no symbol for a butt contact, the male is used instead.

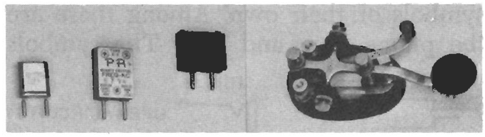


Microphone connectors, left, and phono jacks and plugs. Two forms of phono jacks are shown.

Miscellaneous Symbols

The list of symbols could go on and on, because there are innumerable varieties of components used in electronic circuits.





Three types of crystal mountings, commonly used in amateur equipment, left, and a telegraph key.

However, we need only a few more to give a reasonably complete picture of what may be encountered in circuit diagrams of amateur gear. One is the symbol for a piezo-electric crystal, the kind used for frequency control in a transmitter. This is shown below at A. Another is the symbol for a telegraph key, shown at B. The microphone symbol is given at C, and the loudspeaker at D. Finally, there is a simple circle, somewhat smaller than the circle representing a tube, used as a general symbol for a number of devices such as meters, generators, motors, and the like. The asterisk in the symbol shown is replaced by a letter or abbreviation indicating just what the device is—MA for milliammeter, V for voltmeter, MOT for motor, GEN for generator, and so on. Thus the meaning of the symbol is identified in the actual circuit, so the component is easy to recognize. In many cases, too, a rectangle is used as a general symbol for a component or assembly, all in one piece, that has no special symbol of its own, or which it is not necessary to represent with detailed symbols.

A Three-Transistor Receiver for the Beginner

Now that we've gone over some of the fundamentals, let's think about building some equipment. There is no better way for you to take an active part in the game, before you have the qualifications to pass your license examination, than to try your hand at building a simple receiver. In the process of assembling the receiver, you will learn the fundamentals of the arts of reading circuit diagrams, working metal, and handling the soldering iron. The cost of the receiver to be described will be about $50, if all new parts are used. This may seem like a great deal of money, especially if you are going to school and don't have a job. However, the pleasure you can get from constructing electronic equipment from scratch, and the educational experience you will acquire will be worth many times this price. In addition, when you retire the set, you can salvage most of the components for use in other projects. Later we will discuss some ways of cutting several dollars off the set's price tag.

The receiver shown in Figs. 3-1, 3-7, and 3-8 is called a **regenerative** receiver. It is a type of receiver that was used by almost all amateurs many years ago. The communications receivers you see today on dealers' shelves are all of the **superheterodyne** type. You will not find the regenerative receiver there except occasionally in kit form, and then not usually designed for amateur work. Nevertheless the regenerative receiver represents a very worthwhile project for the beginning amateur because good sensitivity is obtained with simple circuits and construction. The performance of the receiver described here will compare very favorably with that of the less expensive superheterodynes on the market. You will not have to strain your ears to hear plenty of signals—both in the amateur bands and on frequencies in between the bands. At the right time of day or night, you should find many amateur signals as well as commercial code and short-wave broadcast signals strong enough to work a headset with good volume.

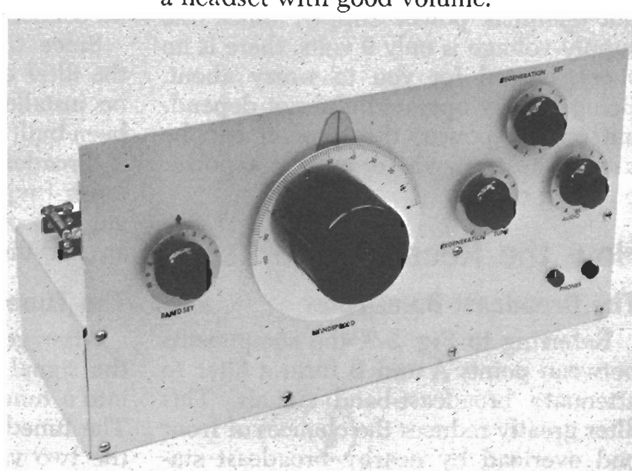


Fig. 3-1 Three-transistors regenerative receiver covering 1.65 to 30 MHz. Six self-contained 1.5-volt flashlight cells power it, with a current drain of less than 3 ma. The bandspread tuning dial is a Jackson Brothers type 4489.

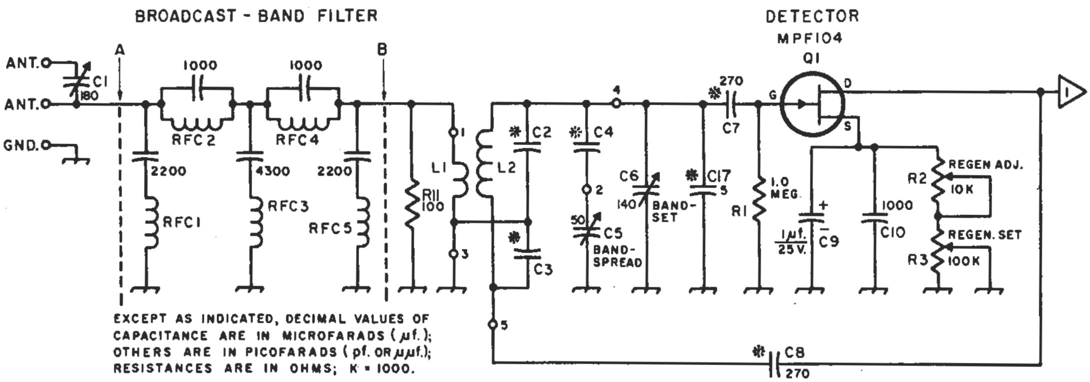


Fig. 3-2 Circuit diagram of three-transistor regenerative receiver. Fixed resistors are ½-watt composition. Capacitors marked with polarity are electrolytic; those marked with an asterisk are dipped silver mica; other fixed capacitors are disk ceramic.

BT_1 — Six 1.5-volt flashlight cells (size D) in series.
C_1 — Antenna trimmer (9-180-pf. mica compression capacitor).
C_2 — Band-set capacitor (see Table 3-1).
C_3 — Feedback capacitar (see Table 3-1).
C_4 — Establishes the effective capacitance of the bandspread capacitor so that each amateur band is spread across the entire dial (see Table 3-1).
C_5 — Bandspread tuning capacitor (Millen 19050).
C_6 — Band-set capacitar (Millen 19140).
C_7 — Gate coupling capacitor (silver mica).
C_8 — Drain coupling capacitor (silver mica).
C_9, C_{16} — Audio bypass capacitar (electrolytic).
C_{10}, C_{11}, C_{13} — R.f. bypass capacitor (disk ceramic).
C_{12} — Power supply bypass capacitor (electrolytic).
C_{14}, C_{15} — Audio coupling capacitor (tubular).
C_{17} — Band-set capacitor (silver mica).
J_1, J_2 — Headphone connector (insulated tip jack).
L_1 — Input coupling coil (see Table 3-1).
L_2 — Detector tuning coil (see Table 3-1).
Q_1 — Detector (Motorola MPF104 field-effect transistor).
Q_2, Q_3 — Audio amplifier (General Electric 2N3860, 2N2925, 2N3391A, 2N3403, or 2N3405 n-p-n transistor).
R_1 — Detector gate leak.
R_2 — Fine regeneration control, linear taper (IRC-CTS Q11-116).
R_3 — Coarse regeneratian control, linear taper (IRC-CTS Q11-128).
R_4 — Detector laad resistor.
R_5, R_6, R_8 — Base bias resistor.
R_7 — Amplifier callector load resistor.
R_9 — Volume control, audio taper, (IRC-CTS Q13-116) with S_1 (IRC-CTS 76-1) attached.

Self-contained flashlight cells are used, eliminating the need for constructing a line-operated power supply. Since the supply voltage is only 9 volts, there is no shock hazard for you to worry about. Being battery operated and not dependent on a.c. power, the receiver can be used almost anywhere, even if a power blackout occurs.

How the Receiver Works

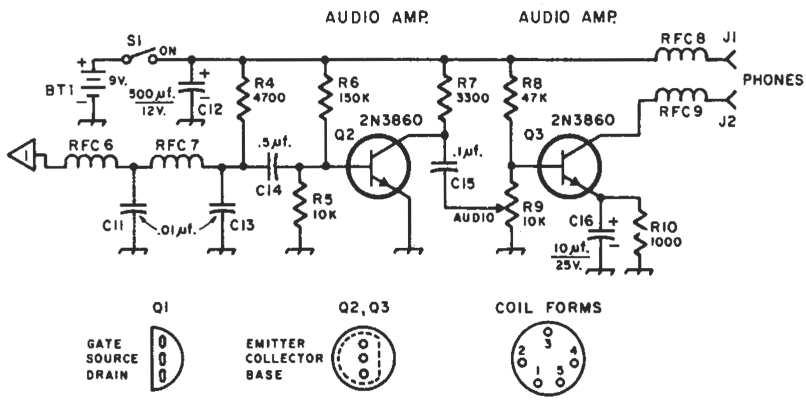
The Broadcast-Band Filter

Referring to Fig. 3-2, the components between points A and B form a filter to attenuate broadcast-band signals. This filter greatly reduces the chances of front end overload by nearby broadcast stations. In locations where there are no powerful broadcast signals, the filter may be left out. Points A and B should then be connected together.

Since the components that make up the filter cost about $4, they should not be installed until after the receiver has been built and tested without them. Then if broadcast signals are heard on the lower-frequency short-wave bands, regardless of where the tuning capacitors are set, the filter can be connected.

The Tuned Circuit

After going from point A to point B, the signal from the antenna is coupled into a tuned circuit by means of link L_1. The tuned circuit is made up of coil L_2, the two variable capacitors, C_5 and C_6, and silver-mica capacitors C_2, C_3, C_4 and



BOTTOM VIEWS

R_{10} — Emitter bias resistor.
R_{11} — See text.
RFC_1, RFC_5 — Broadcast-band filter inductor, 10 μh. (Millen 34300-10[1]).
RFC_2, RFC_4 — Broadcast-band filter inductor, 33 μh. (Millen J300-33).
RFC_3 — Broadcast-band filter inductor, 5 μh. (Millen 34300-5).
RFC_6, RFC_7 — R.f. filter choke, 2.5 mh. (Millen 34300-2500).
RFC_8, RFC_9 — 68-μh. r.f. choke, to keep the headset leads from acting as antennas (Millen 34300-68).
S_1 — Power switch, s.p.s.t.

[1] James Millen Co. will sell direct if you cannot get the components from a distributor. Write to James Millen Co., Malden, Mass., Attn.: Wade Caywood.

C_{17}. This is the part of the set that selects the frequency on which you want to listen. The frequency that it selects will depend upon the size of the coil L_2 (inductance) and the size of the capacitor (capacitance) connected across the coil. The larger the inductance, capacitance, or both, the lower the frequency that will be selected. If we wish to tune the circuit over a range of frequencies, we must make provision for varying the values in the tuned circuit. Although either the inductance or the capacitance could be varied with the same result, it is easier mechanically to provide a variable capacitance than to make the inductance variable. Therefore, a fixed value of inductance is used, and the frequency is changed with a variable capacitor. Inductance also is changed when a large change in frequency is necessary, such as in going from one amateur band to another. In this receiver the change is made by the use of plug-in coils.

The tuned circuit will tune to the same frequency with any size of coil and capacitor provided that the product of capacitance and inductance ($L \times C$) remains the same. The coil can be large and the capacitor small, or vice versa, or any other combination might be used where the inductance times the capacitance gives the same product. However, there may be reasons that make certain combinations of inductance and capacitance more desirable than others.

Frequency Stability

Frequency stability is the ability of a circuit to remain tuned to the same frequency, once the operator has tuned the circuit to that frequency. There are several things that may change the frequency of the tuned circuit without the operator touching the tuning control. Movement of the antenna as it swings in the wind, or movement of the operator's hands around the receiver have the most noticeable effects. Most of these changes not under control of the operator are in the nature of changes in capacitance in the circuit. Therefore, if a large amount of capacitance is used in the tuned circuit,

Table 3-I
Coil and Capacitor Data

Capacitors are dipped silver mica (values are in picofarads) mounted in the coil form close to the base of the form. Coils are close-wound with enameled or Nylclad copper wire on 1-inch diameter 5-pin coil forms (Millen 45005). For winding details see Fig. 3-6.

Coil	*Range MHz.*	C_2	C_3	C_4	L_1 *turns*	L_2 *turns*	*Wire Size*	*Dimensions, inches* A	B	C
I	1.63–2.55	68	1800	short	4½	44¼	No. 26	⅜	½	1⁵⁄₁₆
II	2.45–5.6	—	1300	68	3½	35¼	No. 24	⁵⁄₁₆	⁹⁄₁₆	1⅜
III	4.90–10	—	680	22	2½	18¼	No. 20	¹¹⁄₃₂	¹⁹⁄₃₂	1¼
IV	9.70–18	—	220	12	2½	9¼	No. 20	¹¹⁄₃₂	¹⁹⁄₃₂	¹⁵⁄₁₆
V	16–25.7	—	100	12	2½	6¼	No. 20	¹¹⁄₃₂	¹⁹⁄₃₂	¹³⁄₁₆
VI	20–30	—	68	18	2½	5¼	No. 20	¹¹⁄₃₂	¹⁹⁄₃₂	²³⁄₃₂

List of Components Additional to Those Listed Under Fig. 3-2 and in Table 3-I

3 printed circuit sockets (Elco 05-0786).
1 5-contact tube socket (Amphenol 78RS5).
1 ball drive dial (Jackson Bros. 4489).
1 1⅝-inch dial, 0 to 10 graduations for 180 degrees of clockwise rotation (Millen 10005-A).
3 1⅝-inch dials, 0 to 10 graduations for 280 degrees of clockwise rotation (Millen 10005-B).
1 3 × 13 × 5-inch aluminum chassis (Bud AC-422).
1 7 × 13-inch aluminum panel or bottom plate (Bud BPA-1596).
1 3-terminal screw-type terminal strip (H. H. Smith 873).
2 3-terminal lug-type terminal strips (H. H. Smith 864).
1 5-terminal lug-type terminal strip (H. H. Smith 866).
6 8-terminal lug-type terminal strips (H. H. Smith 870).
2 standoff insulators, ½-inch diameter × 1 inch high (Millen 31001).
3 double battery holders (Keystone 176).
About 25 feet of plastic insulated hook-up wire.
2 ¾-inch 6-32 threaded spacers (H. H. Smith 2123).
2 soldering lugs.
34 6-32 machine screws, ¼ inch long.
22 6-32 hex nuts.
Washers (see text).
2 1000-pf. disk ceramic capacitors.
2 2200-pf. disk ceramic capacitors.
1 4300-pf. disk ceramic capacitor.

the uncontrollable changes are reduced ("swamped") to a small percentage of the total capacitance in the circuit and their effects are minimized.

The series combination of C_3 and C_6 provides most of the capacitance in the tuned circuit of this receiver. C_6 is made variable so that it can be used to adjust the tuning range to frequencies outside the amateur bands for the reception of commercial code signals and short-wave broadcasts. C_6 is adjusted by the small dial on the left-hand side of the panel (Fig. 3-1).

Bandspread

All variable capacitors of conventional type go through their complete range of capacitance with one half revolution of the control shaft. If a capacitor with a large range of capacitance, such as C_6, is used, it will cover so many frequencies that it will be very difficult for the operator to adjust the capacitor to select any one frequency he may desire. C_6 is therefore used only as a **band-set** capacitor to adjust the circuit to the approximate vicinity of the group of frequencies (an

Table 3-II

Coil	*Band*	C_6 *Setting*
I	160	4.5
II	80	7.5
III	40	7.5
IV	20	8.0
V	15	8.0
VI	10	9.5

amateur band, short-wave broadcast band, etc.) where the operator wants to listen. Then a smaller group of frequencies in this vicinity is covered more slowly by another variable capacitor, C_5, with a smaller range of capacitance. This is called the **bandspread** capacitor, and is controlled by the large dial at the center of the panel. The tuning rate can be slowed down still more by connecting a small capacitor, such as C_4, in series with the bandspread capacitor, as shown in Fig. 3-2. Since one amateur band occurs in the frequency range of each plug-in coil, in each case C_4 was chosen so that the amateur band in question occupies the entire tuning range of the bandspread capacitor. Adjustment to the desired signal is made still easier by the friction reduction control (vernier) on the dial, which permits several revolutions of the control knob while the capacitor rotor is making its half revolution.

The Detector

A field-effect transistor (FET), which has high input impedance, is used as the regenerative detector, Q_1. The detailed action of the FET detector is highly complex because it performs several functions simultaneously. It amplifies the signal in the form that it arrives at the antenna (one or more radio frequencies). In this detector, **regeneration** or **feedback** is introduced by coupling some of the drain-circuit energy to C_3 via C_8. Because C_3 is a part of the capacitance of the tuned circuit, this coupling sets up an r.f. voltage across the whole circuit. The voltage that, as a result, develops

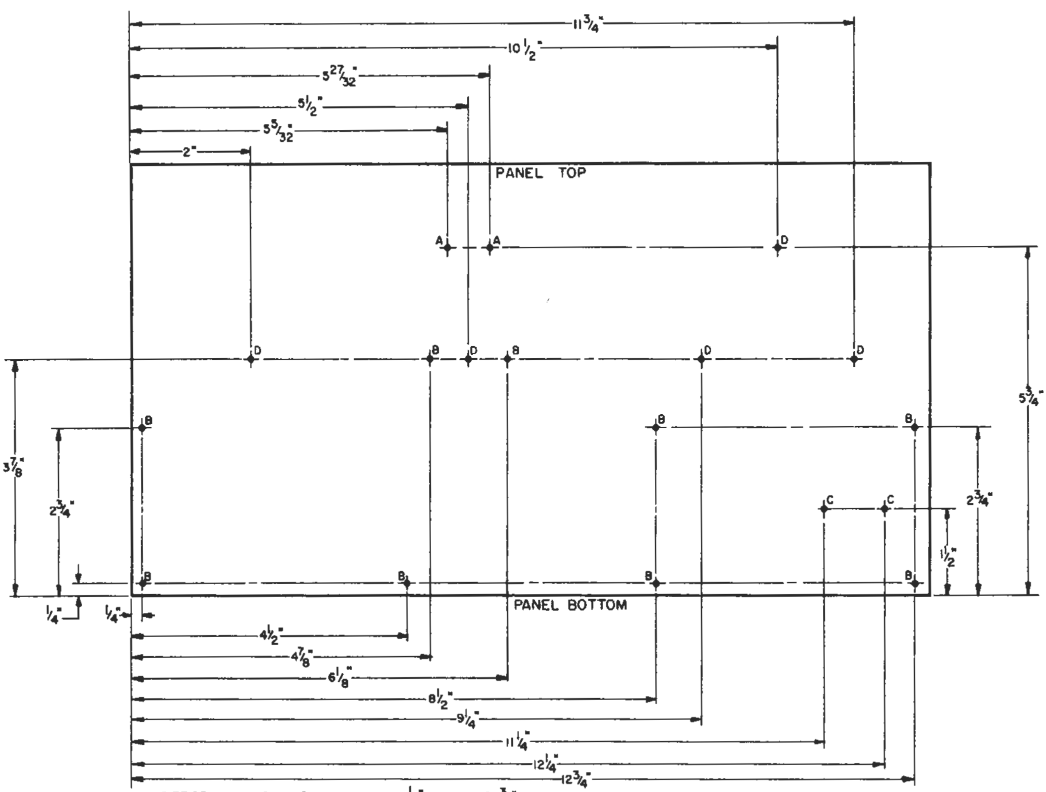


Fig. 3-3 Hole location diagram of the panel (front view). See text before drilling any holes.

