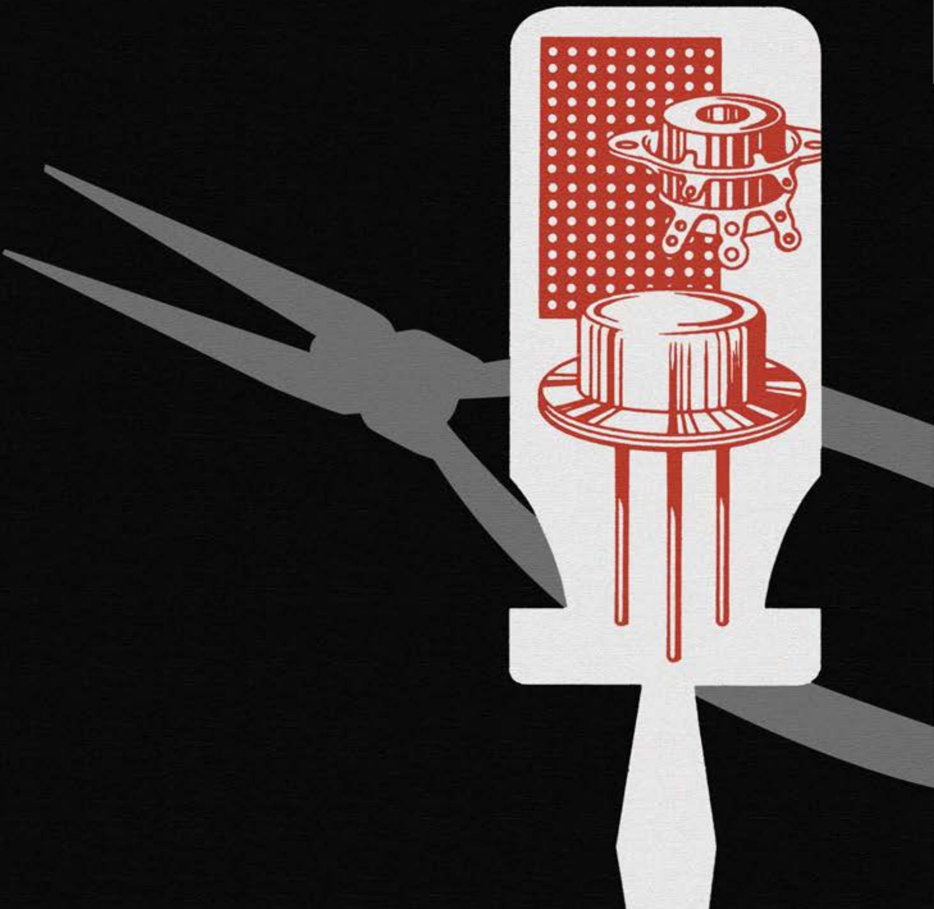
Howard W. Sams PUBLICATION

20670

how to build ELECTRONICS PROJECTS



by John Potter Shields

How to Build Electronics Projects

by

John Potter Shields

HOWARD W. SAMS & CO., INC.
THE BOBBS-MERRILL CO., INC.
INDIANAPOLIS • KANSAS CITY • NEW YORK

FIRST EDITION

THIRD PRINTING—1973

Library of Congress Catalog Card Number: 68-58089

Preface

This book provides an in-depth description of the various commonly used methods of constructing electronic projects. In the pages that follow, you learn the proper method of circuit layout, metal chassis and panel layout, and drilling and punching. The various types of tools used in electronic project construction and their proper use are thoroughly covered.

Electronic components, such as resistors, capacitors, transformers, coils, etc., and their characteristics are described as an aid to project construction. The physical representation of many components in common use, though not ordinarily employed in breadboarding, are presented in Chapter 3.

A chapter is devoted to the rather specialized construction techniques required for semiconductor circuit projects. Another chapter describes the proper methods of etched circuit board preparation, construction, and circuit layout.

Throughout the book, attention is given to the tools, hardware, components, and accessories (such as racks and cabinets) that make electronic project construction easier. Several tools that the novice project builder may not be familiar with (such as automatic wire strippers, chassis punches, and circle cutter) are illustrated.

A well regulated power supply is essential when experimenting with electronic circuits. Both the vacuum tube and semiconductor types are covered. A description of how these circuits function, as well as the physical layout and schematic diagrams, is presented in Chapter 4.

A wide variety of integrated circuits, at a reasonable cost, are available to the experimenter. Their physical and electrical characteristics, and the proper technique of using these units in breadboard circuits are covered in the last chapter.

JOHN POTTER SHIELDS

Contents

CHAPTER 6

CHAPTER 1

Basic Types of Electronic Construction

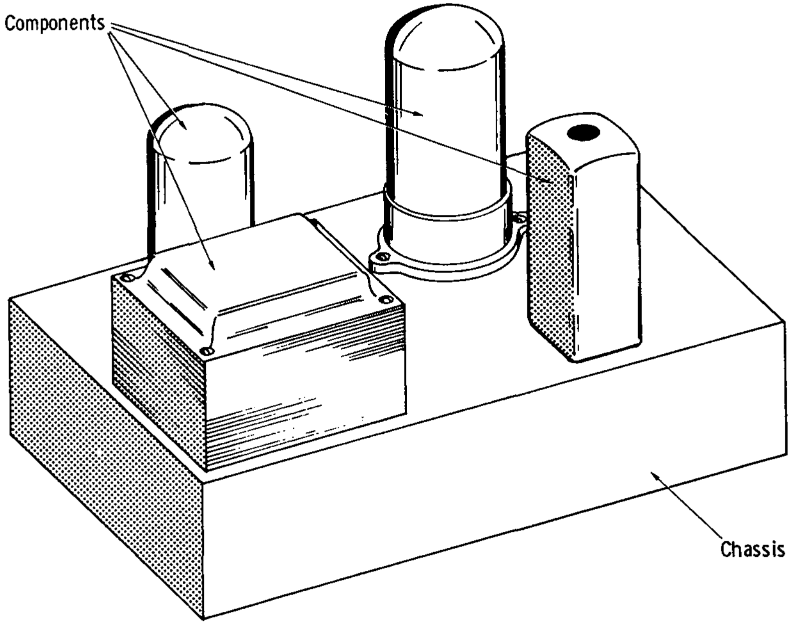
In this chapter, we will examine the various forms of electronic construction. The actual type of construction, of course, depends on the particular piece of equipment. For example, if a project is only in the developmental stage, a technique known as "breadboarding" will be used in its construction. This type of construction permits the easy connection and disconnection of the projected circuit components to help the experimenter determine the proper components for the best circuit performance.

On the other hand, if the correct values of the circuit are known, a more permanent type of construction, such as chassis or etched-circuit is employed.

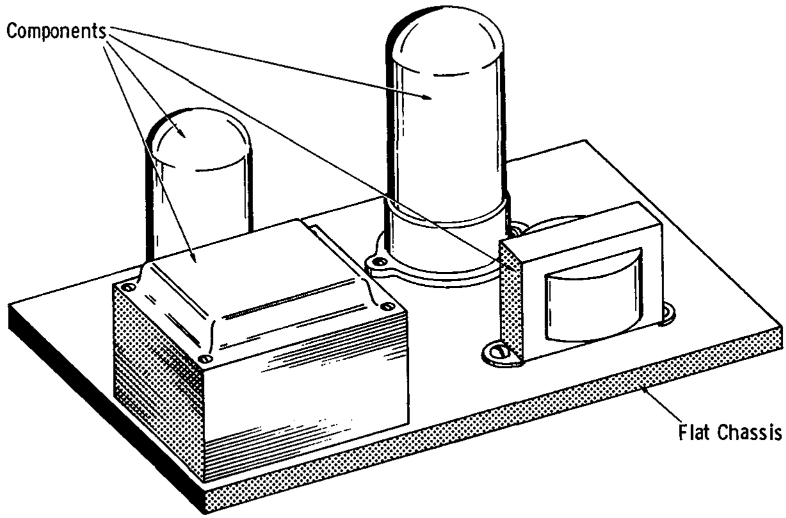
THE METAL CHASSIS

Perhaps the most conventional of all types of electronic construction makes use of the metal chassis. The circuit components—tubes, transformers, potentiometers, etc.—are mounted on the top surfaces of the chassis as shown in Fig. 1-1A. Connections among the various components are made on the underside of the chassis. Sockets are used to make connections to the tube elements.

Metal chassis are available to the home project builder in a number of sizes and shapes. Typical chassis sizes of



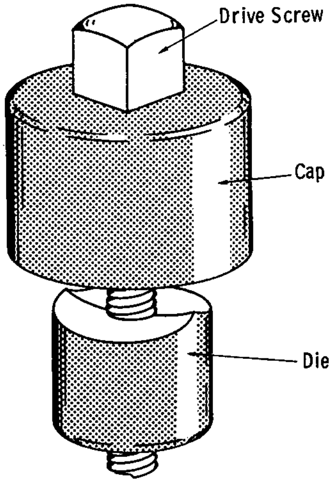
(A) Chassis and components.



(B) Flat chassis.

Fig. 1-1. Metal chassis.

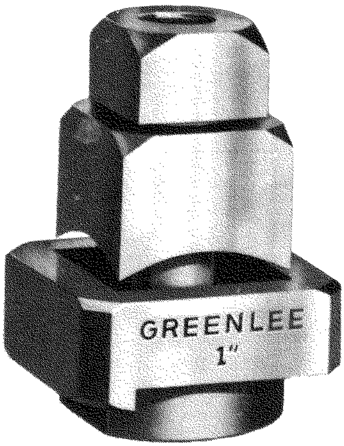
this particular type range from 4″ × 6″ × 3″ to 13″ × 17″ × 3″. They are available in steel or aluminum (which is much easier to cut and drill with the hand tools commonly found in the home workshop). A flat chassis is shown in Fig. 1-1B.



(A) Pictorial representation of a punch.

Courtesy Greenlee Tool Co.

(B) Round punch.



Courtesy Greenlee Tool Co.

(C) Square punch.

Fig. 1-2. Chassis punches.

Metal Chassis Preparation

The metal chassis used in commercially produced electronic equipment is machine punched for the required holes for components. This method is not practical for the average home project constructor, but there are inexpensive hand tools that will make the job relatively easy.

For cutting out large holes, such as those required for tube sockets, the simplest approach is to use punches, as shown in Fig. 1-2. In operation, a hole is first drilled in the chassis. Next, the punch's drive screw is inserted through the hole with its attached cap (see Fig. 1-3), and the drive screw is tightened with a wrench. This draws the tap up through the chassis, neatly cutting a clean burr-free hole.

There are chassis punches that can cut out round, square, "D", double "D", and keyhole openings. Punch sizes range from ½ inch to 3 inches for the round punches; ½ inch to 1 inch for the square punches; ½ inch to ⅝ inch

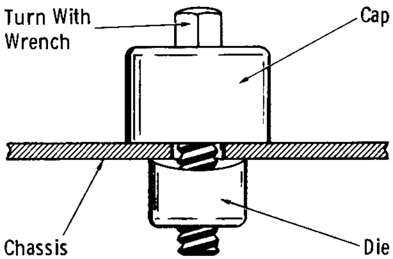


Fig. 1-3. Operation of a chassis punch.

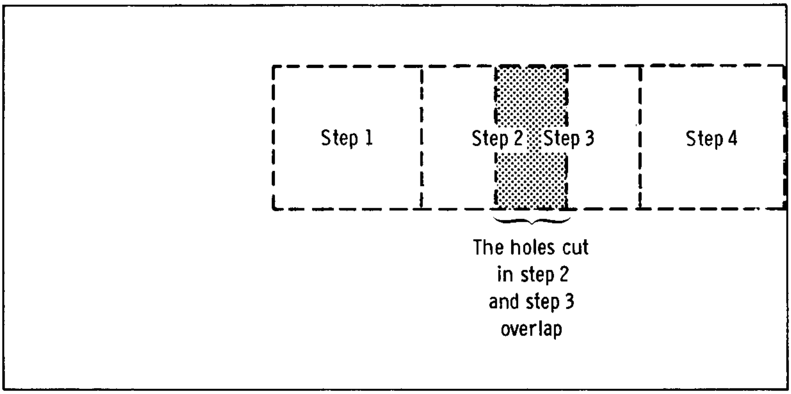


Fig. 1-4. Successive holes with square chassis punch.

for the "D" punches; $1\frac{1}{8}$ inches to $1\frac{5}{8}$ inches for double "D", and $\frac{15}{32}$ inch to $1\frac{24}{64}$ inches for the keynote punches.

The square punch can make either square or rectangular holes. Successive punches are made until the desired hole size is obtained (see Fig. 1-4).

While chassis punches are convenient, they are limited in that a separate punch is required for each hole size.

The circle cutter makes possible the cutting of any desired size hole within its diameter limitation. There are cutters available which will make holes from $\frac{1}{2}$ to 5 inches or more in diameter.