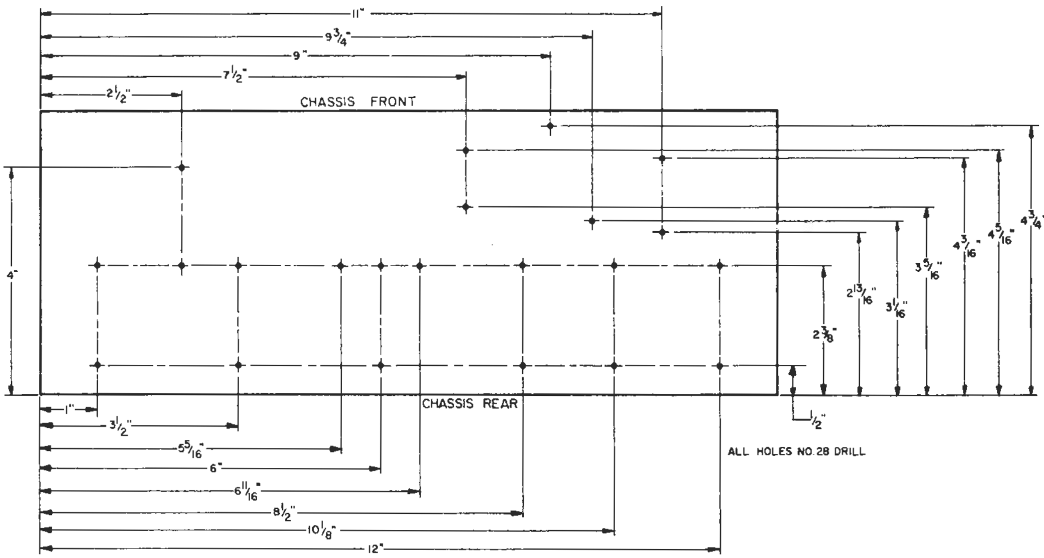


Fig. 3-4 Location of holes on the top of the chassis. See text before drilling any holes.

across C_6 is applied to the gate. This setup provides a means of feeding the amplified r.f. signal from the drain back to the gate so that it can be reamplified in the transistor, thus increasing the total r.f. amplification through the transistor many times.

If an amplitude-modulated signal is received, the detector extracts the audio information from the amplified r.f. signal. If a single-sideband, suppressed carrier (s.s.b.) signal is received, the regenerative detector can be adjusted (made to oscillate) to reinsert the carrier that was removed from the signal before the signal left the transmitter. Once a carrier of the proper frequency is provided, the audio can then be recovered. If an unmodulated signal is received, the detector can be made to oscillate so as to make the incoming signal have the characteristics of a modulated signal, and then handle it as such and deliver an audio signal in the output.

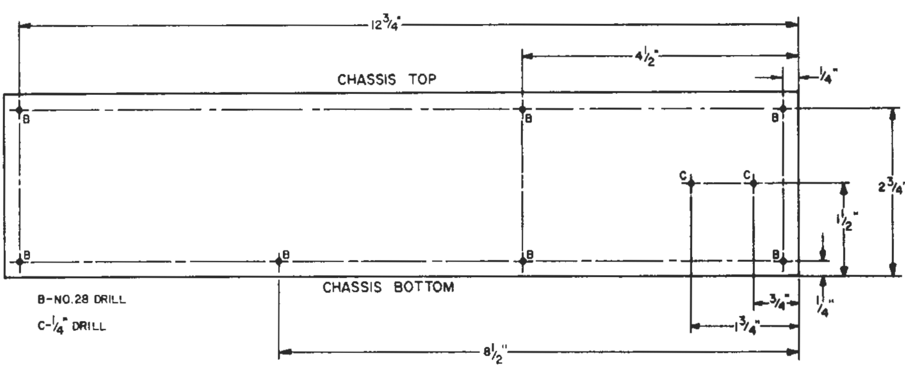


Fig. 3-5 Location of holes on the front of the chassis. Refer to text for details of the drilling operation.

How vigorously the detector regenerates or oscillates depends partially on the ratio of C_6 to C_3. Since the value of C_6 changes markedly as the capacitor is tuned, so does the amount of regeneration. Regeneration is controlled by varying the source bias of Q_1. Although only one regeneration control is normally found in regenerative receivers, two controls are provided here to make adjustments easier. R_3 is for coarse adjustment and R_2, one-tenth the value of R_3, is for fine control. R_{11} (across L_1) also determines to some extent how hard the detector oscillates. Without this resistor it was found that when some antennas were connected to the receiver it was impossible to stop the detector from regenerating over certain tuning ranges, regardless of where R_2 and R_3 were set. If the receiver performs satisfactorily without R_{11}, it is best that the resistor be left out because it loads down the tuned circuit and reduces the receiver's selectivity.

An electrolytic capacitor, C_9, bypasses R_2 and R_3 for audio; without it, the detector would be rather insensitive. C_{10} is an r.f. bypass, and C_7 and R_1 are necessary for proper operation of the detector. RFC_6, C_{11}, RFC_7 and C_{13} form an r.f. filter in the drain circuit of Q_1 to keep r.f. from reaching the base of the first audio amplifier, Q_2. A 4700-ohm resistor, R_4, is used as the detector load. C_{14} is an audio coupling capacitor that insulates the base of Q_2 from the detector drain voltage, yet it allows audio frequencies to reach the base of the audio-amplifier.

The Audio Amplifiers

R_5 and R_6 form a voltage divider for biasing the base of Q_2, and R_7 is the collector load. C_{15} couples the amplified audio signal from R_7 to the arm of the volume control, R_9. As the arm of R_9 is moved toward the base of the second audio amplifier, Q_3, a larger proportion of the total output signal of Q_2 is applied to

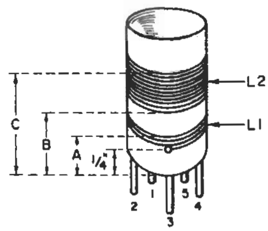


Fig. 3-6 Sketch of typical plug-in coil used in the regenerative receiver. L_1 and L_2 are wound in the same direction. The hole for each wire is drilled directly above the pin to which the wire is to be soldered. The bottom of L_1 goes to pin 3, the top of L_1 goes to pin 1, the bottom of L_2 goes to pin 5, and the top of L_2 goes to pin 4. For specific information on each coil see Table 3-1.

the base of Q_3, resulting in a stronger output signal from the second audio amplifier. R_8 works with R_9 to provide base bias for Q_3, and R_{10} furnishes emitter bias. Audio frequencies are bypassed around R_{10} by C_{16}. Q_3 should have a high-impedance headset (2000 ohms or more) as its collector load. The headset leads are kept from acting as antennas (creating hand-capacity effects on the higher bands) by being isolated from the power supply and Q_3 with r.f. chokes.

The Power Supply

The set's power supply, BT_1, consists of six 1.5-volt, size D flashlight cells connected in series. S_1, a s.p.s.t. switch on the back of the volume control, turns the set off and on, and C_{12}, a 500-μf. electrolytic, bypasses the power supply for audio, thereby reducing the chances of positive feedback and oscillations in Q_2 and Q_3.

Construction

The construction details that follow are not the detailed, step-by-step, take-me-by-the-hand instructions you would get if you were building a commercial kit. Kits are fine, but after building one, schematically you might not be able to tell a resistor from a capacitor. But the main reason for building your own is to learn something about radio, and in order to construct this receiver, you will need to learn to read diagrams. The knowledge gained should help you pass your FCC amateur examination and prepare you for more advanced projects.

While the receiver layout is uncritical and you can vary it considerably to suit your own requirements (but don't alter the detector circuit too much, if you expect it to have the same band coverage as listed in Table 3-I) the beginner is well advised to construct the receiver just as shown in the photographs and become familiar with its operation. Once you have gained some experience, you will be in a better position to make changes, if you want to.

The parts you use in your copy of the receiver don't have to be the same brands as those in the original; it's only necessary that your components have the same electrical specifications. There is no need to buy new parts either. A considerable saving might be made by using parts from a discarded TV set, or from items picked up at a ham auction or swap-shop. New components can be obtained either from local radio stores, which are listed in the yellow pages of your phone directory, or from electronic mail-order houses, whose ads can be found in radio and electronic publications. Incidentally, most firms who deal through the mails will send a free catalog upon request. For those who might have difficulty obtaining parts for this set, it was noted at the time of construction that all the components employed were listed in the Allied catalog,[2] except the Jackson Brothers dial, which was listed in the Arrow catalog,[3] and the Millen components, which were available direct (see footnote 1).

The receiver is built on a 13 × 5 × 3-inch aluminum chassis with a 13 × 7-inch aluminum plate serving as the front panel. If you don't have the tools to cut a piece of sheet aluminum to the specified size, a commercial bottom plate will serve nicely.

Pencil marks are difficult to remove from aluminum without leaving a blemish, so do not disturb the paper that covers the chassis and bottom plate until all holes have been drilled. If your aluminum is supplied uncovered, tape wrapping paper to the outside of the chassis and to one side of the panel.

If exact duplicate components are used, Figs. 3-3, 3-4 and 3-5 can be used as drilling guides. Mark all hole centers with a pencil, and center-punch the marks. Then drill all holes with a No. 28 bit, except those two labeled *A*, which should be drilled with a No. 33 bit. Enlarge *C* and *D* holes with a ¼-inch bit and then further enlarge *D* holes with a ⅜-inch bit. (In drilling holes larger than ⅛ inch, it is always easier and more accurate to start out with a bit ⅛ inch or smaller and then enlarge the hole gradually with larger bits.) If the only drill you own has a ¼-inch chuck, you can make the ⅜-inch holes with a tapered reamer or a ⅜-inch bit that has a ¼-inch shank. Once the drilling has been done, remove the protective paper covering and deburr the holes. A drill bit that's somewhat larger than the hole to be worked on does this job nicely.

Before parts are mounted, the aluminum can be given a satin finish by immersing it in a solution of grocery-store lye and water, as described in the construction-practices chapter of the ARRL *Handbook*.

To insure that the set is securely built, install a lock washer under every hex nut used in the construction. Begin the assembly by fastening the front panel to the chassis with seven 6-32 machine screws and hex nuts. Then install the two tip jacks as shown in Fig. 3-1. Referring to Fig. 3-7, bolt C_5 and C_6 to both the panel and the chassis, being careful not to damage the plates at the front of the capacitors with mounting screws that

[2] Allied Radio, 100 N. Western Ave., Chicago, Ill. 60680.

[3] Arrow Electronics, Inc., 900 Route 110, Farmingdale, N. Y. 11735.

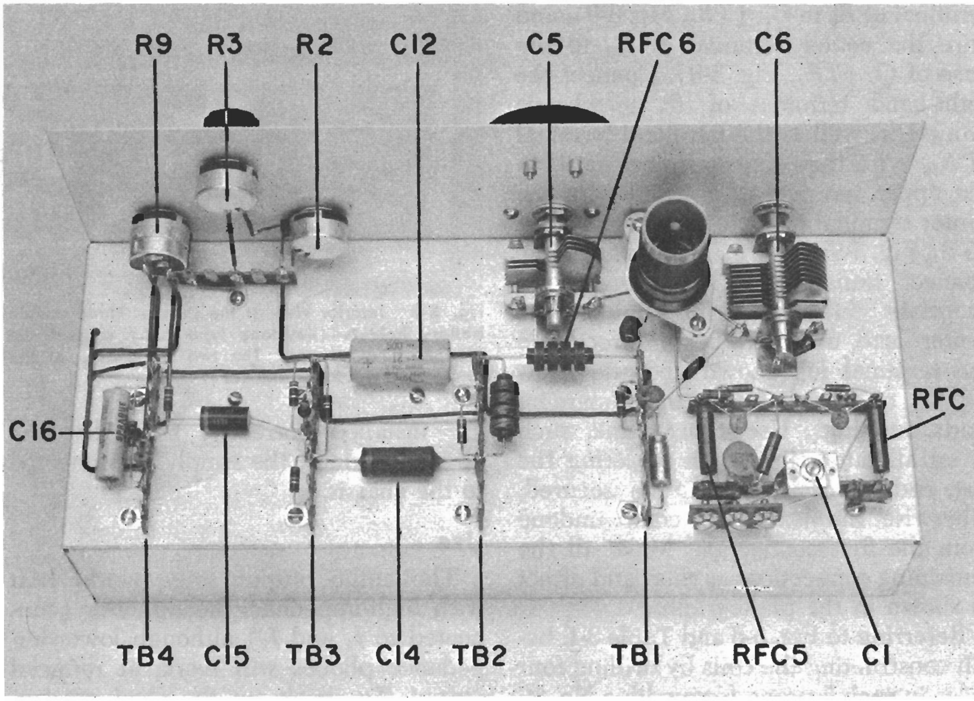


Fig. 3-7 Top view of the regenerative receiver. The two eight-lug terminal strips at the lower right support the components of a broadcast-band filter. Antenna and ground input terminals are located beside the filter at the edge of the chassis; the connector is a cut down screw-type terminal strip soldered to a standard lug-type tie-point. Of the four parallel terminal strips next to the filter, TB_1 and TB_2 support the regenerative detector, Q_1, TB_3 supports the first audio stage, Q_2, and TB_4 supports the output stage, Q_3.

may be too long. Attach two 1-inch ceramic pillars (Millen 31001) to a 5-contact tube socket (Amphenol 78RS5) and position this assembly half way between C_5 and C_6 so that pin 3 of the socket is closest to the front panel. Before bolting the pillars to the chassis, put a soldering lug (to be connected to pin 3) under the ceramic insulator nearest the front panel, and slide a flat washer under the other insulator. Space terminal strips TB_1 through TB_4 2½ inches apart, with the first mounting hole 1 inch from the left edge of the chassis and ½ inch from the rear. Fasten these terminal strips and the battery holders to the chassis with the same screws.

Before mounting R_2, R_3 and R_9, cut off (with a hacksaw) excess shaft length, if necessary, so that when the dials are attached later the knobs will not protrude too far from the front panel. Mount R_3 and R_9 with their terminals pointing toward the chassis, and mount R_2 with its terminals pointing toward R_9. Install C_5's dial mechanism on the front panel using two ¾-inch 6-32 threaded spacers. Attach C_6's dial (Millen 10005-A) so that it indicates 0 at maximum capacitance and 10 at minimum capacitance. Affix the remaining dials (Millen 10005-B) so that they indicate 0 when the controls are turned fully counterclockwise as viewed from the front of the receiver (Fig. 3-1).

By close inspection of the photographs and the schematic diagram, it should be easy to wire the chassis. The circuit runs from left to right in the schematic and from approximately right to left in the rear shot of the chassis. Viewing the set as in Fig. 3-7, wire the left-hand terminal of R_9 to C_{15} (TB_4, Fig. 3-9), and wire the center terminal of R_9 to the base of Q_3 (TB_4, Fig. 3-9). Connect the right-hand terminal of R_9 to chassis ground, as well as the left-hand terminal of R_3. Wire the center terminal of R_3 to the upper terminal of R_2, and wire the center terminal of R_2 to the source of Q_1 (TB_1, Fig. 3-9). Using Fig. 3-9 as a guide, connect transistor sockets to the appropriate terminal strips. Solder the center lead of each socket directly to the terminal lug shown and use short lengths of wire between the remaining leads and lugs. Use a heat sink, such as an alligator clip, when soldering the last end of each wire to be secured, otherwise the lead may come undone from the first connection. Make all the remaining connections as short and direct as shown in the photographs.

Referring to Fig. 3-6 and Table 3-I, begin constructing the coils by drilling four holes in each 5-prong form with a No. 50 drill. Each hole should be drilled above the prong to which the end of the coil will be connected. Wind L_1 first and then L_2. Scrape the ends of the coils with a knife or razor blade, so that good electrical contact can be made to the prongs. It will be easier to get tight windings if the wire spools are held in a vise while the coils are being wound. Wind the coils at a distance from the vise, keeping the wire taut. After L_1 and L_2 have been put on the form, install C_2 (if applicable), C_4 or a short, and C_3 in that order. Push the capacitors down to the base of the coil form, keeping the connecting leads as short as possible. Carefully solder the coil prongs. Wipe away any rosin from the prongs with a cloth dipped in alcohol. To protect the coils, it may be desirable to spray them with clear lacquer or coat them with coil dope.

Before turning the set on, check the wiring carefully with the schematic diagram and the photographs. Be especially careful that the batteries and transistors are installed correctly; note that the negative side of the supply is connected to the chassis.

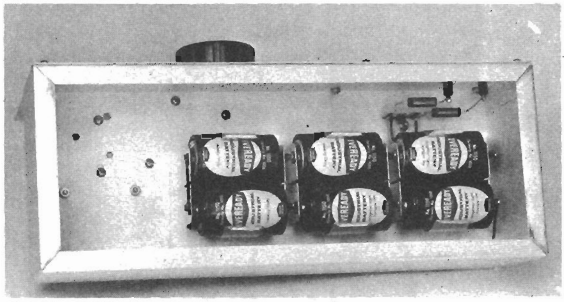


Fig. 3-8 Interior view of the chassis. Three double battery holders (Keystone type 176) support the receiver power supply. The two r.f. chokes at the upper right are RCF_8 and RCF_9.

Use

The audio output stage works best with high-impedance headphones (connected to J_1 and J_2) although lower-impedance phones will work, at reduced output. To check out the receiver, connect an antenna to either antenna terminal and run a ground lead to the set. A random length of wire makes a good antenna for the receiver, as does a coax-fed dipole cut to frequency; however, the broadcast-band filter works better with the latter arrangement, since the filter was designed for use in low-impedance lines. (To get optimum performance from the filter when a random length of wire is used, a special coupling circuit—a "transmatch"—is required to convert the usually high impedance of the feed end of the wire to about 50 ohms. Details of a suitable transmatch for random length wires plus a wealth of information on antennas can be found in *Understanding Amateur Radio.*)

Plug coil II in the receiver and set the 0 to 10 band-set capacitor dial at 7.5. With C_6 at this setting, the bandspread capacitor should tune from approximately 3.5 to 4 MHz. Turn the audio gain control full on. With the fine regeneration control, R_2, at about midrange, advance the coarse regeneration control,

R_3, until the receiver starts to oscillate. The point at which the detector begins to oscillate is easy to recognize, as a thumping sound is heard and the background noise increases. Then by tuning the bandspread capacitor it should be possible to hear signals.