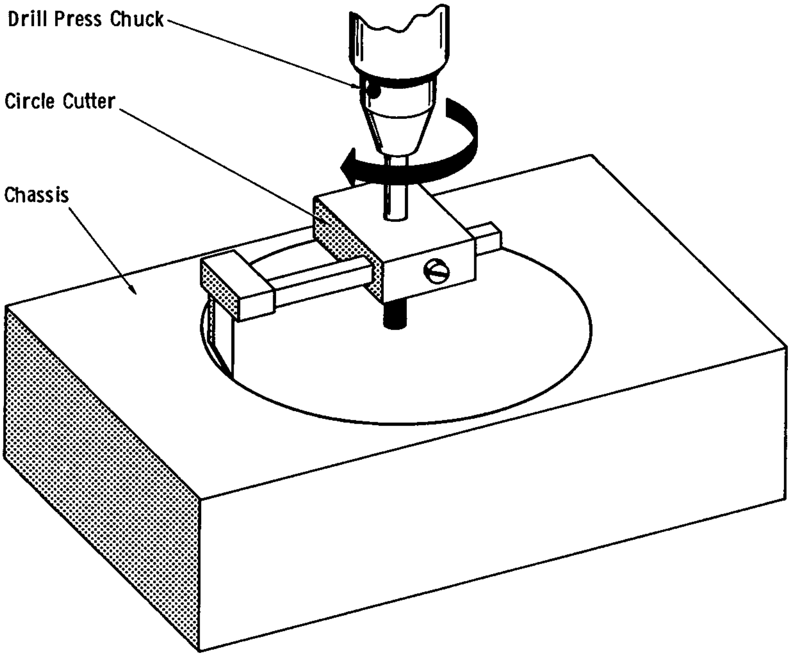
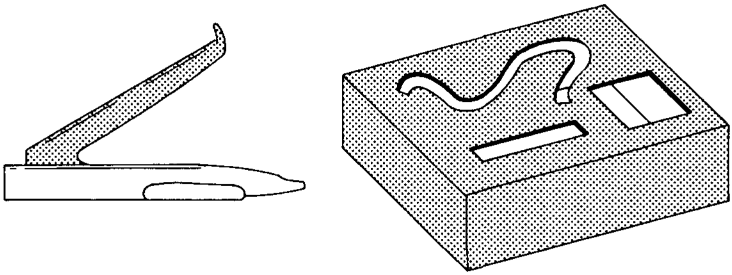


Fig. 1-5. Operation of a circle cutter.

As shown in Fig. 1-5, the shank of the cutter is placed in the chuck of a drill press or hand drill (preferably the former). The distance between the pilot drill and cutter is set for one-half the diameter (radius) of the desired hole. As the cutter is rotated by the drill, the cutting arm rotates, driving the cutting tip gradually through the chassis metal. Compared to the chassis punch, the circle cutter has the advantage in that it can be easily adjusted to cut more than just one hole size. Smaller chassis holes ($1/2$ inch or less) are easily cut with twist drills.

When the circle cutter is used, the hand power drill or drill press should be operated at a relatively low speed—1200 rpm or less. Excessive speed will cause excessive heating, with faster wear of the cutting blade. It is a good idea to lubricate the cutting edge of the blade, perhaps with Vaseline. Finally, be certain that the cutting blade adjusting set screw is securely tightened so that the cutting blade will not loosen and be thrown (due to centrifugal force) when the cutter is turning.

A handy gadget which makes the cutting of odd-size holes in a chassis easy, is a nibbling tool. Fig. 1-6A is a picture of the nibbling tool, while Fig. 1-6B illustrates a few of the shapes that the nibbler tool is capable of cutting. The nibbling tool will cut up to $1/16$-inch aluminum, copper, or plastic.



(A) Nibbling tool.

(B) Nibbling tool cutting capability.

Fig. 1-6. Nibbling tool and capability.

MISCELLANEOUS TOOLS

Aside from the basic tools described previously, there are a number of tools available which, while not essential, make projects much easier and can save considerable time.

Fig. 1-7 shows a set of nut drivers that are very handy for tightening nuts in hard-to-reach places where the use of pliers or conventional wrenches is impossible. These nut

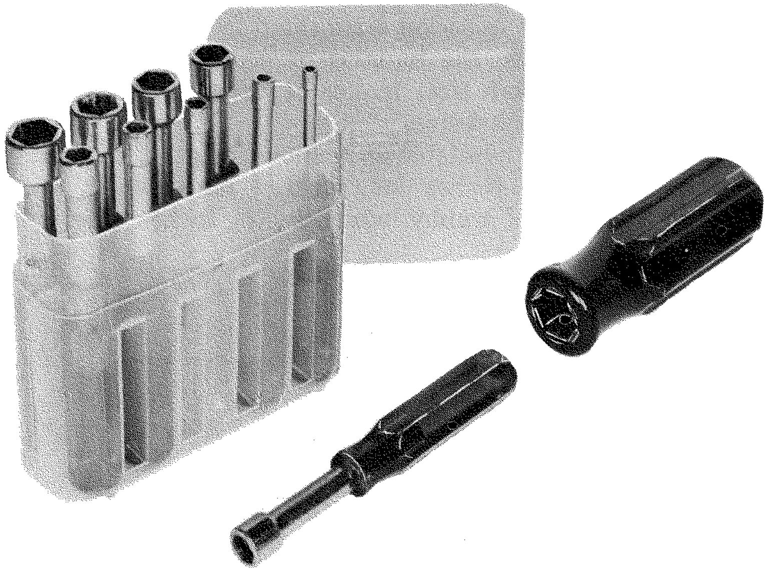


Fig. 1-7. Nut driver set.

Fig. 1-8. Screw holding screwdriver.

drivers are available in socket sizes ranging from $\frac{3}{16}$ inch to $\frac{3}{4}$ inch. Color-coding the handles of socket wrenches according to the socket size, makes it easy to select at a glance the desired socket size.

Nut drivers are available in various lengths, including regular, which is 6-inches long; extra long, which is 9 inches in length; and stubby, which is $3\frac{1}{4}$ inches long.

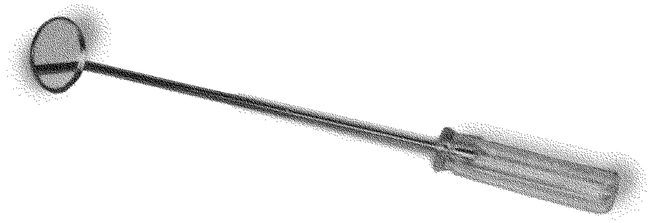


Fig. 1-9. Inspection mirror.

Screw-holding screwdrivers are invaluable for placing screws in hard-to-reach spots that are too cramped for setting the screw in place by fingers or a pair of pliers. Fig. 1-8 shows a typical screw-holding screwdriver.

An inspection mirror (Fig. 1-9) may be obtained with either a plastic or metal handle, and is a real asset in the inspection of "blind spots," such as the underside of tube socket lugs, terminal strips, etc.

Fig. 1-10 shows two types of tweezers that can be very helpful in handling small parts. The tweezers shown in Fig. 1-10B are of the holding type that lightly grasp the object.

(A) Conventional type tweezers.

(B) Holding type tweezers.

Fig. 1-10. Tweezers.

This type of construction, which was originated by the telephone companies, is often employed by radio amateurs when they build their gear. Rack and panel construction permits neat vertical "stacking" of a number of electronic subassemblies. The radio amateur finds this type of construction handy for mounting such subassemblies as a speech amplifier, modulator, power supply, driver, and final rf amplifier.

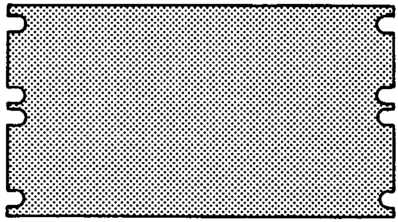


Fig. 1-11. Relay rack panel.

The standard relay rack width is 19 inches. Panel heights range from 1.75 inches to 21 inches. Fig. 1-11 shows a typical rack panel. Note that the edges of the panel are notched to allow for mounting screws.

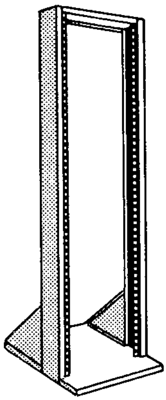


Fig. 1-12. Open relay rack.

Rack panels are available in either steel or aluminum. Panel thickness may be either $\frac{1}{8}$ inch or $\frac{3}{16}$ inch.

Fig. 1-12 shows a typical open relay rack without panels. This type of relay rack is useful when ready access to components is desired.

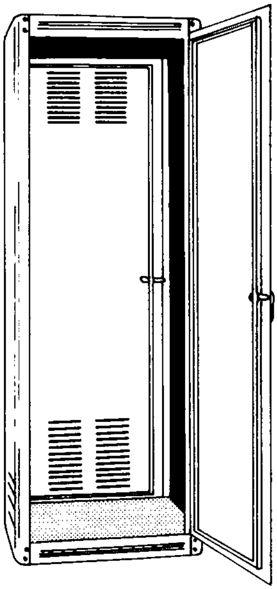


Fig. 1-13. Enclosed relay rack.

Fig. 1-13 illustrates an enclosed relay rack, which gives maximum protection to components.

Miscellaneous Enclosures

A number of other types of enclosures are available to the constructor. For example, Fig. 1-14 shows a two-piece enclosure commonly called a "minibox." This is useful for enclosing projects ranging from small preamplifiers to test equipment.

Utility cabinets, such as shown in Fig. 1-15, are handy for enclosing test equipment, etc.

Amplifier foundations (Fig. 1-16) are also available. Note the perforated top which provides adequate ventilation for circuit tubes and components.

Meter cases, such as those in Fig. 1-17 permit the easy mounting of panel meters. This method of meter housing protects the rather delicate meter movement.

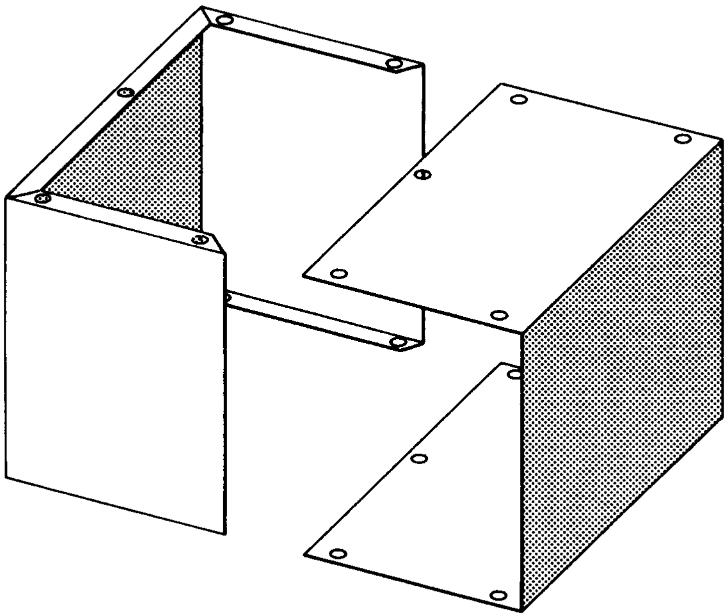


Fig. 1-14. "Minibox" enclosure.

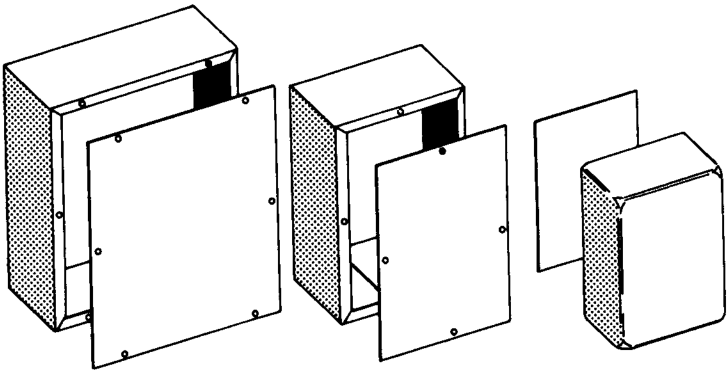


Fig. 1-15. Utility cabinets.

Portable utility cases (Fig. 1-18) are useful in constructing portable pieces of electronic test equipment.

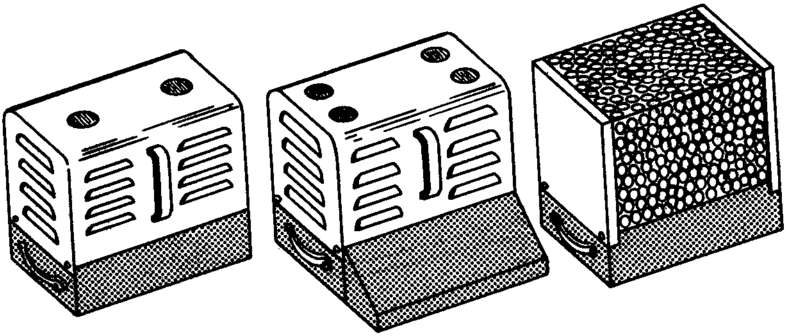


Fig. 1-16. Amplifier foundations.