It will be necessary to vary the regeneration controls for optimum reception of different signal types (a.m., c.w. and s.s.b.), strengths and frequencies. For a.m. reception, advance the regeneration controls to the point just before where the detector oscillates. This is the most sensitive operating point for a.m. signals, and the selectivity of the circuit is better than at lower settings of the regeneration controls. Very strong signals, which may cause "blocking," may be reduced by backing off either R_2 or R_3 or both or by reducing the antenna coupling by connecting the antenna to the receiver through C_1 and opening up the plates of the capacitor as much as required.

The most sensitive setting of the detector for code reception is with the regeneration controls advanced just beyond the point of oscillation. However, very strong signals may overload the detector and become impossible to tune in at low beat notes. This can be overcome by further advancing the regeneration controls or by reducing the antenna coupling as described above. Note that if the regeneration is pushed too far, a point may be reached where an audio squeal will be heard. For satisfactory operation of the receiver, be sure the regeneration controls are set below this point.

S.s.b. is tuned in with the regeneration controls set at the same point as for c.w. The bandspread capacitor should be tuned very slowly through the signal until the voice becomes intelligible. Overloading is conquered in the same manner as for code reception.

Best use of the two regeneration controls will be obtained by following this procedure: Set the band-set capacitor, C_6, for the desired band coverage. Turn C_5 and R_2 to midrange. Set R_3 at the point where the detector just starts to oscillate. Tune C_5 and adjust R_2 as required. In some cases the fine regeneration control may run out of range; it will then be necessary to readjust R_3 to bring it back in the ballpark.

Two undesirable effects may be noticed with this receiver, especially at the higher frequencies. If an inadequate ground system is used, the receiver will exhibit "hand-capacitance" effects: that is, merely moving your hands in the vicinity of the receiver will cause the tuning to vary. Also, as with any regenerative set, an antenna blowing in the wind can cause the frequency to change. If the latter difficulty becomes serious, an indoor antenna might be called for. Lighter antenna coupling (less capacitance at C_1) and coaxial feed will also reduce the effects of antenna movement on the detector.

The bandspread system used in this receiver was set up with the amateur bands in mind. Other bands are spread out to a lesser or greater degree. Table 3-II shows the approximate settings of the band-set capacitor, C_6, for spreading each high-frequency ham band over the tuning range of the bandspread tuning capacitor, C_5. How accurate each setting is, of course, depends on how closely the coils are duplicated.

Possible Modifications

In order to keep costs down, no cabinet was used to house the receiver. The set should perform well in most locations without one. However, in some spots, a.c. hum pickup may be a problem. By using a metal cabinet, there won't be any need to worry about hum, and the set will look more attractive. A cabinet having a hinged cover is the most desirable, as it will facilitate coil changing.

If additional coverage is desired, more coils can be constructed. In order to cover the broadcast band, three plug-in

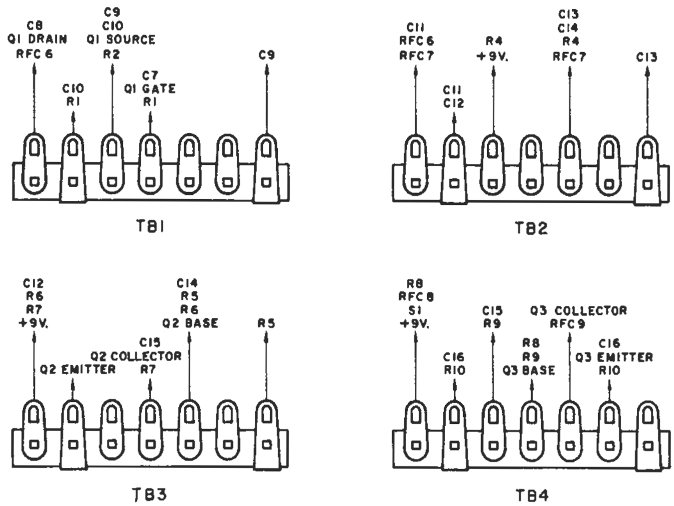


Fig. 3-9 Connections to the four terminal strips, TB_1 through TB_4. The left edge of each terminal strip is closest to the front panel. The tie points were made by cutting down H. H. Smith 8-terminal strips (No. 870) with a pair of diagonal cutting pliers.

coils will likely be required because of the small size of C_6. In addition, it will be necessary to disconnect the b.c. filter to prevent severe attenuation of the broadcast signals.

In order to achieve optimum selectivity with easy-to-make closewound coils, three sizes of wire had to be used. However, if you don't mind the slightly more difficult job of space winding the coils, you can save yourself the cost of two spools of wire. Using the same dimensions and turns count given in Table 3-I, wind coils II through VI with No. 26 wire, being careful to equally space the turns.

If you want more bandspread for the Novice frequencies, use a smaller value of capacitance at C_4 than that listed in Table 3-I. Try a 10-pf. capacitor in coil II and 8-pf. capacitors (3- and 5-pf. units in parallel) in coils III and V. If this change is made, the setting of the bandset capacitor for the amateur band in question will be different than that listed in Table II, but you should be able to find the right setting without much difficulty.

Since the current drain of the receiver is less than 3 ma., just about any size of 9-volt battery can be used to power the set. However, a bank of ordinary flashlight cells is preferred as they are available at more stores than any other type, and will last a long, long time in this receiver.

Interpreting What You Hear

Now that you have finished building your receiver (or have bought or borrowed one) and mastered its operation, you're in for the indescribable thrill of receiving many kinds of signals you've never head before. Within the range of this receiver you will hear voice signals from radiotelephone stations (usually called "phone" by hams—the regular telephone becomes "landline" in ham lingo!), signals in the International Morse Code (referred to as "c.w.," an abbreviation of "continuous waves"), time signals which go "beep-beep" or which have a steady tone with a clock-like ticking mixed in, and several types of automatic sending equipment which are unreadable without special apparatus.

The phone stations won't pose too many problems to the beginner although you may be confused at first by the technical subjects often discussed or by the

ITU Word List

ALFA	NOVEMBER
BRAVO	OSCAR
CHARLIE	PAPA
DELTA	QUEBEC
ECHO	ROMEO
FOXTROT	SIERRA
GOLF	TANGO
HOTEL	UNIFORM
INDIA	VICTOR
JULIETT	WHISKEY
KILO	X-RAY
LIMA	YANKEE
MIKE	ZULU

Example: W1AW . . .

W 1 ALPHA WHISKEY . . . W1AW

use of phonetic words to identify letters of the alphabet. (For instance, to avoid confusion an amateur station might say, "This is W1AW, W 1 Alpha Whiskey.") Otherwise, good operators use a minimum of abbreviations—best practice on phone is to "say it with words."

When you get down to the serious business of learning the code, required by international law for amateurs the world over, you'll want to try copying some code stations through your own receiver.

Call signs are quite readily identifiable, since they are usually repeated several times, so it is probable that they will be the first symbols you can recognize from the jumble of dits and dahs emitted by your receiver.

By confining your more serious listening to the 3500-kHz. amateur band, as we suggest you do, practically all of the stations you hear will be in nearby areas. All amateur call signs issued by the Federal Communications Commission begin with a W or K. In areas of heavy amateur growth where single-letter prefixes are exhausted, the initial letters WA and WB are also used. The special prefixes KN, WN or WV indicate Novice call signs. The U. S. is divided into ten areas for licensing purposes and from the number in the call you will be able to tell the general area of the country in which the station is located (see map above). Examples of amateur calls are W1AW, W3IEM, WA6BCD, WØFK. Certain two-letter prefixes are assigned outside the continental U.S.A., such as KH6 (Hawaii), KP4 (Puerto Rico), etc.; you will become familiar with these as you progress. Canadian prefixes are VE and VO. Although unlikely on the 3500-kHz. band, you may hear foreign stations signing prefixes such as G (England), F (France), and XE (Mexico). When one station calls another it sends the call of the station being called several times, then the letters "de" once (meaning "from" in French, and agreed upon internationally as the sign to separate the call of the calling station from the call of the station being called) and then its own call repeated a number of times. If you hear this on the air—WØTSN WØTSN DE W1AW W1AW—it means that W1AW is calling WØTSN. Many times what you hear will be like this: CQ CQ CQ DE W2AEN W2AEN W2AEN. "CQ" is a general call to any station which may want to talk with the station doing the calling, and in the case we have cited means that W2AEN is indicating that he is ready to talk with anybody and will answer any station he may hear.

When you first start "copying" stations you may become confused in trying to interpret what is being sent. Don't worry —what you are putting down on paper may be abbreviations used by radiotelegraph operators to save time while talking with each other. Over the years a large number of these have become standardized through common usage. For your information, we list on this page some of the more common abbreviations in use on the ham bands:

ABT	About
AGN	Again

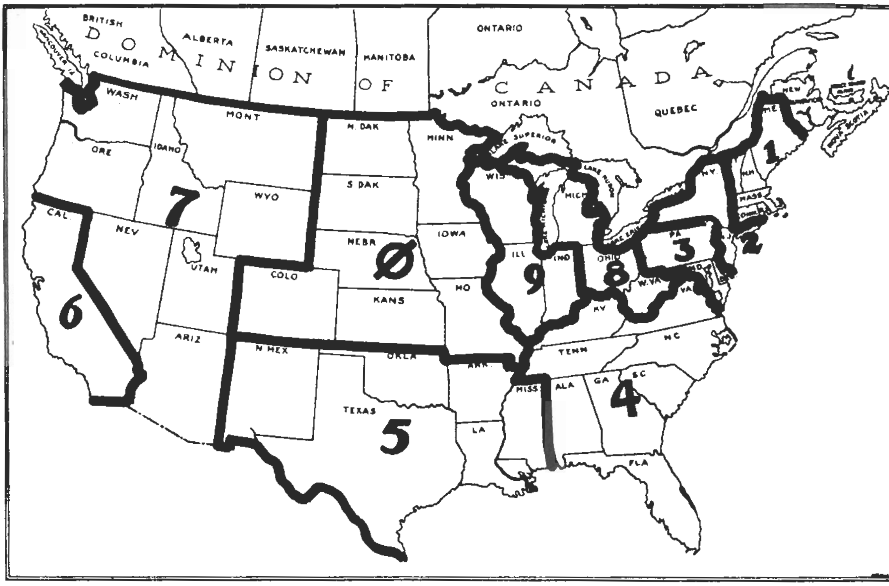


Fig. 3-10 Amateur call areas in the United States.

AMP	Ampere
ANI	Any
BCNU	I'll be seeing you
BK	Break
BTR	Better
CRD	Card
CUD	Could
CUL	See you later
DX	Distance
ES	"&"
FB	Fine business, excellent
FM	From
FR	For
GA	Go ahead, good afternoon
GE	Good evening
GG	Going
GM	Good morning
GN	Good night
GUD	Good
HAM	Amateur
HI	Laughter
HR	Hear, here
HRD	Heard
HV	Have
HW	How
NIL	Nothing
NR	Number, near
NW	Now
OB	Old Boy
OM	Old Man (all male amateurs are "OMs" regardless of age!)
OP	Operator
PSE	Please
RCVR, RX	Receiver
SED, SEZ	Said, says
SKED	Schedule
SIGS	Signals
SRI	Sorry
TKS, TNX	Thanks
TMW	Tomorrow
TT	That
TU	Thank you
U, UR	You, your, you're
VY	Very
WL	Well, will
WX	Weather
XMTR, TX	Transmitter
XYL	(Ex-Young lady) Wife or married woman operator
YL	(Young lady) An unmarried woman or girl operator
73	Best regards

Other abbreviations used by radio amateurs are the internationally-recognized "Q" signals. The "Q" signals constitute a handy way for amateurs—or any class of radio station—to exchange certain kinds of information without having to spell out long sentences. In addition, whatever the language be, "Q" signals have the same meaning; therefore they are a helpful way of exchanging information between two operators of different nationalities who do not speak each other's language. A French amateur sends "QTH?" and the American amateur he is in contact with knows he is asking for his address and replies "QTH 17 Pine Street, Podunk Hollow, Nebraska," or whatever it may be. A list of common Q signals can be obtained fom the ARRL Communications Department free of charge.

An Abbreviated List of Q Signals

(Q abbreviations take the form of questions only when each is sent followed by a question mark.)

QRM Am I being interfered with? You are being interfered with.

QRN Are you troubled by static? I am being troubled by static.

QRQ Shall I send faster? Send faster (...... words per min.).

QRS Shall I send more slowly? Send more slowly (....w.p.m.).

QRT Shall I stop sending? Stop sending.

QRU Have you anything for me? I have nothing for you.

QRZ Who is calling me? You are being called by..... (on ..... kHz.).

QSL Can you acknowledge receipt? I am acknowledging receipt.

QSY Shall I change to transmission on another frequency? Change to transmission on another frequency (or on .... kHz.).

One of the first adjuncts to your "shack" should be a call book, so that you can locate the stations whose calls you hear over the air. The ARRL does not publish an amateur call book but an excellent one known as *The Radio Amateur Call Book Magazine* is available. One edition, giving the calls of all United States stations, may be secured for $6.95 plus 25 cents for mailing from the publishers (The Radio Amateur Call Book Magazine, 925 Sherwood Drive, Lake Bluff, Ill. 60044). A foreign edition, $4.95 plus 25 cents for mailing, lists calls of amateurs outside the U. S.

Chapter 4

A Simple Two-Tube Transmitter

Now that you have a receiver, it's time to think about a transmitter. This chapter will tell you how to build a small c.w. transmitter with which you should be able to cover distances of 1000 miles or more, under favorable conditions, using the amateur 80- or 40-meter band. Three views of this transmitter are shown in the photographs that follow.

Fig. 4-1 shows the wiring diagram of the transmitter in schematic form and, associated with the diagram, will be found a list of the electrical components that will be needed. Several additional items, listed in the accompanying table will also be required.

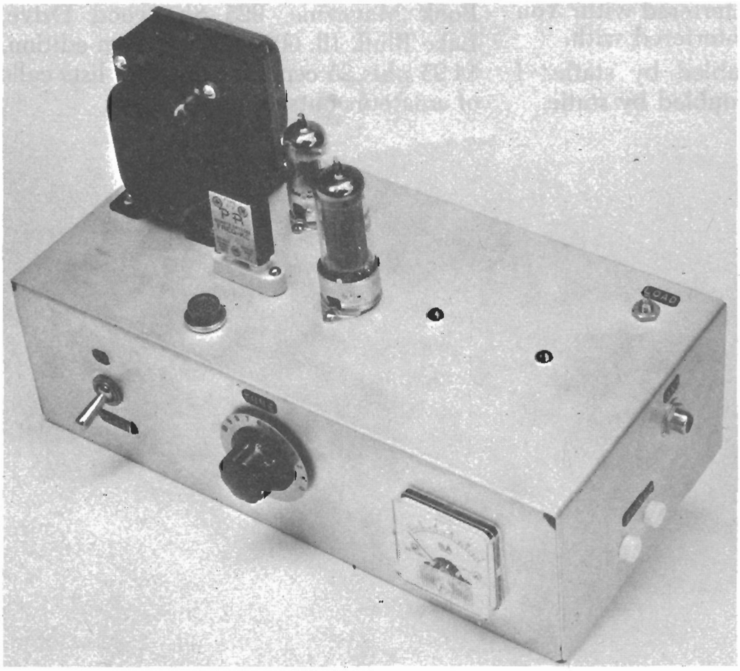
Sources of Components

In many of the larger cities there are electronics supply houses where most of the components needed for the construction of the transmitter may be obtained. Amateurs outside of urban areas may find it necessary to select components from the catalogs of one or more of the several large supply houses who handle mail orders. Those listed below[1] are mentioned specifically only because all components used in the prototype, or sufficiently close equivalents, are to be found in their current catalogs combined. There are several other equally reliable firms with national distribution from whom at least some of the needed items may be obtained. You will find their advertisements in various radio publications.

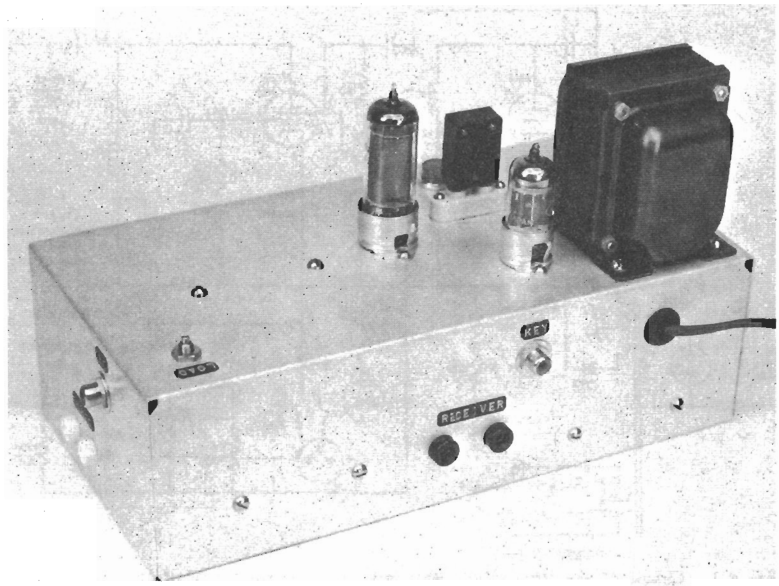
In the majority of cases, the brand and type number of the component are in-

[1] Allied Radio, 100 N. Western Ave., Chicago, Ill. 60680; Lafayette Radio Electronics, 111 Jericho Turnpike, Syosset, L.I., N.Y. 11791.

If the component is listed in a catalog of only one of these two firms, it is indicated by A, or L, respectively, at the end of the line describing the item. If no designating letter is given, the components may be obtained from either. Catalogs may be obtained free upon request.



Front view of the 15-watt transmitter. The oscillator tube is to the right of the power transformer; the amplifier tube is to the right of the crystal. The power-indicator lamp is in front of the crystal. The loading capacitor, C_{12} is in the right rear corner. The antenna and headphone jacks are mounted on the end apron.



Rear view of the transmitter chassis. Shielded sockets are not necessary.

cluded as further aid in identifying the specific component used in the prototype. However, other brands with equivalent electrical characteristics may be substituted with appropriate adjustment for any differences in physical size or mounting-hole pattern.

Preparing the Chassis

Figs. 4-2 through 4-6, inclusive show the locations of the centers of the holes that must be drilled in the chassis, and the size of each hole. Where a number is given, rather than the hole diameter, the number indicates the size of drill that should be used to make the final drilling. It should be borne in mind that the hole positions and diameters are for the specific components used in the prototype. Since dealers sometimes will substitute close equivalents, and also because different production runs by a manufacturer may have slight differences, it is always advisable to check mounting dimensions against the sketches before marking the holes for any component.

Identify the locations of the hole centers on the chassis by marking cross lines with pencil or scriber, as indicated in the sketches. To preserve the appearance of the chassis, scribe marks should be made short enough so that they will disappear when the hole is drilled out, or will be hidden when the component is mounted. Use a square against the edges of the chassis in measuring the distances to the holes.

A center punch should be tapped lightly with a hammer, at each hole center. The small dent that results will hold the drill point steady when the drilling is first started. Start each hole by drilling first with a small drill about 1/16 inch in diameter. (If a larger drill is used, the point of the drill may "walk out" of the center-punch dent and damage the surface of the chassis.) The holes may then be enlarged to the sizes indicated in the sketches by using successively larger drills until the final size is reached.

Sheet-metal or "chassis" punches (also carried by most electronic supply houses) are convenient for making larger-size holes. But if they are not available, the holes may be made by first drilling out to the largest drill size available, and then filing out to the required size, using round and half-round files. In this case,

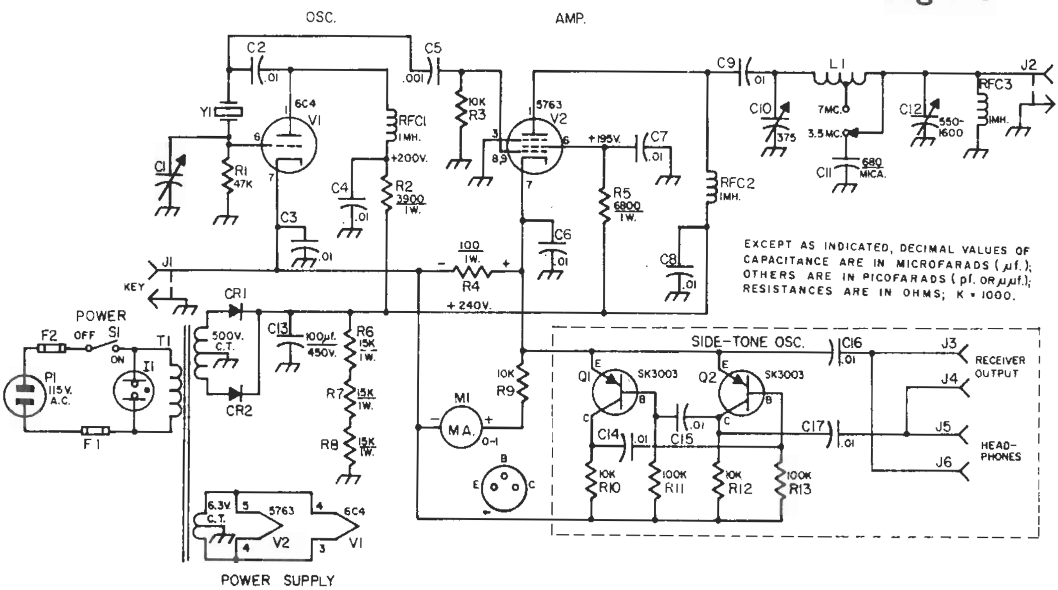


Fig. 4-1 Circuit of the transmitter. Resistors are ½-watt composition, unless indicated otherwise. Voltages shown are approximate for key-down conditions.

C_1 — Mica or ceramic trimmer, approx. 3-30 pf. (Elmenco, or similar) (A).
C_2, C_3, C_4, C_6, C_7, C_8, C_9, C_{14}, C_{15}, C_{16}, C_{17}—0.01-μf. ceramic disk capacitor, 500 volts.
C_5 — Similar to C_2, 0.001 μf.
C_{10} — Variable air capacitor, single section, approx. 375 pf., broadcast-replacement t.r.f. type.
C_{11} — 680-pf. mica capacitor.
C_{12} — Similar to C_1, 550-1600 pf.
C_{13} — 100-μf. 450-volt electrolytic capacitor (Cornell-Dubilier BR-100-450).
CR_1, CR_2 — Silicon diode, 1000 p.i.v., 300 ma. (RCA 1N3563).
F_1, F_2 — ½-ampere fuse (Littlefuse 3AG).
I_1 — 115-volt neon panel lamp (Leecraft 32-2111, or similar) (A).
J_1, J_2 — Phono jack, single-hole mounting (Switchcraft 3501-FP, or similar).
J_3, J_4 — Insulated banana jack (Johnson 108-903, H. H. Smith 1508).
J_5, J_6 — Insulated tip jack (Johnson 105-601, H. H. Smith 240).
L_1—27 turns No. 20, 1-inch diam., 16 turns per inch, tapped at center (Barker & Williamson 3015 Miniductor, Illumitronics 816T Airdux, Polyphase 1748 Polycoil).
M_1 — Miniature 0-1-ma. d.c. meter (Lafayette 99 H 5052).
P_1 — 115-volt a.c. fused plug.
Q_1, Q_2 — P-n-p germanium transistor, 9 volts (RCA SK3003).
R_1-R_{13}, incl. — As indicated (R_4 and R_9 preferably 5% tolerance).
RFC_1, RFC_2, RFC_3 — 1-mH rf choke, 250 mA (Millen 34300-1000).
S_1 — S.p.s.t. toggle switch.
T_1 — Power transformer: 500 volts, center-tapped, 40 ma.; 6.3 volts, 2 amperes. (Knight 54 B 2551) (A).
V_1 — Type 6C4 triode.
V_2 — Type 5763 pentode.
Y_1 — Quartz crystal, FT-243 mounting, 0.486-inch pin spacing, 0.093-in. pin diameter (see text).

the outline of the hole should be scribed on the surface of the chassis with a compass before any drilling is done, using the center-punch mark as a center. (Machine shops and sheet-metal shops usually have suitable punches, and will often do the job for you for little or nothing.) The burrs that usually result from drilling should be carefully removed with the point of a drill much larger in size than the hole, or by cutting with a knife or chisel.

Tube Sockets

Tube-socket mounting holes are not located in the drawings. Rather than to rely on measurement, these holes can be scribed, after the center hole has been cut, by placing the socket in the hole, turning it to the proper position, and marking the chassis through the mounting holes, using the socket itself as a template. The oscillator-tube (V_1) socket should be turned so that its No. 7 pin

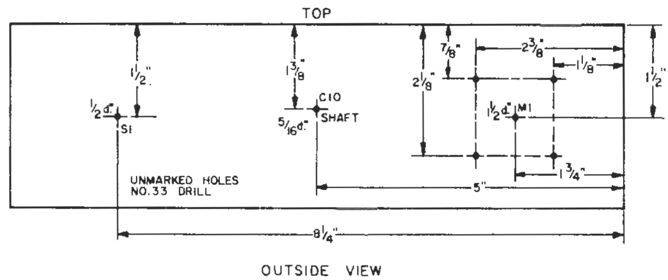


Fig. 4-2 Drilling pattern for front side of chassis.

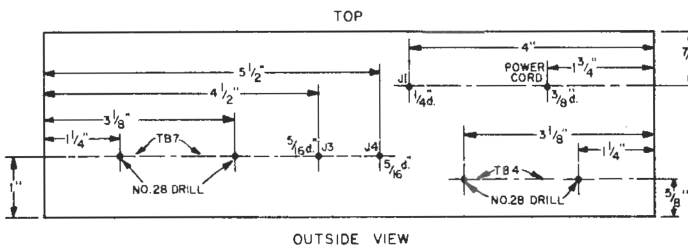


Fig. 4-3 Drilling pattern for rear side of chassis.

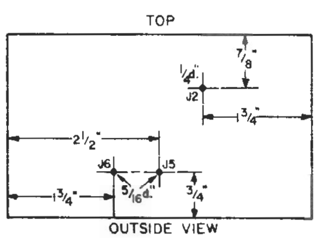


Fig. 4-4 Drilling pattern for left end of chassis.

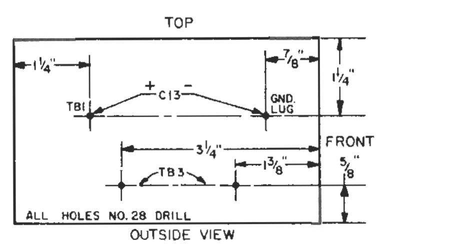


Fig. 4-5 Drilling pattern for right end of chassis.

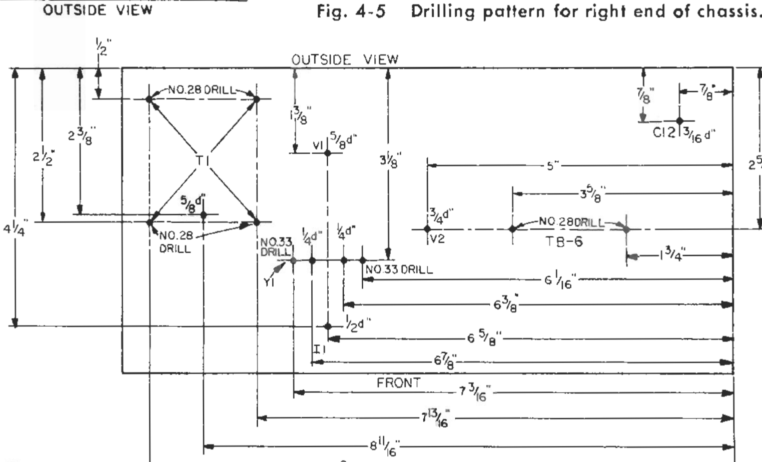


Fig. 4-6 Drilling pattern for top of chassis.

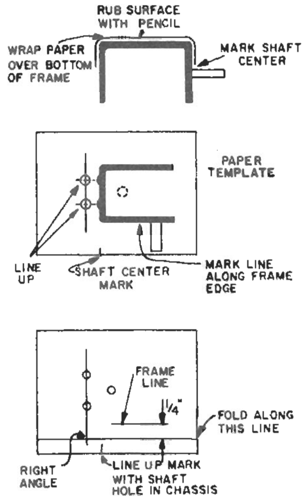


Fig. 4-7 Making a drilling template for the tuning capacitor for mounting the capacitor under the top side of the chassis. (A) Paper should be drawn taut over frame, with the front edge touching the shaft. Make a mark at this edge indicating the center of the shaft. Holding the paper securely in the same position, rub entire top surface lightly with a pencil to obtain the mounting-hole pattern. (B) Draw a line through the in-line holes in the pattern. Lay the capacitor on its side, line up the capacitor mounting holes and the in-line pattern holes, and draw a line along the front edge of the frame. (C) At a point ¼ inch closer to the front of the pattern, draw a line at exact right angles to the mounting-hole line. Fold the paper accurately along this line. Place the fold over the front edge of the chassis, with the shaft center line on the pattern lining up wih the shaft-hole center in the chassis front. Tape the template to the chassis, and punch-mark all three mounting holes. Mounting holes should be drilled out to No. 28 drill size, and shaft hole to ⅜ inch.

is toward the front of the chassis, and the amplifier-tube (V_2) socket with its No. 9 pin toward the front.

Tuning Capacitor

The mounting hole patterns of capacitors that may be used for C_{10} vary from one brand to another. The one used in the prototype has threaded mounting holes in the front end, as well as in the bottom of the frame, permitting the capacitor to be mounted either against the front wall of the chassis, or against the under side of the top. For front mounting, a template can be made by carefully cutting a hole, that will closely fit over the shaft, in a piece of paper. Hold the paper securely against the front of the capacitor frame and, when a pencil is rubbed lightly over the entire surface, the hole locations should be transferred to the paper. Remove the paper template and make a hole with a small drill at the shaft location on the chassis indicated in Fig. 4-2. Place the template on the chassis, and adjust its position until the chassis hole is accurately centered in the template shaft hole, and the mounting holes are in a position that will make the capacitor frame parallel to the top of the chassis when the capacitor is mounted. Tape the template to the chassis in this position, and mark the mounting holes with the center punch. In mounting the capacitor, it may be necessary to use tubular spacers on the mounting screws, between the capacitor frame and the chassis to clear any projections on the frame. Be careful to choose mounting screws of a length that will not extend into the capacitor so far that they touch the capacitor plates.

For mounting the capacitor against the under side of the chassis top, the method shown in Fig. 4-7 may be used. The sketch shows a triangular pattern of mounting holes, which will be found on most capacitors of this type. There may be variations, but the same general method may be used to make a template.

Tubular spacers should be used on the mounting screws to line the capacitor shaft up with the shaft hole in the chassis. Again, be sure that the mounting screws are short enough to avoid contact with the capacitor plates.

Finishing the Chassis

Handling the chassis during its preparation will usually leave the outside surface smudged, and minor scratches are difficult to avoid. To remove the blemishes, sandpaper the entire outer surface of the chassis with a fine grade

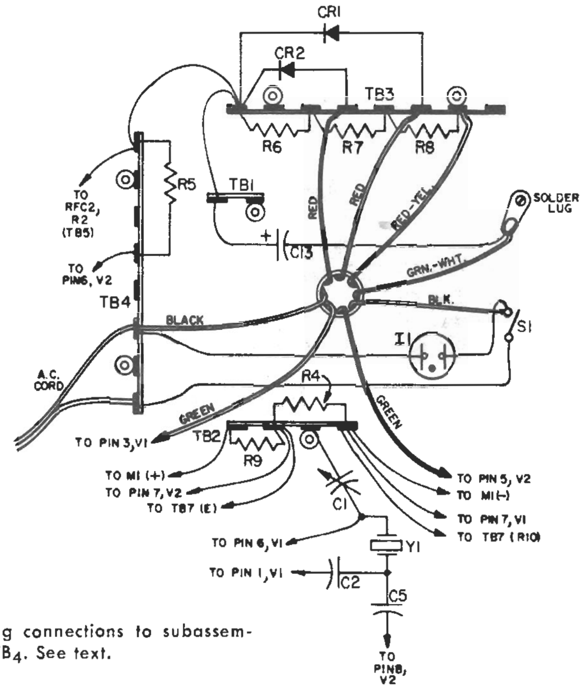


Fig. 4-8 Sketch showing connections to subassemblies TB_1, TB_2, TB_3 and TB_4. See text.

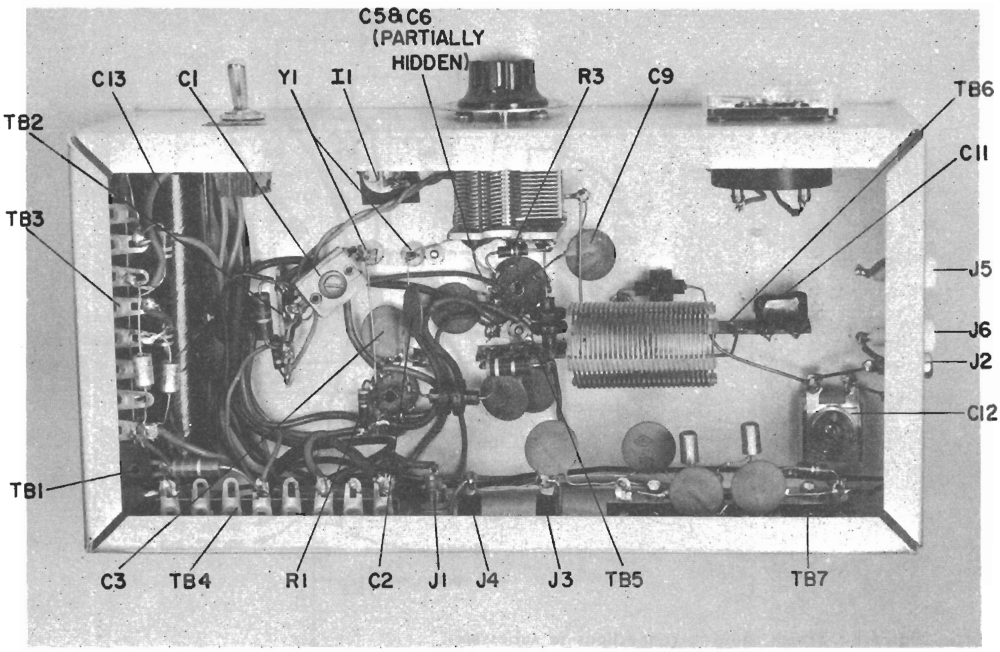
of sandpaper until the surface has a bright sheen. Use firm strokes parallel with the longest edge of the surface being sanded. As soon as the sanding is finished, wipe all surfaces clean with a cloth, and then spray lightly with clear acrylic from a pressure can. Don't attempt the same process on the inside of the chassis, since spraying will make it difficult to secure good electrical contacts to the chassis. If chassis lettering is desired, apply the lettering before spraying, being careful not to smudge the surface again. The simplest method of lettering is to use a "Tapewriter." Decal lettering makes a somewhat more professional job, but it is more difficult to apply.

Assembly

The assembly and wiring of the transmitter will be described in steps. Both to help in understanding the wiring diagram and to make sure that no connections have been forgotten, it is a good idea to keep a record by marking over the connecting lines in Fig. 4-1 with red pencil as each connection is made.

Most of the small components are mounted in terminal-strip subassemblies prepared outside of the chassis where they can be worked on more conveniently. Each subassembly is then mounted in the chassis as a unit.

Start the assembly by mounting S_1, C_{10} and M_1 on the front of the chassis (see Fig. 4-2 for locations). Mount J_1, J_3 and J_4 on the rear wall of the chassis, and install a ⅜-inch rubber grommet in the hole where the a.c. line cord will be led out (see Fig. 4-3). Mount TB_1 (2-contact terminal strip) and the solder lug inside the left-hand end of the chassis (see Fig. 4-4). Mount J_2, J_5 and J_6 on the right-hand end of the chassis (see Fig. 4-5). Mount the two tube sockets (with a solder lug under each mounting nut), so that pins 7 and 9 are toward the front of the chassis. Mount the crystal socket, and I_1 on top of the chassis; mount C_{12}



Bottom view of the transmitter chassis. Components not designated here may be identified from the sub-assembly sketches.

underneath (see Fig. 4-6). Insert the large rubber grommet at T_1.

Connect Pin 3 of V_2 to the nearest grounding lug. Connect a 0.01-μf. disk capacitor from each of these pins to the most convenient grounding lug: Pin 7 of V_1 (C_3); Pins 6 and 7 of V_2 (C_7 and

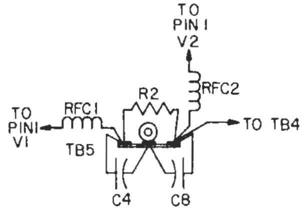


Fig. 4-9 Sketch showing connections to sub-assembly TB5. See text.

C_6). Also connect a similar capacitor (C_9) from Pin 1 of V_2 to a stator terminal of C_{10}. Connect R_1 from Pin 6 of V_1 to the nearest grounding lug. Connect R_3 from Pin 8 of V_2 to the nearest grounding lug. Connect the center terminal of J_1 to Pin 7 of V_1. Dress the wire flat against the chassis contour.

Bunch the leads of T_1 together and feed them down through the grommet hole, and mount T_1 (see Figs. 4-6 and 4-8, and the bottom-view photograph). Dress the transformer leads temporarily toward the right-hand end of the chassis.