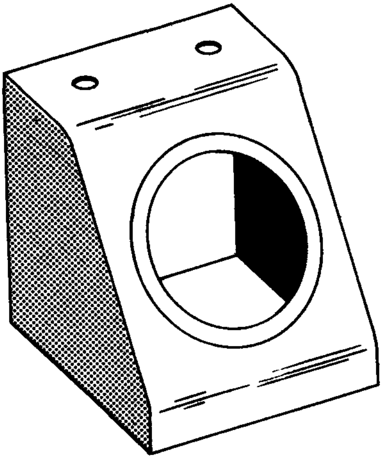


Fig. 1-17. Meter case.

ETCHED CIRCUITS

This is a relatively new type of electronic construction. In the etched-circuit technique, copper foil is bonded to one side of a piece of thin insulating material, such as phenolic board or fiberglass. Predetermined portions of the copper foil are etched away, leaving areas of copper that serve as conducting paths between components mounted on the board. The basic idea of this is shown in Fig. 1-19.

The etched circuit, sometimes called a "printed circuit," offers several advantages over the more conventional point-to-point wiring. First, it is more economical because a large

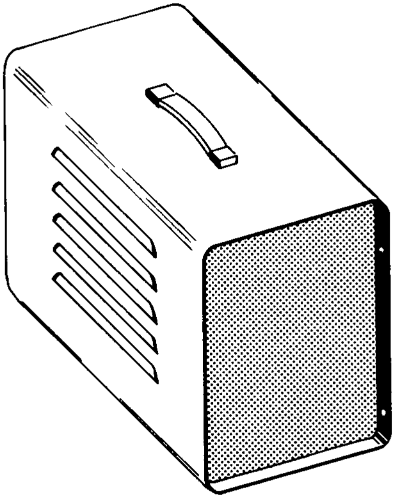


Fig. 1-18. Portable utility case.

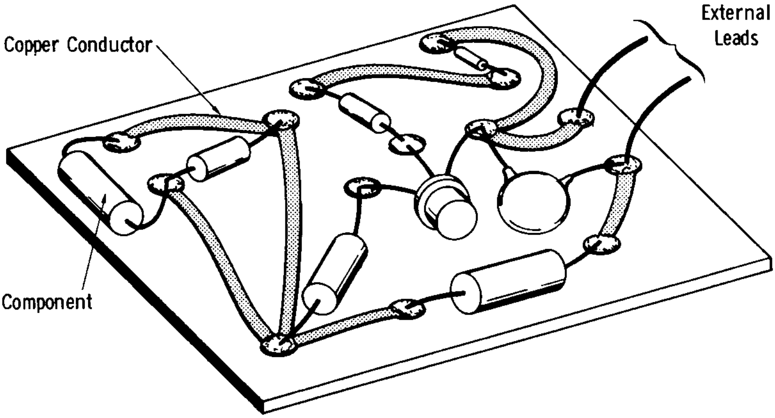


Fig. 1-19. Etched circuit board.

number of printed-circuit boards may be rapidly etched from a master photographic negative. Second, the etched "wiring" can provide more compact circuit packaging than conventional wiring techniques. Etched circuits can often provide greater electrical stability than conventional wiring, particularly where high-frequency circuits are concerned.

The home experimenter can work readily with etched circuits due to the availability of etched-circuit board stock and etching chemicals.

There are two basic approaches that may be used to prepare etched circuits. Perhaps the simplest involves the use of a special masking tape to mark out the portions of the copper that form the circuit "wiring" from the etching solution.

The second method involves a photographic negative which is used in conjunction with a special photosensitive etching-resist chemical. This procedure is somewhat more involved than the tape method and is not too practical for a single etched circuit.

ELECTRONIC CIRCUIT ENCAPSULATION

Circuit encapsulation is a process in which an electronic circuit is encased in an insulating material to completely seal it against the effects of the surrounding environment.

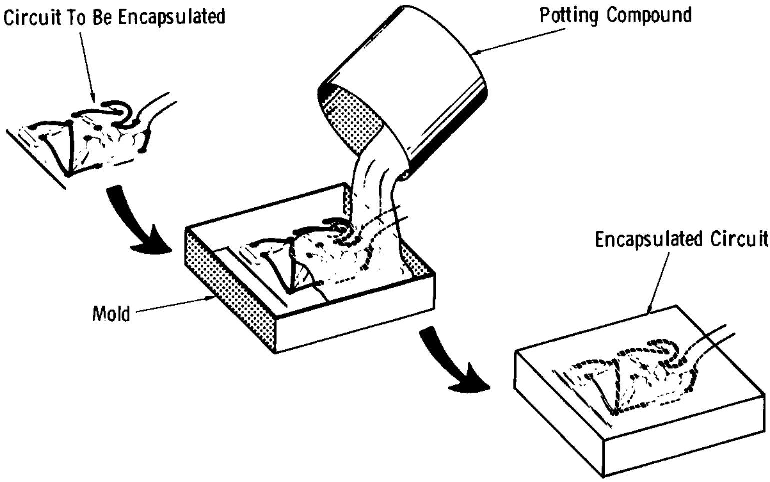


Fig. 1-20. Encapsulated circuit.

Fig. 1-20 illustrates the basic idea of circuit encapsulation. The circuit to be encapsulated is placed in a suitable mold. Next, the encapsulating solution is poured into the mold until it completely surrounds the circuit components. After allowing the encapsulating compound to harden, the complete assembly is removed from the mold. Leads that go to external connections are left outside the encapsulation.

CHAPTER 2

Electronics Tools and How to Use Them

In this chapter, we will take a look at the essential tools that you will need to construct electronic equipment; then we will cover those tools which, while not necessarily essential, can make many of the tasks much simpler, easier, and faster.

Also covered in this chapter will be the proper procedure for laying out a metal chassis in preparation for drilling and punching. As in any task, knowing the proper procedure will not only make the job much easier; it will result in a finished project that will work well, and of which you will be proud.

THE BASIC TOOL KIT

The basic tools essential in working with electronic equipment are:

(a) pliers.
(b) screwdriver.
(c) wire stripper.
(d) soldering iron or gun.
(e) wrenches.
(f) socket punches.
(g) files.

The basic plier group consists of:

(a) electrician's side cutting pliers.
(b) diagonal cutters ("dykes").
(c) long-nose pliers.
(d) tongue and groove pliers.

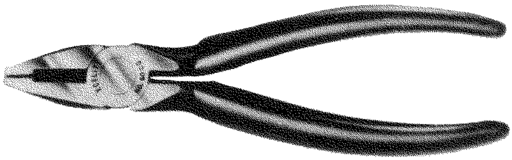


Fig. 2-1. Electrician's side-cutting pliers.