Place C_{13} in the left-hand corner of the chassis, with the + terminal toward TB_1. Connect the capacitor as shown in Fig. 4-8.

Mount R_4 and R_9 on TB_2 (5-contact terminal strip, one terminal removed), and mount TB_2 under the front right-hand mounting nut of T_1 (see Fig. 4-8).

Assemble components on TB_3 (8-contact terminal strip), as shown in Fig. 4-8.

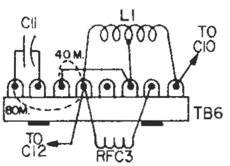


Fig. 4-10 Sketch showing connections to sub-assembly TB6. See text.

Additional Components

1 3 × 5 × 10-inch aluminum chassis.
2 Phono plugs (Switchcraft 3502, or similar).
2 Banana plugs (Johnson 108-303, H.H. Smith 211) (A).
1 Crystal socket, 0.486-inch pin spacing, for 0.093-inch pins (Millen 33102, National CS-6) (L).
1 7-pin miniature-tube socket (Amphenol 147-505, Cinch-Jones 7AM1).
1 9-pin miniature-tube socket (Amphenol 59-410, Cinch-Jones 9AM).
4 8-contact (2 ground) terminal strips (H.H. Smith 870).
1 5-Contact (1 ground) terminal strip (H.H. Smith 866, one end of contact cut off).
1 3-contact (1 ground) terminal strip (H.H. Smith 864).
1 1-contact terminal strip (H.H. Smith 861).
1 Small tuning knob for C_{10}, ¼-inch shaft (Millen 10005, or similar).
4 No. 4 machine screws, ¼ inch long (for tube sockets).
2 No. 4 machine screws, ½ inch long (for crystal socket).
14 No. 6 machine screws, ¼ inch long.
Nuts for the above screws.
5 Soldering lugs.
1 Rubber grommet for ⅝-inch hole.
1 Rubber grommet for ⅜-inch hole.
1 Radiotelegraph key.
Several feet of insulated hookup wire.
A few feet of lamp cord.

(When soldering CR_1 and CR_2, hold the leads with pliers to conduct away heat that might damage the diodes.) When the soldering is complete, check to make sure that there are no shorts. Mount TB_3 inside the chassis (see Fig. 4-4). Connect TB_3 to TB_1 (see Fig. 4-8).

Solder R_5 on TB_4 (8-contact terminal strip). Mount TB_4 inside the chassis (see Fig. 4-3). Connect TB_3 and TB_4. Make the connection from TB_4 to Pin 6 of V_2, keeping the wire flat against the walls of the chassis (see Fig. 4-8).

Complete all of the wiring shown in heavy lines in Fig. 4-8. Except for the leads to TB_3, keep all wiring as flat against the contour of the chassis as possible. Route the green wires from T_1 around TB_2 and Y_1. Cut off any excess length of transformer leads before soldering.

Connect Pin 5 of V_2 to Pin 4 of V_1, and connect Pin 3 of V_1 to Pin 4 of V_2.

Make the connections to TB_2 indicated in Fig. 4-8, except for the connections to TB_7. Use different-colored wires for the connections to M_1, and twist them together. Identify the + and – connections by the color. Keep the wiring to Y_1 spaced about ½ inch above the chassis surface. Keep other wiring flat against the chassis. Solder C_1 directly between TB_2 and the nearest terminal of Y_1.

Mount the components on TB_5 (3-contact terminal strip), as shown in Fig. 4-9. Leave about ¼ inch of lead between RFC_2 and TB_5, and about ⅝ inch between RFC_1 and TB_5. Mount TB_5 under the rear nut of the V_2 socket. Make the connections indicated in Fig. 4-9, running the lead to TB_4 flat against the chassis.

Cut the coil to the specified number of turns, leaving an extra turn at each end to be straightened out to form a connecting lead. Locate the center turn of the coil. Indent the adjacent turn on either side of the center turn by pushing firmly inward with the narrow blade of a small screwdriver. Remove the insulation from a short length of hookup wire. Bend a small hook in one end. Tin the center turn of the coil at the connecting point, and the hook by flowing a small amount of solder onto the wire. Fish the hook around the center turn, pinch tight with pliers and solder fast. Make sure that there are no shorts between turns.

Mount components on TB_6 (8-contact terminal strip), as indicated in Fig. 4-10. Leave about ½ inch of lead length between L_1 and the terminal-strip contacts. If operation is to be on 80 meters, wire a jumper from the first to the fourth terminal, as shown. For 40-meter operation, omit the 80-meter jumper, and run the jumper between the third and fourth terminals. Mount TB_6 in the chassis (see Fig. 4-6 and bottom-view photograph), and make the connections indicated in Fig. 4-10. Keep the leads spaced from the chassis.

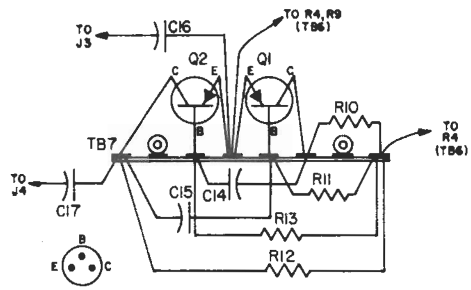


Fig. 4-11 Sketch showing connections to subassembly TB7. See text.

From the same terminal of C_{12} to which L_1 is connected, run a wire to the center terminal of J_2. Connect the other terminal of C_{12} to the grounding lug of J_2.

Side-Tone Monitoring Oscillator

The subassembly shown in Fig. 4-11 makes up the monitoring oscillator shown inside the dashed lines in Fig. 1. This section is not essential to the functioning of the transmitter, and therefore it may be omitted. However, to transmit good code, it is necessary that the operator have some way of listening to his own keying as he transmits. In some instances, it is possible to monitor the keying by listening to the transmitter signal on the receiver. To do this, it is necessary that the receiver be tuned to the transmitter frequency. This may not be convenient when the station you are talking to is on a different frequency than your own. Also, in many cases, the transmitter signal will be so strong that it will block the receiver, and all that will be heard is a series of thumps or clicks, as the transmitter is keyed. This is almost surely to be the case if the receiver described earlier is used. The side-tone oscillator avoids these troubles.

The assembly of Fig. 4-11 is essentially a duplicate of the one used in the code-practice oscillator described in Chapter 6. If this unit has been built previously, it can be substituted in the transmitter, with slight modification to bring it into agreement with Fig. 4-11. Otherwise, the assembly procedure is as follows:

Assemble the components on TB_7 (8-contact terminal strip), as shown in Fig. 4-11. Do not cut the transistor leads too short; leave plenty of length so that the lead will reach the proper terminal without stress. Hold each transistor lead with pliers while soldering to avoid damage to the transistor from the heat of the soldering iron. When the assembly is complete, inspect it carefully to make sure that there are no shorts between leads or to the two mounting lugs which will be grounded to the chassis. Mount TB_7 in the chassis (see Fig. 4-3), and make the external connections indicated in Fig. 4-11. Keep the wiring to TB_6 flat against the chassis. Connect J_3 to J_6, and J_4 to J_5. Keep these wires flat against the chassis. This completes the construction of the transmitter.

Crystals

A separate crystal is required for each frequency on which it is desired to operate. In purchasing a crystal, it is necessary to specify the desired frequency. For operation in the Novice portion of the 80-meter band, the crystal frequency must lie between the limits of 3700 and 3750 kHz. For the Novice section of the 40-meter band, the crystal frequency must lie between the limits of 7150 and 7200 kHz.

The exact frequency produced by a crystal depends to some small extent on the circuit in which the crystal is used, and the adjustment of that circuit. Also, crystal manufacturers guarantee frequencies only within some specified tolerance. For these reasons, it is advisable to select crystal frequencies not closer than 2 kHz. to any band-segment limit.

Testing the Transmitter

Before testing the transmitter, check the wiring carefully once more against the circuit diagram of Fig. 1.

WARNING! All transformer-powered

tube transmitters, including low-power transmitters such as this one, require operating voltages that are high enough to be lethal. In this transmitter, there are no points on the outside of the chassis where contact with a dangerous voltage is possible. Therefore, no hazard is involved in normal operation of the unit. However, extreme care must be used in probing into the inside of the chassis. After the unit has once been plugged into the power line, *NEVER* touch anything inside the chassis without first pulling the power plug from the outlet, and making sure that the filter capacitor C_{13} is discharged, by shorting the terminal to which both diode rectifiers are connected (the terminal on TB_3 connected to TB_1 and TB_4) to the chassis with a long screwdriver having an insulated handle. The bleeder resistors (R_6, R_7 and R_8) will discharge the capacitor to a safe level in approximately 30 seconds. However, there is always a possibility that there may be a poor connection to a resistor, or that a resistor may be defective, in which case the bleeder would offer no protection at all. Without some means of discharge, the capacitor can retain a dangerous voltage for several hours. So *always* short the high-voltage terminal to the chassis after pulling out the power plug and waiting at least 30 seconds, before touching anything inside the chassis. (If the short is made immediately after the power plug is pulled out, there will be a large and noisy spark as the capacitor is shorted. This can be avoided by waiting until most of the charge has been dissipated in the bleeder. Even after a 30-second delay, a small spark may be observed when the short is made. If the spark is large and loud after the delay, it indicates that the bleeder circuit is defective at some point.)

To test the transmitter, plug the tubes into their sockets, and a key into J_1. Plug a crystal in at Y_1—an 80-meter crystal for 80-meter operation, or a 40-meter crystal for 40-meter operation. (Be sure that the jumper on TB_6 is in the correct position for the desired band.) Insert a No. 6 screw about 1 inch long into J_2 until it makes firm contact. Connect a 15-watt 115-volt lamp to the output of the transmitter, with one terminal of the lamp connected to the screw at J_2, and the other terminal of the lamp connected to some convenient point on the chassis. (The transmitter should never be operated without some sort of load connected to the output—either a dummy load, represented by the lamp, or an antenna.) If a socket with short leads isn't available for the lamp, solder wires to the shell and base contacts.

Turn the shaft of C_{12} with a screwdriver to its maximum-capacitance position. With the capacitor specified, this requires counterclockwise rotation, but another brand of capacitor may require clockwise rotation. When the adjusting screw is turned for maximum capacitance with either type, it will be indicated by an increase in turning friction as the capacitance approaches maximum. In turning toward minimum capacitance, the friction will become less and, at minimum capacitance, the adjusting screw will become quite loose. Set C_{10} also to maximum capacitance (plates fully meshed).

Plug the power cord in and turn the power switch to its ON position. The indicator lamp, I_1 should light. Wait approximately 30 seconds for the tube heaters to warm up. Then press the key. The meter should show a deflection to about half scale. While watching the meter, turn C_{10} very slowly toward minimum capacitance. At some point in the adjustment of C_{10}, there should be a dip in the meter deflection. This is the *resonance* point. If the load lamp lights at all, it will probably be quite faint.

Open the key, and decrease the capacitance of C_{12} a bit (not more than one full turn). Close the key, and readjust C_{10} for the dip point again. (This should require only a small adjustment of C_{10} toward maximum capacitance.) You may notice now that while the dip in meter reading still occurs, the dip is not as pronounced as it was on the first trial. Keep reducing the capacitance of C_{12} a bit at a time, and retuning to resonance with C_{10}, until the dip at resonance is only about 5 ma. (one meter-scale mark). At this point, the meter should be reading between 50 and 60 ma. (0.4 and 0.6 on the meter scale), and the load lamp should be lighting quite noticeably. Repeat this procedure several times until you are thoroughly familiar with it.

With the crystals used to test the prototype transmitter, best keying characteristics were obtained with C_1 at maximum capacitance. Other crystals may require an adjustment of this capacitance to avoid "chirpy" keying.

A second dip in meter reading may be obtained if C_{10} is turned near minimum capacitance. This adjustment should be avoided, since the transmitter will be tuned to twice the crystal frequency. With proper adjustment, C_{10} is *always* set at not less than one third of maximum capacitance. Make sure that this is the case.

With the transmitter tuned up for maximum output as described, plug a pair of headphones into J_5 and J_6. A clear tone of good strength should be heard each time the key is closed.

Antenna

The transmitter is designed to work into one particular type of antenna. For 80-meter operation, this consists of a quarter wavelength of wire (60 feet of wire for the Novice section of the 80-meter band), and a ground connection to the nearest available piping system. One end of the antenna wire should be connected to the center pin of a phono plug fitting J_2, while the other end should be led to the outside by lowering the upper sash of a window just enough

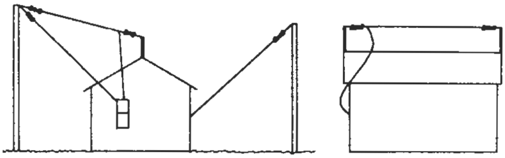


Fig. 4-12 Some methods of installing the antenna.

to allow the wire to pass. If the window frame is of metal, or if the wire must pass a metal-frame screen or storm window, the wire should be covered with plastic tape for a few inches to avoid any possible contact with the metal frame.

After leaving the window, it will usually not be possible to run all of the remaining length vertically, but it should preferably be run as nearly vertical as possible. Several suggested arrangements are shown in Fig. 4-12. Trees may be used as supports instead of the masts indicated. If necessary, to accommodate the full length of wire, the wire can be run vertically or diagonally to one tree, and then horizontally to another. An anchorage to a tall tree can be made by throwing a weighted line of twine over a branch, and then using the line to pull the antenna up.

A quarter wavelength of wire (30 feet) can also be used for 40-meter operation. However, since the length is physically short, only a relatively small portion of it can be elevated very much. Considerably better results will usually be obtained if the wire is made ¾ wavelength long (90 feet). The same procedures in suspending the antenna suggested for the 80-meter antenna can be used.

The ground connection can be made to a pipe by means of a TV-type ground clamp. Either bare or insulated wire may be used to connect the clamp to the shell side of the phono plug at J_2 (or to the chassis itself). The ground wire should be as short and direct as possible. A connection to a cold-water pipe is preferred, but if the nearest point to such a connection is more than 10 feet from the transmitter for 80-meter operation, or 5 feet for 40-meter operation, it would be preferable to make a shorter connection to hot-water or heating-system conductors if such are available. If connection to any piping system is not available within the appropriate distances mentioned, a connection can be made to two or three TV ground rods driven into the earth directly under the point where the antenna emerges. If the transmitter is located so far above ground level that a connection to ground rods cannot be made with a short wire (such as on a floor above ground level), it would be preferable to use a second wire, the same length as the antenna, fed out under the lower window sash and thence to a support at the far end that will elevate the wire to a height where it will not constitute an obstruction to pedestrians or vehicles. The station end of the wire should be connected to the chassis of the transmitter, and the far end should terminate in an insulator attached to the support.

Although the final adjustment arrived at may be different, the same tuning procedure should be followed in feeding the transmitter into the antenna as when feeding the dummy load. Start with C_{10} and C_{12} at maximum capacitance, tune C_{10} for the dip at resonance. Gradually decrease the capacitance of C_{12}, and retune to resonance with C_{10} until there is a dip of only about 5 ma. at resonance.

Combined Transmitter and Receiver Operation

If the keying monitor is included, an interconnecting two-wire cable should be made up to connect the transmitter and receiver. One end of the cable should be terminated in a plug to fit the receiver headphone jack. Banana plugs should be attached to the other end of the cable. These are plugged into J_3 and J_4. Then, when the headphones are plugged into J_5 and J_6, both the receiver signals and the monitor signal should be heard.

The same antenna may be used for both transmitting and receiving. However, this sort of operation will require a switch to transfer the antenna from one to the other, as shown in Fig. 4-13. Switching can be avoided by using a separate antenna for the receiver. This antenna need not be elaborate, for quite satisfactory results should be obtained with a simple indoor antenna. You will find that the ability to start sending and listening without the necessity for throwing a switch—break-in operation—has many advantages.

How the Transmitter Works

Refer to the circuit of the transmitter, shown in Fig. 4-1. The crystal-controlled oscillator, V_1 generates a small amount of r.f. power which is used to drive the amplifier, V_2. The amplified power is then fed to the antenna through an impedance-matching network commonly referred to as a *pi network*. The voltages necessary for operating the oscillator and amplifier tubes are furnished by the power-supply circuit at lower left. Both oscillator and amplifier are keyed simultaneously by opening and closing the connection between the cathodes of the tubes and the negative side of the high-voltage supply (chassis ground), thus interrupting the plate-current flow of the

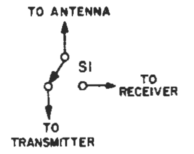


Fig. 4-13 If separate transmitting and receiving antennas cannot be used, a single antenna may be switched between the two units. S_1 should be a rotary switch.

oscillator and the plate- and screen-current flow of the amplifier. This system is called *cathode keying*. Enclosed in dashed lines at lower right in Fig. 4-1, is the circuit of an audio oscillator which is keyed along with the transmitter, and serves as a keying monitor.

The crystal-oscillator circuit is known as the *Pierce* circuit. The frequency of the signal generated by the oscillator is determined by the quartz crystal at Y_1. An equivalent oscillator circuit is shown in Fig. 4-14. The crystal is equivalent to a resonant circuit, L_xC_x tuned permanently to one fixed frequency. Therefore, a separate crystal is required for each frequency on which it is desired to transmit. Feedback to induce oscillation is obtained by virtue of the capacitive voltage divider C_PC_G across the tuned circuit. C_P is the capacitance that exists internally between the tube plate and cathode. C_G is the similar capacitance that exists between grid and cathode. These capacitances are not adjustable, of course, and it would be only by fortunate circumstance that these fixed values would provide optimum feedback. Therefore, C_1 is added externally, to increase the capacitance between grid and cathode. (A tube of different internal construction and characteristics might require that C_1 be placed from plate to ground to increase the capacitance between plate and cathode. In this instance, however, experience has shown that optimum feedback requires more capacitance from grid to cathode.) C_1 is a variable capacitor to permit adjustment of feedback.

Returning to Fig. 4-1, C_2 is used because an r.f. connection between the tube plate and the crystal is required, but a d.c. connection is not necessary. The oscillator would function just as well with C_1 omitted, and the plate connected directly to the crystal, but this would place the crystal socket and holder directly in contact with the high-voltage supply. This might constitute an un-

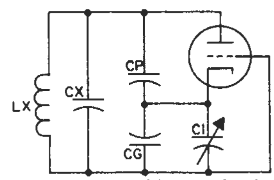


Fig. 4-14 Equivalent oscillator circuit. See text.

necessary hazard to the operator, and might cause damage to the tube if the crystal holder were faulty.

The high-voltage supply is connected to the plate of the oscillator tube through R_2 and RFC_1. If the supply were connected directly to the plate of the tube, the connection would short circuit the r.f. output of the oscillator. R.f. choke RFC_1 has a high impedance for r.f., and therefore may be connected across the output of the oscillator without ill effect. The choke has negligible d.c. resistance, so its insertion in series with the d.c. supply causes no significant loss in plate voltage.

Although the output voltage from the power supply is appropriate for the amplifier tube, it is higher than necessary for satisfactory operation of the oscillator. For best frequency stability, and also because excessive oscillator plate voltage may cause the crystal temperature to rise sufficiently to fracture the quartz, it is desirable to use the minimum oscillator plate voltage that will give the r.f. power needed to drive the amplifier. Therefore, the voltage is reduced by inserting resistor R_2 between the supply and the oscillator plate.

R_1 is the oscillator grid leak that provides a means of biasing the grid of the oscillator tube. C_3 and C_4 are r.f. bypass capacitors that serve as a low-impedance path for r.f. current that otherwise would have to flow through the keying leads and power-supply wiring, introducing loss in r.f. power, and possibly undesired coupling to other parts of the circuit.

C_5 is a *coupling* capacitor. It serves as a means of avoiding overloading of the oscillator by the input circuit of the amplifier. The smaller this capacitance is made, the less the amplifier will load the oscillator. However, if the capacitance is made too small, the amplifier will not receive sufficient driving voltage.

R_3 is the amplifier-biasing grid leak. R_5 is a series resistor to reduce the screen voltage and limit the screen current so that the screen dissipation rating will not be exceeded. RFC_2 is used in the amplifier for the same purpose that RFC_1 is used in the oscillator. C_6, C_7 and C_8 are r.f. bypass capacitors. C_9 is a voltage-blocking capacitor to remove the d.c. plate voltage from the components of the pi network, while allowing r.f. current to pass.

To operate efficiently, the impedance across the amplifier output must be of the order of a few thousand ohms. The antenna system to be suggested for use with the transmitter constitutes a low-impedance circuit (50 ohms or less). The circuitry of the pi network transforms this low impedance to the higher value required for efficient operation of the amplifier tube. The network is a selective circuit and thus serves the additional purpose of reducing harmonics (signals at multiples of the crystal frequency that are always generated in a transmitter) that might cause interference to other radio services.

The principal components of the pi network are C_{10}, L_1, and C_{12}. C_{10} is the *tuning capacitor*, the principal element in adjusting the output circuit to resonance. C_{12} is the *loading capacitor*. This is the principal element in adjusting the coupling to the antenna (adjusting the impedance transformation).

RFC_3 is used primarily as a safety device to short circuit the amplifier d.c. plate voltage to ground, should C_9 break down, thus avoiding the possibility of high voltage appearing on the antenna where it would be dangerous to anyone coming in contact with the antenna. Since the choke represents a high impedance, it can be placed across the low impedance of the antenna without affecting the operation so far as r.f. is concerned. C_{11} is a fixed capacitor added in parallel with C_{12} to provide the necessary loading capacitance for 80-meter operation.

The pi-network output circuit is arranged to give the operator a choice of either 80-meter operation, or 40-meter operation. The circuit as shown in Fig. 1 is for 80-meter operation. If 40-meter operation is desired, the 80-meter crystal is replaced by a 40-meter crystal, and the arrow-head lead going to C_{11} is transferred to the tap on the coil. This one operation removes C_{11} from the circuit, and shorts out part of L_1 to reduce its inductance.

Power Supply

The power-supply circuit has a full-wave rectifier using silicon-diode rectifiers. C_{13} is the *filter capacitor* that smooths out the pulsations in the d.c. voltage coming from the rectifiers to avoid a rough tone on the transmitted signal. R_6, R_7 and R_8 constitute a *bleeder resistance*, the purpose of which is to discharge the filter capacitor after the power has been turned off. Otherwise, the capacitor might retain a dangerous charge for a long time after turning off the power, and thus present a hazard to the operator if he probes into the inside of the chassis.

I_1 is a neon indicator lamp that lights up and serves as a warning when the power is turned on by S_1. A 6-volt winding on T_1 provides power for the tube heaters.

Keying Circuit and Keying Monitor

The portion of Fig. 1 enclosed in dashed lines provides a means of monitoring the keying of the transmitter.

The circuit, using two transistors and

associated resistors and capacitors, constitutes an audio oscillator which generates a tone that can be heard when headphones are connected to the output terminals J_5 and J_6. The output terminals of the receiver are connected to the headphones through J_3 and J_4, so both the received signals and the signal from the monitor can be heard without switching from one to the other.

When the key is closed, amplifier plate and screen currents flow through R_4. This causes a voltage drop across R_4, with the cathode end of the resistor positive in respect to the other end of the resistor. With the amplifier drawing normal current, the voltage across the resistor will be 5 to 7 volts. This voltage is used to power the transistors in the side-tone oscillator. Thus, whenever the key is closed, plate voltage is applied to the two tubes, and the resulting flow of amplifier plate and screen current through R_4 causes operating voltage to be applied to the side-tone oscillator.

Metering

The voltage drop across R_4 is also used to actuate the meter M_1, and the circuit is so arranged that the deflection of the meter will indicate the value of the combined amplifier plate and screen currents. Thus if 50 ma. flows through R_4, the voltage drop across R_4 will be $100 \times 0.050 = 5$ volts, according to Ohm's law. This 5 volts will cause a current to flow through R_9 and the meter. Since the value of R_9 is 10,000 ohms, the current through the meter is $5/10{,}000 = 0.0005$ ampere, or 0.5 ma. So, we know that when the meter reads 0.5 ma., the current flowing through R_4 is 50 ma. Similarly, when the meter reads 0.1 ma., the current through R_4 is 10 ma. When the meter reads full scale (1 ma.), the current through R_4 is 100 ma. In other words, the cathode current (which is the sum of amplifier plate and screen currents, since both of these currents flow in the cathode circuit), is always 100 times the current indicated by the meter.

DANGER! HIGH VOLTAGE!

In some of the equipment described in this booklet the voltage between certain points may run as high as 300 or 400 volts. Since individuals sometimes are killed by coming in contact with ordinary 115-volt home lighting circuits, the beginner must forever be aware of the potential danger attached to *careless* handling of amateur radio equipment—particularly transmitters.

Make it your *first* rule to form the habit never to touch anything behind the panel of a receiver or transmitter without first turning off *all* power. Thousands of amateurs, young and old, work daily with equipment carrying voltages as high as 2000 or 3000 with complete safety. But the operator should never forget for a moment that harmless-appearing gear can and has been lethal in isolated instances when the operator became careless. NEVER TOUCH ANYTHING BEHIND THE PANEL UNTIL YOU ARE CERTAIN THAT ALL POWER HAS BEEN TURNED OFF!

The World Above 50 Megahertz

The frequencies above 50 MHz. have been a fruitful field for the newcomer to amateur radio for many years, and their popularity has multiplied since the advent of the Novice and Technician classes of license. The two most-used ham bands in this part of the radio spectrum are 50.25 to 54 MHz. and 144 to 148 MHz. Of these the Novice may use only the middle portion of the higher band, 145 to 147 MHz. His transmitter must be crystal-controlled, run no more than 75 watts input, and use only telegraphy. The Technician may use the 50-MHz. band, the same portion of the 144-MHz. band as the Novice, and any higher frequency assigned to amateurs. Except for the frequency restriction in the 144-MHz. band, his operating privileges are the same as for holders of more advanced classes of license.

These bands do not often provide the long working ranges that are available much of the time on lower bands, but they do offer unequalled opportunity for reliable interference-free communication over short distances, with moderate power. Even with relatively simple gear, the v.h.f. beginner in fairly open terrain can expect to work out to 50 miles or so consistently, usually without the interference that so often breaks up contacts on lower bands.

V.h.f. techniques are still in their developmental phases, so work here has a special appeal for the experimentally inclined amateur. Complete stations ready

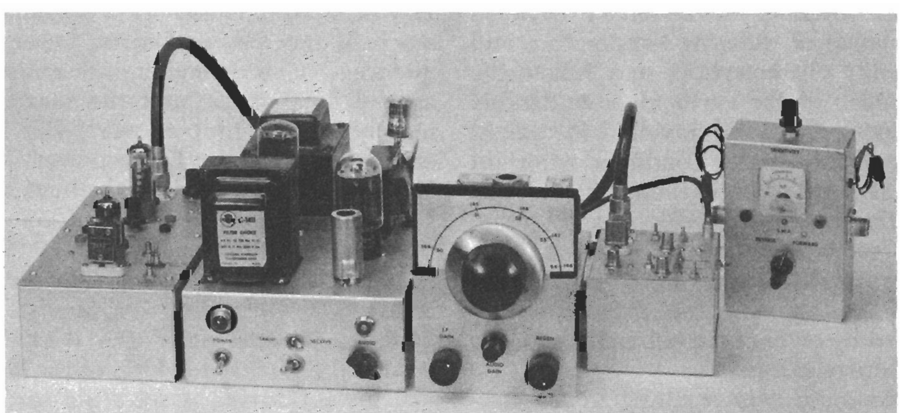


Fig. 5-1 This v.h.f. station, complete except for the antenna, can be built by the v.h.f. beginner. Its construction has been described in detail in *QST* (please see note on page 87 of this booklet), and templates are available to simplify the mechanical work. It is a two-band setup for 50 and 144 MHz., and it gives excellent performance.

to go on the air can be bought, but home construction of equipment is probably more widely done than for lower bands. Antennas are small in size and easy to erect, so many v.h.f. men build their own, and enjoy adjusting them for maximum efficiency. The means by which v.h.f. signals reach distant points are still far from completely understood, and this air of mystery adds spice to the DX that is possible on occasion. The following paragraphs will give the reader some idea of what to expect from v.h.f. and u.h.f. work.

Nature of the Bands Above 50 MHz.

50 to 54 MHz.: This is borderline territory; a v.h.f. band with at least a touch of all varieties of DX found on lower frequencies. Almost anything can happen on 50 MHz. and this variable nature looms large in its appeal to dedicated followers. In reliable day-or-night local range, it is the equal of any amateur frequency, being only slightly affected by conditions that may impair or interrupt communication on lower bands at times. Extension of the reliable range is possible when any of the following are present.

Tropospheric bending associated with readily-observed weather conditions may double or triple normal coverage. V.h.f. waves entering the boundary between air masses of differing temperature and humidity characteristics may follow the curvature of the earth for considerable distances, instead of travelling in straight lines off into space. Conditions are right for this most often in the spring and fall months, but they develop in any season. The early morning and late evening hours are usually favorable, as are periods of stable weather, usually accompanied by higher than normal barometric pressure readings.

Sporadic-E skip resulting from reflection of the 50 MHz. wave by highly-ionized patches in the *E* region of the ionosphere permits work over distances of 400 to 1300 miles. Occasionally "multiple-hop" propagation develops, bringing in signals over distances of 2500 miles or more. Sporadic-*E* propagation, is most common in May, June and July, less frequent in midwinter, and an occasional phenomenon at any season. Until recently it was almost a complete mystery, and even today it is not entirely understood.

Auroral DX is possible during periods of pronounced ionospheric disturbance, which may wipe out communication on lower frequencies. Work is usually over distances of 100 to 600 miles, though up to 1200 may be possible on rare occasions. The signal is reflected from the region of the visible aurora, but the effect often begins in the afternoon hours, before darkness would make a visible display possible. Auroral effects have been observed on the v.h.f. bands as far south as the Gulf States, but they occur most often in Northeastern U. S. A. The phenomenon is very rare in the Southwest. Because the reflection is diffused in nature, any voice or other modulation on the signal is badly distorted, making c.w. the only reliable mode of aurora communication.

Reflection from the F *region of the ionosphere* has been possible on 50 MHz. during the peak years of the last two 11-year sunspot cycles. This is similar to much of the DX worked on lower frequencies. The minimum distance is around 1800 miles, and the maximum may be anything, up to worldwide coverage. Some F-layer DX was worked in 1967 and is expected through about 1970. The period from 1956 to 1959 was marked by phenomenal DX on 50 MHz.

Though most of the communication on 50 MHz. is with voice, c.w. pays off for all kinds of weak-signal DX work. For this reason the first 100 kHz. of the band, 50.0 to 50.1 MHz., is set aside for A-1 emission only.

145 to 147 MHz.: Normal range on this band is very similar to that on 50 MHz., but it is far less subject to ionospheric effects. Sporadic-*E* skip is very rare, and *F*-layer skip is probably impossible. Auroral possibilities are much like 50 MHz., and if there is a pronounced auroral opening on 50 it probably will be observed on 144 as well. Distortion by the aurora is greater on the higher frequency, and voice work during aurora is very rarely possible. Contacts out to 1000 miles or so are fairly common in the areas of the country where visible auroras are a frequent occurrence.

Weather affects this band more than lower frequencies, so the 2-meter man gets more fun out of tropospheric bending than does the 6-meter operator. Tropospheric work with good signals is common at distances up to 300 miles or so, and 500 miles is not rare. The best-equipped stations work up to 1000 miles or more under the most favorable conditions, when stable weather patterns develop over large geographical areas simultaneously. The world tropospheric record is 2540 miles, between the West Coast and Hawaii. The overland record is 1400 miles.

As with 50-MHz. work, weak-signal communication is greatly improved if c.w. is used. The top 100 kHz. of the band, 147.9 to 148 MHz., is set aside for c.w., but a major part of all c.w. work is done near 144 MHz.

220 to 225 MHz.: Propagation on this band is much like that on 144 MHz. Auroral effects are less pronounced, and sporadic-*E* and *F*-layer propagation are unknown. Tropospheric propagation may be even better than on 144 MHz., at times. The California-to-Hawaii path has been covered on this band, and the overland record is about 900 miles. The general level of activity is much lower than on 50 or 144 MHz., though interest is rising.

420 to 450 MHz.: A fine experimental band, in the region where circuit design departs from the conventional coil-and-capacitor techniques and moves into cavities and coaxial lines. Propagation is not unlike 144 and 220 MHz., except for the absence of ionospheric effects. The world record is the same transpacific 2540-mile hop, and contacts between Texas and Florida, up to 1150 miles, have been made in favorable weather conditions. In certain areas there are power restrictions on this band.

Bands Above 1000 MHz.: All amateurs except Novices may use our bands at 1215 to 1300 MHz., 2300 to 2450 MHz., 3500 to 3700 MHz., 5650 to 5925 MHz., 10,000 to 10,500 MHz., 21,000 to 22,000 MHz., and any frequency above 40,000 MHz. All except the last two may be worked with equipment that is within the reach of the average skilled amateur. Most communication is with converted war-surplus gear originally intended for radar or other noncommunications applications. Communication by means of reflection from the moon has been achieved by amateurs, using highly developed gear in the 1215-MHz. band, and this band is becoming of general interest for local communication as well. The frequencies above 20,000 MHz. have been employed in a purely experimental way by amateurs thus far.

The entire spectrum above 1000 MHz. has been little explored for communications purposes, and work throughout the microwave field is a fine opportunity for the technically-qualified amateur.

Getting Started on the V.h.f. Bands

Buy or build? This question confronts every newcomer, and it is likely to stay with him throughout his ham career. You can buy a complete v.h.f. station in one package, ready to go on the air. There are ready-made component parts of a station, such as transmitters, receivers, converters and the like, with which you can assemble a station. You can buy your station in kit form, and assemble and wire it at home. Or you can build the works yourself, from information that has appeared in *The Radio Amateur's V.H.F. Manual*, *QST*, *The Radio Amateur's Handbook*, *Understanding Amateur Radio*, or other amateur publications.

Though buying a complete package is the quick and easy way to get started on a v.h.f. band, and the kit approach may be the least expensive, there is much to be said for the last method. There is no substitute for home construction when it comes to learning your way around with ham equipment. Building all or part of your station, as and when you need it, can give you a setup that meets your own requirements more completely than is likely with ready-made or kit equipment. The result will be *your* station, something that you can describe over the air or show to your friends with a feeling of pride that the fellow who bought his way into the game will never know.

If building your own gear appeals to you, *The Radio Amateur's V.H.F. Manual* is your best source of information. The beginner approach to v.h.f. hamming has also been the subject of many *QST* articles, and they contain a wealth of ideas and detail available from no other source. Many back issues of *QST* can still be obtained from ARRL Headquarters. A bibliography of v.h.f. articles of interest to the newcomer will be sent upon request. In addition, every issue of *QST* for many years back has a department devoted solely to v.h.f. activity. You will find it a great aid in increasing your enjoyment of v.h.f. work.

What kind of equipment? Though v.h.f. gear operates on the same basic principles as that for lower bands, it differs in several practical ways. Most receivers made for amateur use do not cover 50 MHz., and none for lower bands cover 144 MHz. and higher frequencies. The popular packaged v.h.f. stations include a complete receiver, usually for the one band that the transmitter is designed for. By far the most popular receiving system for v.h.f. use is a frequency converter that works with a receiver designed for lower bands.

In its simplest form a converter would be as shown in Fig. 5-2. Reception in the 50-MHz. band is shown, but the same principle applies to all higher frequencies. Signals come from the antenna to a *mixer* stage. Also fed to this mixer is energy on some other frequency, from an oscillator that is part of the converter unit. The oscillator energy beats with the signal, and the resultant *intermediate frequency* (i.f.) is passed on to a communications receiver. The oscillator and i.f. can be any suitable combination for the receiver used. The 7-MHz. setup shown is merely an example.

The injection frequency can be variable, as in the upper part of the diagram. In this case the i.f. (receiver) remains fixed at one spot, which is 7 MHz. in this instance. A fixed injection frequency, usually crystal-controlled, may also be used, as at the bottom. This requires that the receiver be varied over a 4-megacycle range, in this case 7 to 11 MHz., to receive

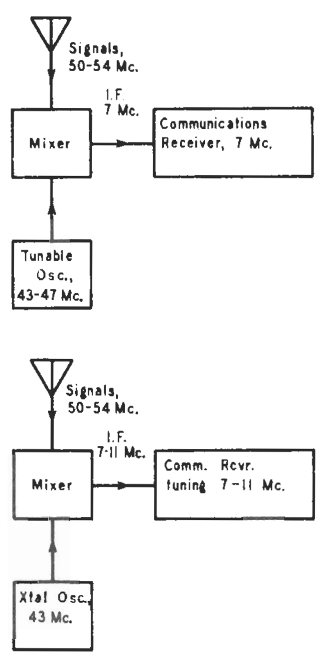


Fig. 5-2 Two methods of providing v.h.f. reception with converters used with communications receivers. At the top is the tunable-oscillator approach, wherein the receiver is left on a single frequency and the converter is tuned across the band. The crystal-controlled converter, lower, is fixed in frequency. The receiver is tuned across the intermediate-frequency range.

across a v.h.f. band. In the first instance you tune the converter; in the latter you tune the receiver. The crystal-controlled converter is the more commonly used, as it provides stability where it is most needed, in the first oscillator. Mechanically the dial on a good communications receiver is likely to be superior to anything you could make yourself, which is another argument in favor of the tunable i.f.

There is usually more to good v.h.f. reception than this. The simple mixer-oscillator setup will work, and it is shown in the 1-tube converter pictured herewith, but most converters employ one or more r.f. amplifier stages ahead of the mixer. The performance of the r.f. amplifier is of great importance in v.h.f. reception. Noise picked up by the antenna limits usable receiver sensitivity on lower frequencies, but this noise drops off rapidly at 50 MHz. and higher. High-gain low-noise amplifiers thus pay off markedly in weak-signal reception, and their worth increases with frequency.