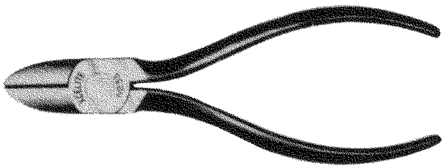


Fig. 2-2. Diagonal cutters.

Electrician's side-cutting pliers (Fig. 2-1) are a general purpose type of pliers that finds a myriad of uses, including holding, tightening, crimping, and cutting. This type of pliers may be used to cut small bolts and machine screws.

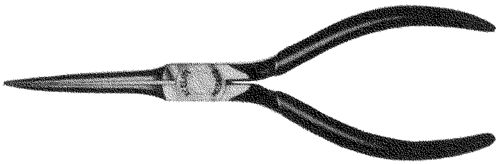


Fig. 2-3. Long-nose pliers.

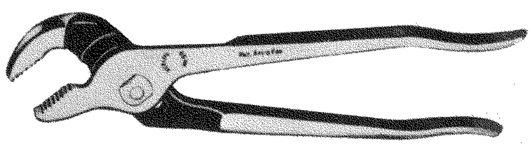


Fig. 2-4 Tongue and groove pliers.

Diagonal cutters (Fig. 2-2) are used to snip hookup wire, component leads, etc., to the proper length. This type of pliers is available in a wide variety of sizes to suit all needs.

When using diagonal cutters, it is important that they not be used as bolt or screw cutters, as this will severely damage both their cutting edges and hinge points.

Long-nose pliers are used to hold small objects and for crimping. As shown in Fig. 2-3, their construction permits their use in cramped quarters.

Tongue and groove pliers are useful due to their adjustability to a wide variety of jaw opening sizes. This type of pliers (Fig. 2-4) is used primarily for tightening joints, bolts, etc.

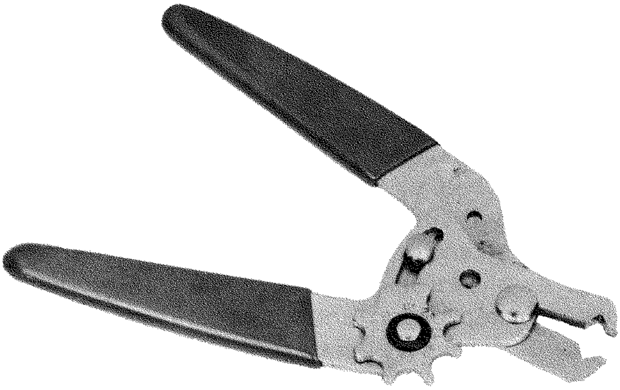
A good set of screwdrivers is mandatory. The required screwdrivers are:

(a) large standard screwdriver.
(b) small standard screwdriver.
(c) large Phillips head.
(d) small Phillips head.

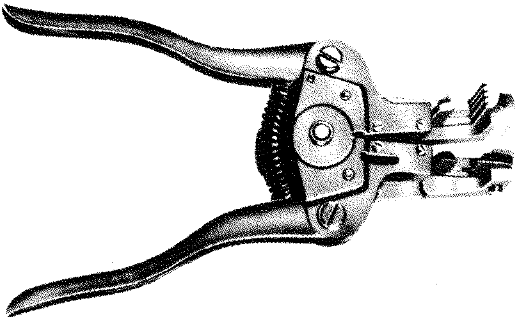
It is important to use the right screwdriver for each application. For example, do not try to tighten a Phillips-head screw with a small standard screwdriver. A screwdriver should not be used as a wedge or chisel either. The former will most likely wear the slots in the Phillips-head screw being tightened, and the latter will quickly ruin a good screwdriver blade. It is also important that the proper Phillips-head screwdriver be used for the particular Phillips-head screw. A too large or too small screwdriver will cause excessive screw head wear.

Although it is a relatively minor item, a wire stripper is well worth its small expense. Fig. 2-5 shows two commonly available types of wire strippers. The one shown in Fig. 2-5A is an inexpensive type which is adjustable to wire sizes from No. 10 gauge to No. 22 gauge.

The stripper shown in Fig. 2-5B is a more elaborate version which holds the wire firmly as it is being stripped. Also, this type of stripper can be adjusted to strip a specific length of insulation from the wire.



(A) Inexpensive wire strippers.



(B) Automatic wire strippers.

Fig 2-5. Wire strippers.

Aside from its convenience, a wire stripper prevents nicking of the wire, which often occurs when a knife is used.

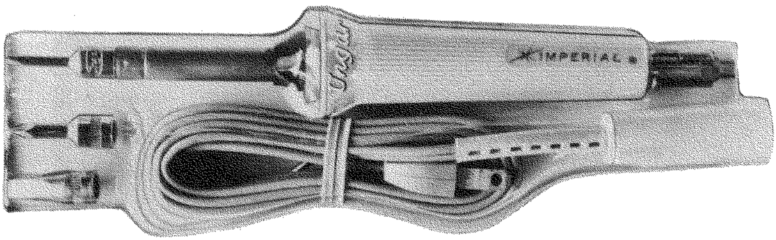
SOLDERING TOOLS

To do an adequate job of electronic circuit wiring, it is important to choose the proper soldering iron or gun. Fig. 2-6A shows a soldering gun, and Fig. 2-6B shows a soldering iron.

The decision to use a soldering iron or gun depends on several factors. Because the soldering gun provides rapid heating, it can be used on a job, then promptly tucked away

Courtesy Wen Products, Inc.

(A) Soldering gun.



Courtesy Unger Electric Tools

(B) Soldering iron.

Fig. 2-6. Soldering gun and soldering iron.

without any danger of a tip retaining heat and causing an unexpected burn or possible fire.

On the other hand, the tip of the soldering gun continues heating as long as its trigger switch is depressed. This means that it is difficult to obtain precise control over the tip temperature. Also, the tinning on the tip may be burned away if the trigger switch is held down too long.

Due to the danger of excessive tip temperatures, a soldering gun is generally not recommended for use on printed circuit work. An excessive tip temperature can lift the foil from the base. Also, excessive tip temperature can burn the delicate connections found in miniaturized electronic equipment.

Soldering irons are available in a wide range of tip sizes and wattage ratings. As to tip size, the 3/16-inch designed tip is satisfactory for most electronics wiring. Standard tip sizes range from 1/8-inch to 1 1/8-inch.

Wattage ratings of soldering irons correspond to the tip size—the larger the tip, the higher the wattage rating. In general, a wattage rating of 60—120 watts is satisfactory for most work. For printed-circuit work, a 30-watt iron is recommended.

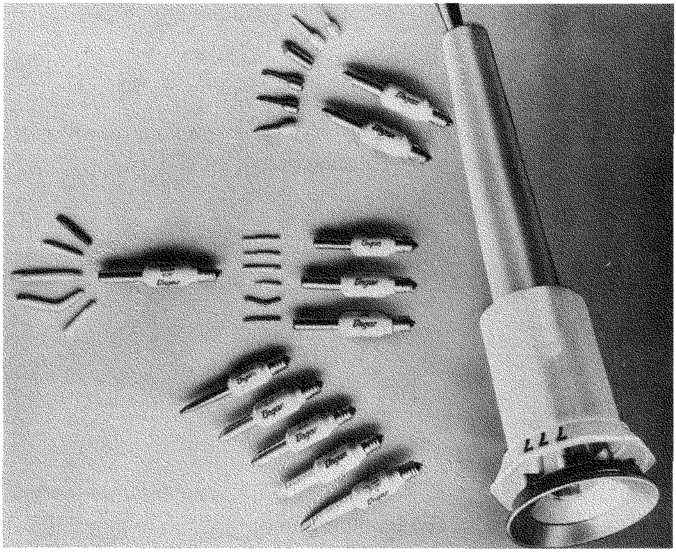


Fig. 2-7. Soldering iron and replacement tips.

Fig. 2-7 shows a novel type of soldering iron construction in which the soldering tip and its heating element are separate from the iron handle. This arrangement permits the use of different tip sizes.

Soldering irons are also available which may be operated from a 12-volt battery. This type of iron is useful in the field where there is no other available source of power. Incidentally, this type of iron is handy for use by the radio amateur in his field trips.

Solders

The type of solder used is as important as the soldering iron or gun. For electrical and electronic work, it is mandatory that a non-acid flux solder be used. *Never use acid-core solder.*

Nonacid-core solders are available with either natural resin flux or the new synthetic fluxes. Any of these types are satisfactory. Several manufacturers now market "multicore" solders which contain either three or five individual cores of flux. These solders provide easier soldering due to the more ready flow of flux during the operation. Fig. 2-8 is a sketch of a multicore solder.

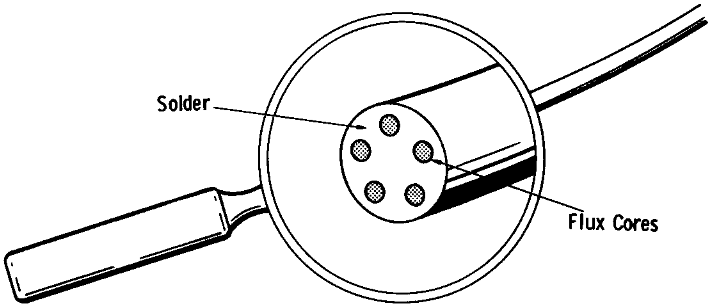


Fig. 2-8. Multicore solder.

Wire solders are available in a variety of gauges—the most popular ranging from No. 16 to No. 22 gauge.

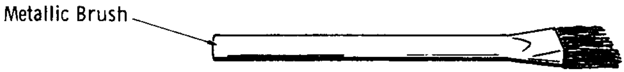
Soldering Aids

There are several small tools available to assist the soldering operation. Fig. 2-9 illustrates two of the most popular of these tools. Fig. 2-9A is a combination tool, which has a pick at one end and a fork at the other end. The pick is useful for removing bits of solder and for cleaning out solder-filled terminals, etc. The forked end is handy for untwisting wires and component leads that may be twisted around a tube socket lug, terminal, etc. The ends of this tool are made of a material to which solder will not adhere.

The second tool (Fig. 2-9B) is a small metallic brush that is most useful for removing globs of molten solder from heated soldered connections.

The tools described up to this point are the "essentials" for basic electronic assembly work, such as kits, in which all of the mechanical fabrication has been done and all that is required is the actual assembly of components.

(A) Fork and pick.

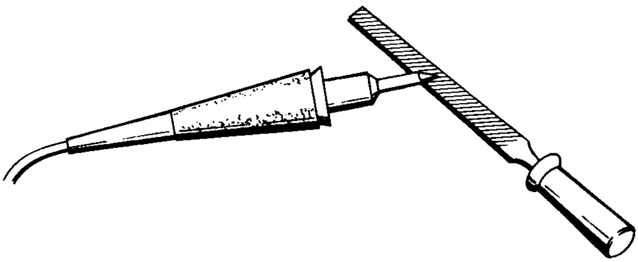


(B) Metallic brush.

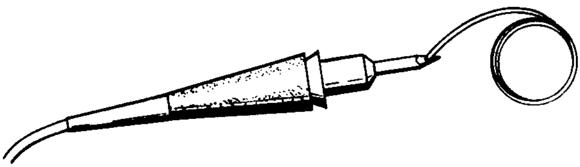
Fig. 2-9. Soldering aids.

Soldering Tips

Before proceeding further with a description of the various tools, let us take a moment to review some basic soldering techniques.



(A) Cleaning the tip.



(B) Applying solder.

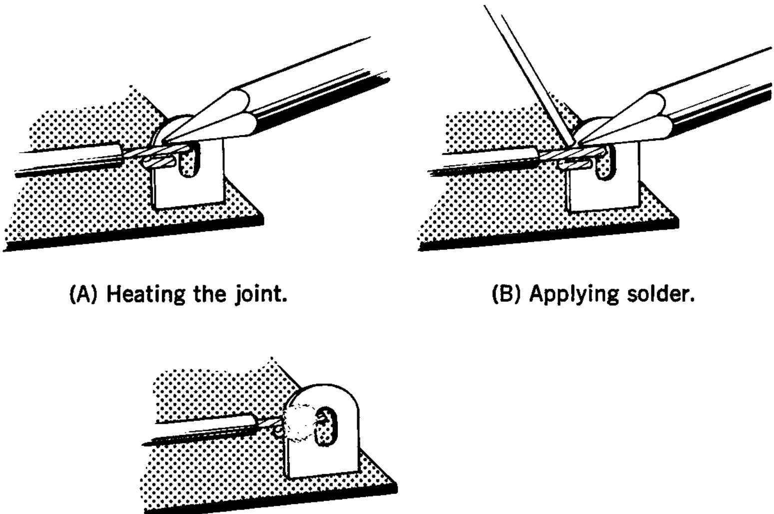
Fig. 2-10. Tinning a soldering iron.

One of the most important points to remember in soldering is to *always* keep the soldering iron or gun well tinned. A well-tinned tip is essential for proper heat transfer between the iron tip and the point being soldered. If the tip of the iron or gun is not well tinned, adequate heat transfer will not be obtained, and a poorly soldered connection will most certainly result.