Transmitters for the v.h.f. bands usually employ crystal control. This is required by law for the Novice, and it is recommended for all beginners. Crystal control is the simplest way to achieve the stability that is necessary for effective v.h.f. work, and since crystals are inexpensive the v.h.f. enthusiast usually can afford enough of them to permit him to move around as band conditions may require. Good variable-frequency control is hard to come by, and it is by no means so necessary for effective work as on lower and more crowded frequencies. Crystals are usually at about 6 or 8 MHz., and one or more frequency multiplying stages are used to reach the operating frequency. Direct frequency control at 50 MHz. is possible, but it is not recommended for the beginner.

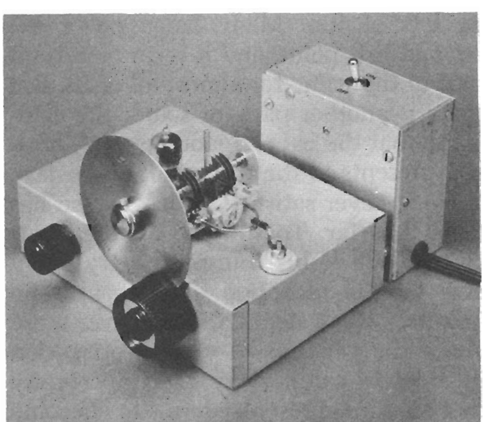


Fig. 5-3 One-tube converter, with 144-MHz. oscillator tuned circuit in place. Selenium rectifier power supply, shown plugged onto rear of the converter, may be omitted if power is taken from the receiver.

Many v.h.f. stations run no more than 8 to 15 watts input. You can do good work with even this low power, and this is the most economical power bracket from the power supply standpoint. It is also practical for a station that must run from a car storage battery, and mobile and portable operation are important in the v.h.f. picture. The next popular power level is around 100 watts. Here supplies that deliver 400 to 600 volts are common, and these, too, are relatively inexpensive. Going to 1000 volts or higher, to run power levels of 200 watts to a kilowatt, entails higher expenditures all along the line, though quite a few advanced v.h.f. enthusiasts would be satisfied with nothing less. Ordinarily, high power is not as much needed as on lower bands, for it is not so often necessary to over-ride other stations on the same frequency in order to get through on a v.h.f. band. A good receiver, a high-gain antenna system, and an awareness of unusual conditions, all may be more important than mere power in achieving outstanding results in v.h.f. work.

Antennas

You can buy good v.h.f. antennas ready-made, but working with antenna design and adjustment can be a fascinating business, so many v.h.f. men still build their own antenna arrays. Generally speaking, the antenna should be as large and high as your finances, construction ability, and local restrictions will permit. The best station in the world will give only mediocre results unless it is hitched to a good antenna system.

Almost all v.h.f. work is done with directional arrays, equipped with rotators designed for the TV trade. The various means of hand-rotating antennas should not be overlooked, as they are usually inexpensive and trouble-free. TV antennas are often used for v.h.f. communication. The popular conical TV array will work after a fashion on any v.h.f. band, and the Yagi types can be modified for amateur use. Channel 6 Yagis, for example, are usually readily cut down for 144-MHz. work. A Channel 2 array needs only a slight extension of the elements to make it work well on 50 MHz. Channel 13 Yagis trim down easily

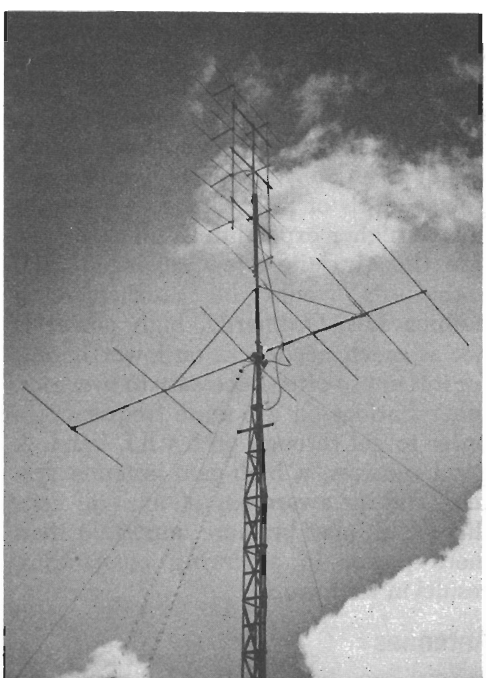


Fig. 5-4 Here are a 6-element long Yagi for 50 Mc. and a 16-element collinear array for 144 Mc., both being all-metal construction. These are mounted on a guyed metal tower, and the open-wire feed lines can be seen coming up from the lower left.

for use on 220, and some u.h.f. TV arrays, notably the bow-tie and corner-reflector types, will work on 420 MHz.

Because transmission line losses are high on the v.h.f. bands it is important to keep the line as short as possible. In using open-wire or other balanced lines it is well to avoid sharp bends and to keep the line at least two inches away from metal towers, rain gutters and the like. Coaxial line can be taped to metallic objects without causing trouble.

Keep the antenna itself well away from, and preferably above, any metallic objects or wires of appreciable size. Indoor antennas seldom work well, as there is rarely enough clearance in all directions to permit their elements to work normally. If you must put a v.h.f. antenna above a metal roof, try to get it at least a half wavelength above the metal, or some multiple of a half wavelength, if it can go higher. For detailed information on v.h.f. antenna design and construction, see *The Radio Amateur's V.H.F. Manual,* the ARRL *Handbook* and *Antenna Book.*

Making the V.h.f. Bands Pay Off

Just getting on the air and chatting with the local gang on a v.h.f. band will be lots of fun. Many hams never get beyond this point, and it is an important part of the game for almost all of us. But there is another part for some: the challenge that the ever-expanding v.h.f. horizon presents to the true v.h.f. enthusiast.

He is never satisfied with what he has done thus far. To squeeze another watt or two out of his transmitter, try every new idea in reception so as to miss no infinitely weak signal, to learn ever more about the vagaries of v.h.f. propagation in order to catch every DX opportunity that nature presents him, to become proficient in the use of all modes of communication and use them to their fullest potential—these are some of the ways by which v.h.f. men have made the world above 50 MHz. the fascinating part of amateur radio that it is today.

Some may feel that all this is straining the point, but fellows who have gone all the way will tell you that v.h.f. hamming, like any other specialized hobby, returns to the participant in proportion to what he puts into it. Their own enthusiasm for the game, ever growing as the years pass and their skills increase, is perhaps the best argument that could be advanced for this point of view.

Chapter 6

The Final Steps

And now it's time to clean up the final odds and ends and become a radio amateur. Let's tackle these items briefly, one by one. Patience, OM or YL! You're on the final steps!

Learning the Code

Learning the code can be a lot of fun, and it's really easy if you approach it properly—that is, think of it in terms of sound. If you think of "dots and dashes" you add an extra step, a useless one, to the process of learning. The International Morse Code is a language in itself, with only two basic sounds—a short, staccato sound, the "dit," and a longer, drawn-out sound, "dah." All the letters, numbers and punctuation marks in the code are made up of combinations of these sounds.

To learn correct spacing, and the relationship between the short and long sounds, practice by speaking a series of dits — dididididididit — and then a string of dahs, smooth and steady, with the smallest of spaces between them. Switch back and forth a few times. You should get four dits in the time taken by one dah and the space which follows it.

Learn the code a few letters at a time, from the chart. It's best to take the letters at random, such as E, T, A, R, I, S, N, M, O, H, D, and so forth, rather than straight down the list. It will go a lot faster if you have someone working with you. With the little code-practice oscillator shown here, you can take turns sending and copying.

In any case, when you know the alphabet, or even part of it, you should try copying signals you hear on your receiver. Regular code practice is transmitted every night by W1AW, the ARRL headquarters station, and at frequent intervals by other amateur stations. Send a stamped, self-addressed envelope to the American Radio Relay League, Newington, Conn., 06111, for an up-to-date schedule of times and frequencies of the various sessions.

Many other hints for learning the code, including groupings of letters for easy learning, practice words and sentences, group instruction, and valuable tips on rhythm in sending can be found in another booklet published by ARRL, *Learning the Radiotelegraph Code.* It sells for fifty cents, and can be purchased at your local radio-parts store, or by mail directly from ARRL headquarters.

The code practice set shown on the next page is a simple audio-frequency oscillator circuit using two transistors and a few inexpensive resistors and capacitors. Except for the Fahnestock-clip connectors for the key and headphones, practically the entire circuit is wired between the soldering lugs of an 8-point terminal strip. Fig. 6-2 shows both the schematic diagram and the actual wiring of the strip. The whole thing, including the 9-volt transistor battery which provides power for the oscillator, is mounted on a small piece of wood. The wooden base can be any scrap you may have handy, as long as

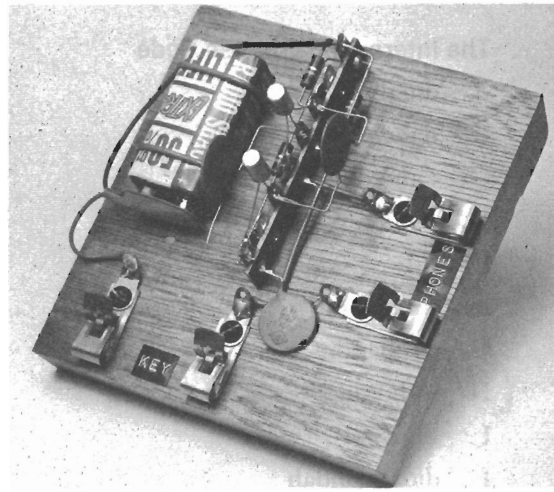
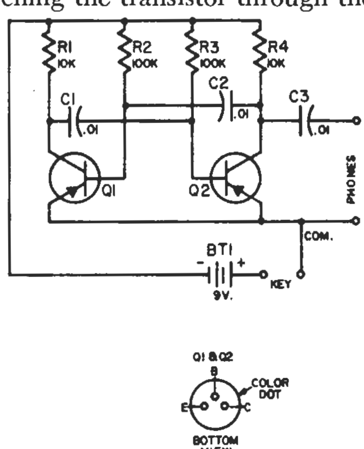


Fig. 6-1 This simple code-practice oscillator can later be used as a keying monitor when installed in the transmitter described earlier in this booklet. Including the battery, the parts will cost about $3.50.

it is large enough to contain the terminal strip, battery, and the connection clips. The terminal strip and Fahnestock connectors are fastened to the base with wood screws, and the battery is held in place by two short pieces of wire which go through holes drilled in the base; the ends of the wires are twisted underneath to hold the battery firmly to the base.

Special care should be taken when soldering the transistor leads to the terminal tie points, since excessive heat reaching the transistor through the leads is likely to damage it. This can be avoided by using a pair of long-nose pliers to hold the transistor lead being soldered, close to the body of the transistor. Other than this, normal care to make good soldered joints is the only requirement.

(When you build your transmitter the terminal strip on which this oscillator is built can be transferred intact to the transmitter chassis, where it becomes a keying monitor. Only a few additional parts are needed, as shown in the transmitter circuit diagram in Chapter 4.)



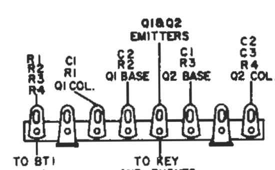


Fig. 6-2 Circuit diagram and wiring layout of the code-practice oscillator. Practically all parts are mounted on the tie-point strip as shown below the circuit.

C_1, C_2, C_3 — 0.01-μf. disk ceramic, 50-volt rating or higher.
BT_1 — 9-volt transistor-radio battery.
Q_1, Q_2 — RCA SK-3003, or almost any inexpensive p-n-p transistor.
R_1, R_4 — 10,000 ohms, ½ watt.
R_2, R_3 — 100,000 ohms, ½ watt.
Additional parts needed: 4 Fahnestock clips, any size large enough to take phone-cord tips; 1 8-terminal tie-point strip (H. H. Smith type 870); plug connector for 9-volt transistor battery; wooden base.

The International Morse Code

A didah
B dahdididit
C dahdidahdit
D dahdidit
E dit
F dididahdit
G dahdahdit
H didididit
I didit
J didahdahdah
K dahdidah
L didahdidit
M dahdah
N dahdit
O dahdahdah
P didahdahdit
Q dahdahdidah
R didahdit
S dididit
T dah
U dididah
V didididah
W didahdah
X dahdididah
Y dahdidahdah
Z dahdahdidit
1 didahdahdahdah
2 dididahdahdah
3 didididahdah
4 dididididah
5 dididididit
6 dahdidididit
7 dahdahdididit
8 dahdahdahdidit
9 dahdahdahdahdit
0 dahdahdahdahdah*
Period didahdidahdidah
Comma dahdahdididahdah
Question Mark dididahdahdidit
Error didididididididit
Double dash ($\overline{BT}$) dahdidididah
Wait ($\overline{AS}$) didahdididit
End of message didahdidahdit
Invitation to transmit dahdidah
End of work ($\overline{SK}$) dididididahdidah

*The numeral zero is usually written Ø to distinguish it from capital O.

Licenses

As we have said before, you must have a government license before you can go on the air with your transmitter. The amateur license is really two licenses in one: one for the station, the other a personal amateur operator license. Both are required by law, and are issued in the U. S. by the Federal Communications Commission. The operator license requires some study of elementary theory and the U. S. radio laws and regulations as they apply to amateur stations. This knowledge is not difficult to acquire, however, and if you start to study at about the same time you start construction of the station, you should be adequately prepared by the time the station is finished.

At this point we may say that only citizens and nationals of the United States are eligible for either station or operator licenses. However, licensed amateurs of certain countries may be able to operate here under a reciprocal operating agreement. (See *License Manual* for latest lists.)

The station portion of the license is your station's official "registration"; it licenses your transmitter for operation in the amateur bands and designates the call to be used. It is issued after filling out a form provided for the purpose—no examination is given in connection with it. However, station authorizations are issued only to persons who also qualify for operator licenses. Actually, both operator and station authorizations are combined in a single card license. The operator portion of the license is your personal authorization to operate an amateur station—not only your own station but any amateur station within the privileges of both operator and station license.

There are at present six classes of amateur licenses—Amateur Extra, Advanced, General, Conditional, Novice and Technician. Advanced and Extra Class are licenses which are related to special experience requirements and separate examinations, so you as a newcomer will not now be interested.

General Class is the "standard" amateur license. It conveys privileges on parts of every amateur band. Conditional Class authorizes the same privileges, except that it is issued to persons who take the examination by mail whereas General Class is issued to those who take the examination before an FCC representative. Persons living more than 175 miles from one of the basic examining centers designated by FCC* are permitted to take the examination by mail and have the code test given them, under oath, by an already-licensed operator. For either license, you must pass an examination including a code test at 13 words per minute and a written test on radio fundamentals (basic theory and practice) and regulations governing amateur operation. There are about 50 questions; approximately two-thirds are on technical subjects, while the remainder concern themselves with the United States radio laws and the amateur regulations. These licenses run for five-year terms and may be renewed upon showing of amateur activity.

The Technician Class license requires the standard written examination but a code test of only 5 w.p.m. It authorizes operation only in 50.1–54 MHz., 145–147 MHz. and above 220 MHz. It is available only by the mail procedure mentioned above for the Conditional Class license, and is not normally given at FCC offices.

The Novice Class is the simplest stepping-stone to amateur radio and will therefore be of primary interest to you. It requires the slower code test of 5 w.p.m., and only a very simple written quiz. At the same time it conveys restricted privileges: use of c.w. (code) only in 3700–3750 kHz., 7150–7200 kHz., 21,100–21,250 kHz., and 145 to 147 MHz. Maximum power permitted is 75 watts, and the frequency must be crystal-controlled. Provided you select a crystal in the range 3700–3750 kHz., or 7150–7200 kHz., therefore, the simple transmitter described earlier in this booklet will be ideal for operation as a Novice. And simple 145-MHz. gear can be built and is similarly ideal for a Novice who wishes to use that band as a starter. The Novice Class is therefore an excellent means of entry into amateur radio, since it has a very minimum of requirements and yet adequate privileges for you to sample the various kinds of activities that take place in the amateur bands. The Novice examination, like that for Technician, is available only through the mail procedure, no matter where the applicant lives.

However, the Novice Class license will be good for only two years *and is not continuously renewable.* So, if you aim for the Novice Class as a start, remember it's only a stepping stone, and keep in mind that you'll want to work toward the General Class (or Conditional Class if you live more than 175 miles from an examining point) as soon as you get on the air as a Novice.

Although the examination deals with elementary radio, it is necessary to engage in some study for it. If you will carry out this study in conjunction with the constructing of your apparatus, you

* See the *License Manual* for the latest list.

will find that your reading helps you to understand the operation of your sets and your construction of the equipment helps you to absorb the new knowledge. You are going to obtain an immense amount of enjoyment from amateur radio; it is well worth learning about. In the first place, if you do not possess a fair knowledge of elementary electricity, such as is taught in a high school physics course, we suggest that you obtain from your local library a good elementary electrical textbook. That is the groundwork for all radio theory. Then you should study the "Fundamentals" chapter of this booklet, which deals with radio itself in equally simple fashion, explaining elementary radio theory and the functioning of simple practical apparatus. We also would recommend that you obtain a copy of *The Radio Amateur's Handbook,* an American Radio Relay League publication which is a complete manual of amateur electrical and radio theory, construction and operation. While you will eventually find a personal copy of this book indispensable, you will probably be able to borrow a copy or find it at your local public library. In the U. S. A., it may be obtained at a local radio distributor's store or from the League for $4.00, postpaid.

The Radio Amateur's License Manual explains in detail the procedure in applying for licenses, lists many questions similar to those that will be asked in the examination and gives their correct answers, and includes the full text of the amateur regulations and pertinent portions of the radio law. It is really indispensable to the new applicant. The current *License Manual* may be obtained at a local radio distributor's store or from the ARRL at Newington, Conn., 06111, for $1.00.

Canada

Canadian amateurs are regulated by the Department of Communications, Ottawa. There are two classes of operator certificates, the Amateur grade and the Advanced Amateur grade. Examinations include code sending and receiving (10 w.p.m. for Amateur, 15 for Advanced), diagrams, oral test and written test. There is an annual fee of $10.00 for the station license. The minimum age is 15 years. Excerpts of the radio law and other information of value to prospective Canadian amateurs may be obtained from the Department of Communications, Ottawa, Ontario, or from its regional offices. The *Radio Amateur Licensing Handbook* is a good reference work on Canadian matters and may be obtained for $2.50 in radio stores or from R. Mack and Co. Ltd., 1485 S.W. Marine Dr., Vancouver 14, B. C., Canada.

Arranging the Station

It is helpful to arrange the station neatly and to keep paper, pencils, the log book, etc., where they are always handy. Furthermore, it is as easy to make a shipshape job of the station as to have it look "haywire." You do not want to have to apologize for the appearance of your equipment.

The operating table should be as roomy as space permits. Place the receiver at a distance back from the front edge that will permit you to operate it with comfort. The transmitter, which requires readjustment only when you change frequency, may be placed farther back on the table if desired. It is advisable to space the receiving and transmitting units at least a foot apart. Place the key in the position where it can be handled most comfortably.

If cables are provided for the power supplies, power units may be placed on a shelf or on the floor under the table. Make sure, however, that they are not within easy reach of your feet.

Since the antenna feed-line wires probably will be brought in at the window as a convenience, place the table as close to the window as conditions permit.

While the 300-ohm line for the v.h.f. antenna may simply be brought directly in under or over a window sash, the simplest way of bringing an open feed line in to the transmitter is through medium-size feed-through insulators set in a strip of wood. This strip should be a couple of inches wide and only slightly shorter than the width of the window sash, so that it may be slipped in place in the window frame, either over the top sash or under the bottom sash. When the window is closed against the strip, there will be only a slight overlap of the sashes.

When you have the board in place, cut enough wire off the feed line to reach from the transmitter output terminals to the inside terminals of the feed-through insulators. Then attach the feed line itself to the outside terminals of the insulators. (The lengths shown in the table include the wire inside the station.)

When operating at the lower frequencies, it is common practice to use a separate antenna for receiving, not only because it is more convenient but also because it will permit you to change back and forth between transmitting and receiving with a minimum loss of time. You can start transmitting immediately after the station you are working signs off, without the need to throw switches. Good results can be expected with a single wire anywhere between 25 and 150 feet long, indoors or outside. The longer outside antenna may give somewhat better results (see page 60), but you should hear plenty of strong signals on a wire running around the picture molding, or even laid across the floor if a better antenna isn't possible. If the separate antenna is put up outside, it should be placed as far away from the transmitting antenna as practical and run as near at right angles to the transmitting antenna as possible.

The 80- and 40-meter transmitting antenna will, of course, make an excellent receiving antenna. To use the antenna for both purposes, it will be necessary to provide a switch. An ordinary porcelain-base double-pole double-throw knife switch is suitable. The feed-line wires are brought to the two central terminals of the switch instead of to the transmitter. One pair of end terminals should be wired to the receiver input terminals, while the other end terminals connect to the transmitter output terminals.

If a grounded Marconi-type antenna system is used for 80- and 40-meter work, the ground wire should run as directly as possible to a water pipe. Special clamps for connecting to water pipes are available. With a grounded antenna, only the single wire need be switched for receiving.

A properly grounded antenna should not constitute a lightning hazard. Fig. 44 shows a simple system for grounding the antenna when it is not in use. The length of feedline between the switch and the transmitter should be included in the length B mentioned in the earlier section discussing the antenna. The switch should be mounted close to the point where the feedline enters the station. If the feedline is brought in through a window, the window sill is a good spot for the switch. The ground wire should run directly downward in a straight line to the grounding rod.

Getting On the Air

And now, after you have built your receiver and transmitter and put them in operating condition, have obtained your licenses, and have learned something of the customs and practices of operating, you are ready to take your final step—the step for which you have worked through all these weeks—your first actual operation on the air as an amateur.

You sit down some evening before your receiver and light up the tubes. Tuning in on the 3700-kHz. band, let us say, you hear some station (not too far away!) sending a "CQ" and finally signing his own call. You turn on your transmitter, and call that station—just a bit

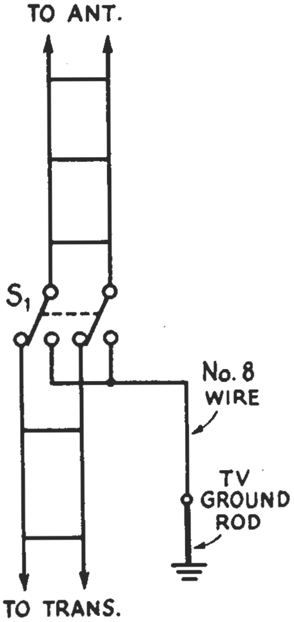


Fig. 6-2 A simple system for grounding the antenna for lightning protection. S_1 is a d.p.d.t. porcelain knife switch.

shakily, no doubt. After making a reasonably long call, you sign off and listen for him again. Perhaps he does not come back. Too bad!—but don't be discouraged. While it has happened that amateurs have worked the first station they ever called, this experience is not the rule. Try again. Perhaps you will still fail to "connect," and you may call all that evening without working anybody.

But you keep on trying the next night, and soon there comes a time when you enjoy the never-to-be-forgotten thrill of hearing the other fellow call your station. And then you talk with him, learn where he is, and hear him tell you how good your signal is at his "shack" and perhaps make a schedule to call him again the next night for another talk. So you start to learn the thrill and pleasure that come from talking to another fellow-being hundreds (even thousands) of miles away, from the privacy of your own home, and with apparatus that you have constructed with your own hands. It is a thrill that never wears off.

Oh yes—don't forget to keep a log of your station operation. For one thing, the United States amateur regulations require you to do this, but aside from that every worthwhile amateur keeps a neat log as a matter of pride. Your log should record all calls made by the transmitter, calls of station worked, time, frequency band and power of your transmitter, and the name of the operator.

You are now a full-fledged amateur, and ready to take your place in the amateur ranks. Do not try to hurry matters in building your station or operating it. Be a gentleman on the air and don't be afraid to admit that you are a beginner. If someone sends too fast for you, tell him so—don't give some lame excuse such as "QRM" or "QRN" for having missed some of his remarks. A genial request to send slower will get the desired result, and those you are working will think more of you for it.

The American Radio Relay League, at Newington, Conn., 06111, which publishes this pamphlet, is a society of and for amateurs, and it will be more than glad to help you out with your problems. It may be that, later, you will wish to become a member of the League. Most active amateurs are members. Station ownership is not necessary to membership—you have only to be interested in amateur radio. Dues are $6.50 a year in Canada and the U. S. (foreign $7.00), and include a year's subscription to the monthly magazine *QST*, often referred to as the "amateur's bible." Every amateur reads *QST;* each month's issue is filled with information on the latest types of receivers and transmitters, and news from all over the country. If you cannot obtain it from your local radio store, a sample copy may be obtained for 75 cents from the ARRL. We also invite you to send for a copy of *The Radio Amateur's Operating Manual* ($1.50) or our free booklet *Operating an Amateur Radio Station.*

Abbreviations Commonly Used for Technical Terms

a.c.—alternating current
a.f.—audio frequency
a.f.c.—automatic frequency control
a.f.s.k.—audio frequency-shift keying
a.g.c.—automatic gain control
a.l.c.—automatic load control
a.m.—amplitude modulation
a.n.l.—automatic noise limiter
a.v.c.—automatic volume control
b.f.o.—beat-frequency oscillator
c.f.m.—cubic feet per minute
c.o.—crystal oscillator
c.p.s.—cycles per second
c.r.—cathode ray
c.r.t.—cathode-ray tube
c.t.—center tap
c.w.—continuous wave (telegraphy)
d.c.—direct current
d.f.—direction finder
d.p.s.t.—double-pole single-throw
d.p.d.t.—double-pole double-throw
d.s.b.—double sideband
e.c.o.—electron-coupled oscillator
e.m.f.—electromotive force (voltage)
f.d.—frequency doubler
f.m.—frequency modulation
f.s.—field strength
f.s.k.—frequency-shift keying
g.d.o.—grid-dip oscillator
h.f.—high frequency
h.t.—high tension
h.v.—high voltage
i.d.—inside diameter
i.f.—intermediate frequency
l.f.—low frequency
l.o.—local oscillator
l.s.b.—lower sideband
m.f.—medium frequency
m.g.—motor-generator
m.o.—master oscillator
n.b.f.m.—narrow-band frequency modulation
n.c.—normally closed; no connection
n.o.—normally open
o.d.—outside diameter
p.a.—power amplifier
p.e.p.—peak envelope power
p.i.v.—peak inverse voltage
p.o.—power output
p.p.—push-pull
p.s.—power supply
r.f.—radio frequency
r.m.s.—root-mean-square (effective) value
RTTY—radioteletype
s.b.—sideband
s.e.o.—self-excited oscillator
s.f.—standard frequency
s.h.f.—superhigh frequency
s.l.c.—straight-line capacitance
s.l.f.—straight-line frequency
s.n.r.—signal-to-noise ratio
s.p.s.t.—single-pole single-throw
s.p.d.t.—single-pole double-throw
s.s.b.—single sideband
s.w.—short-wave
s.w.r.—standing-wave ratio
t.r.—transmit-receive
TV—television
u.h.f.—ultrahigh frequency
u.s.b.—upper sideband
v.c.—voice coil
v.f.o.—variable-frequency oscillator
v.g.—voltage gain
v.h.f.—very high frequency
v.l.f.—very low frequency
v.o.m.—volt-ohm-milliammeter
v.p.—velocity of propagation
VR—voltage-regulator
v.s.w.r.—voltage standing-wave ratio
v.t.v.m.—vacuum-tube voltmeter
v.x.o.—variable crystal oscillator
VOX—voice-operated control
w.v.—working voltage
w.w.—wire-wound

Metric Prefixes Used in Radio Work

Name	*Abbreviation*	*Multiplier*
kilo	k	10^3 (1000)
Mega	M	10^6 (1,000,000)
Giga	G	10^9 (1,000,000,000)
milli	m	10^{-3} (1/1000)
micro	μ	10^{-6} (1/1,000,000)
micromicro / pico	$\mu\mu$	10^{-12} (1/1,000,000 × 1/1,000,000)

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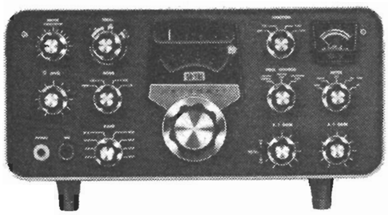
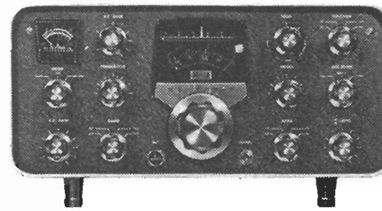
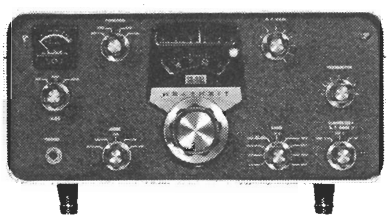


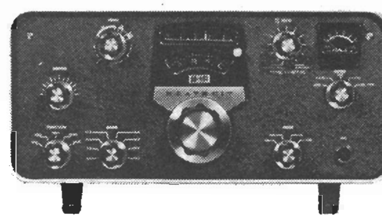
SB-101 80 Through 10 Meter SSB Transceiver . . . 180 watts PEP SSB, 170 watts CW. Front panel control for SSB or CW selectivity. Provisions for external LMO. Features USB/LSB & CW. PTT & VOX. Fixed or mobile optional power supplies. Unmatched engineering & design.
Kit SB-101, 23 lbs. **$370.00***



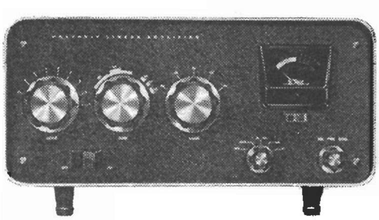
SB-110A 6-Meter SSB Transceiver . . . puts the famous Heath SB-Series on "6". 180 watts PEP input SSB . . . 150 watts CW — with single-knob linear tuning, 1 kHz dial calibration, and the ultimate in stability.
Kit SB-110A, 23 lbs. **$299.00***



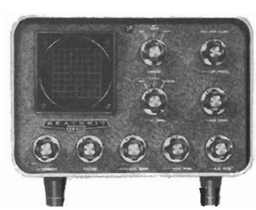
SB-301 Amateur Band Receiver . . . SSB, AM, CW, and RTTY reception on 80 through 10 meters +15 MHz WWV reception. Tunes 6 & 2 meters with SBA-300-3 and SBA-300-4 plug-in converters.
Kit SB-301, 25 lbs. (less speaker) **$270.00***



SB-401 Amateur Band SSB Transmitter . . . 180 watts PEP SSB, 170 watts CW on 80 through 10 meters. Operates "Transceive" with SB-301 — requires SBA-401-1 crystal pack for independent operation.
Kit SB-401, 36 lbs. **$295.00***
SBA-401-1 crystal pack, 1 lb. **$29.95***



SB-200 KW SSB Linear Amplifier . . . 1200 watts PEP input SSB, 1000 watts CW on 80 through 10 meters. Built-in antenna relay, SWR meter, and power supply. Can be driven by most popular SSB transmitters (100 watts nominal output).
Kit SB-200, 41 lbs. **$220.00***



SB-610 Signal Monitor Scope . . . operates with transmitters on 160 through 6 meters at power levels from 15 watts through 1 kw. Shows transmitted envelope. Operates with receiver IF's up to 6 MHz, showing received signal waveforms. Spots over modulation, etc.
Kit SB-610, 14 lbs. **$79.95***

SB-220 2-kW PEP Linear Amplifier for a really big signal on 80-10. Uses a pair of rugged, dependable Eimac 3-500Z's. Double shielded for TVI protection. Continuous monitor of Ip, plus switch-selected monitor of Rel Pwr, Ep & Ig. The world's best value in a 2-kW Linear Amplifier.
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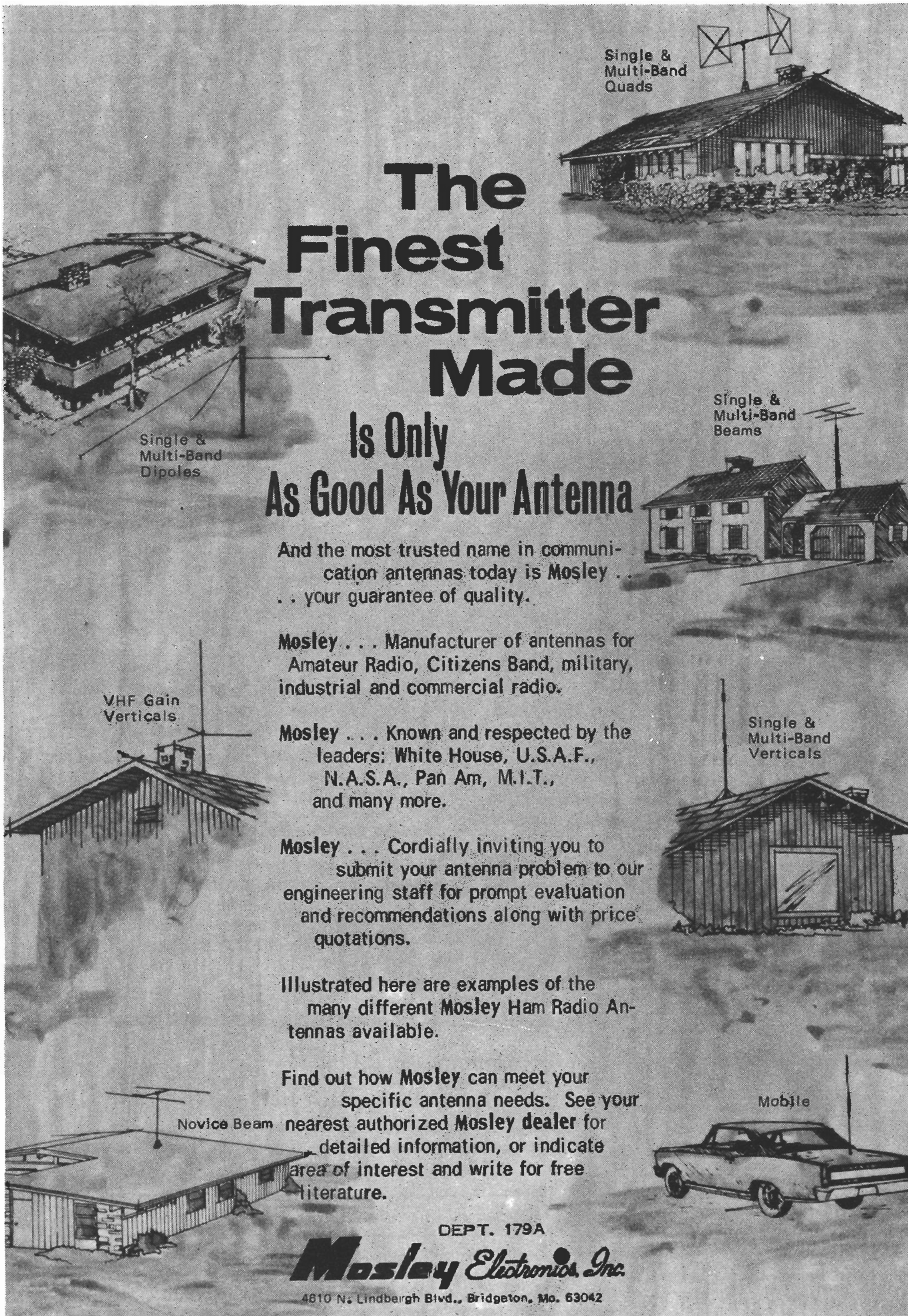

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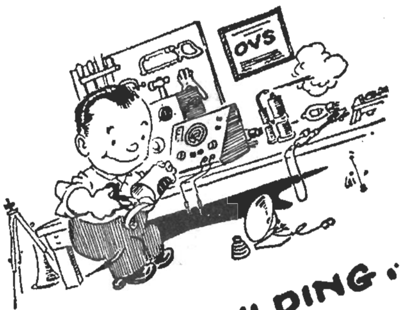
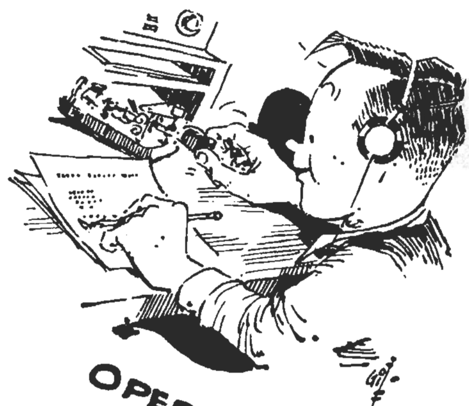
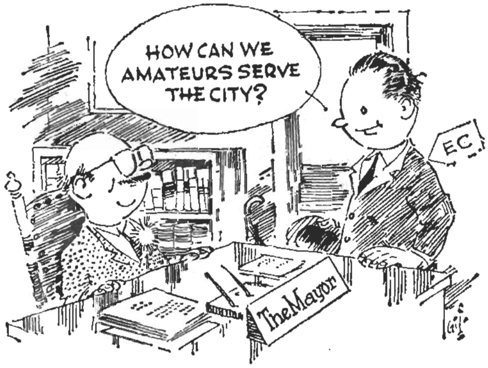


BUILDING...



OPERATING...



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