Fig. 2-10 shows the proper technique in tinning a soldering iron or gun tip. First, the tip is thoroughly cleaned with a piece of fine-grained emery cloth. If the tip is badly pitted, it may be necessary to use a fine-tooth file to remove the pits (see Fig. 2-10A). The file should be used sparingly so as not to remove an excessive amount of the tip's surface. NOTE: Some tips are made of materials which must never be filed. Before filing, check the instructions that come with the iron.

When the tip is well cleaned, allow the iron or gun to reach operating temperature and apply a light coating of solder, as shown in Fig. 2-10B. Remove excess solder by wiping the tip lightly with a piece of cloth.

When making a soldered connection, it is important to remember that the solder should never be directly applied



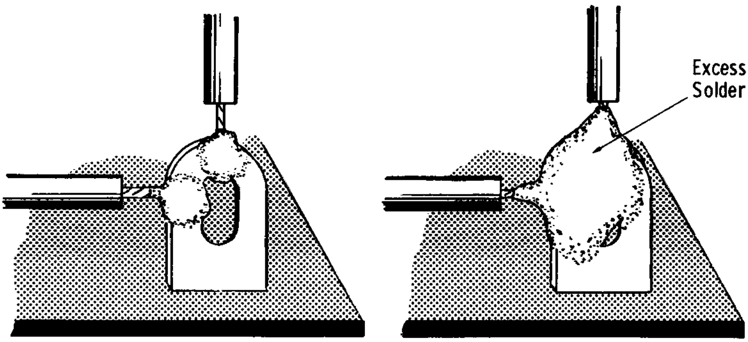
(A) Heating the joint.

(B) Applying solder.

(C) Finished joint.

Fig. 2-11. Proper soldering techniques.

to the iron tip. Instead, the joint itself should be heated directly with the tinned iron tip, as shown in Fig. 2-11A. When the joint has been heated sufficiently, the solder is then applied directly to it, as shown in Fig. 2-11B. When sufficient solder has melted over and covered the joint, the solder is removed *first,* and then the iron tip is removed from the joint, as shown in Fig. 2-11C.



(A) Correct solder joint. (B) Incorrect solder joint.

Fig. 2-12. Correct and incorrect soldering techniques.

Only sufficient solder should be used to cover the actual electrical connection. Fig. 2-12A shows a satisfactory connection as the solder covers only the actual electrical connection. Fig. 2-12B is a poor connection, as the solder not only covers the actual electrical connection, but the entire terminal hole. It is important that excess solder not be used, as it is not only wasteful, but can often cause a short circuit by joining to otherwise insulated connections.

Sufficient heat must be applied to the connection so that the solder will flow over the entire electrical connection. In a properly soldered connection, the solder will "sweat" onto and into the connection. This means that the solder will flow easily, like water, over the connection.

A soldered connection that has not been heated sufficiently will not have the desired "shiny" appearance of a well-soldered connection; rather, it will appear grayish and have a grainy texture. Such a joint, known as a "cold" solder joint, possesses poor mechanical strength and will offer a relatively high electrical resistance. (Solder connections, however, should not be relied on for making good mechanical connections. Solder is used to make good *electrical* connections.)

After a soldered connection has been made, and while it is cooling, the leads of the connection should not be moved because any movement will weaken the bond.

SPECIAL ETCHED-CIRCUIT SOLDERING TECHNIQUES

The technique involved in soldering components into, and removing them from, etched-circuit boards varies somewhat from soldering techniques employed in conventional circuit assembly.

When soldering to etched-circuit boards, a relatively low-temperature solder should be used. Solders with high tin content have this characteristic; therefore, 60-40 (60% tin—40% lead) solder should be used.

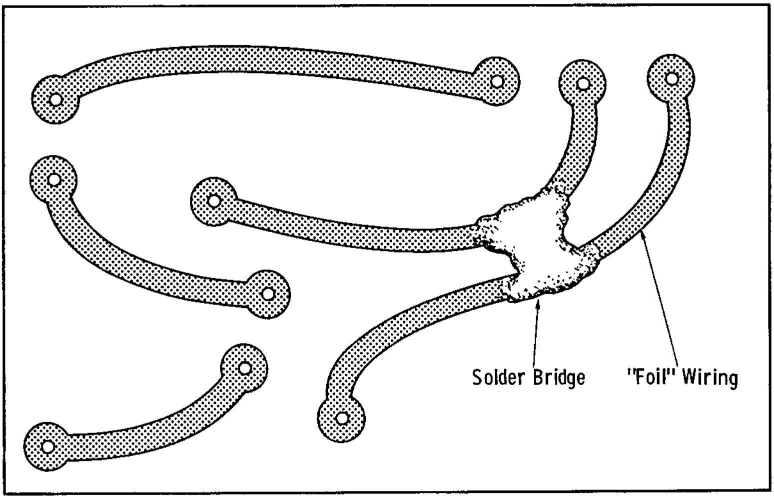
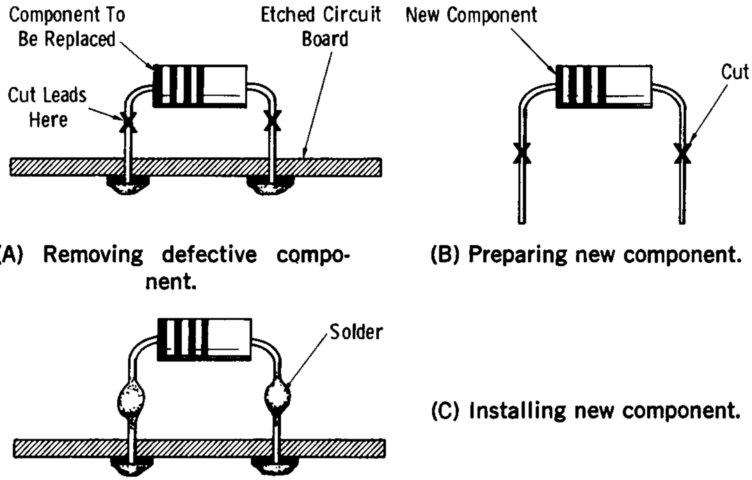


Fig. 2-13. Solder bridge.

Care must be taken when soldering to an etched circuit board so that the minimum amount of solder consistent with a good electrical connection will be used. Excess solder can cause "solder bridges" between adjacent foil conductors, which can cause short circuits, as shown in Fig. 2-13. If these solder bridges do occur, they can be removed by carefully heating the solder bridge until it is melted, and then quickly brushing it away with a small wire bristle brush.

Special techniques are employed in desoldering a component from an etched-circuit board. Fig. 2-14A shows a method that is simple and lessens the chance of damage to the foil due to excessive heat. As shown in Fig. 2-14A, the



(A) Removing defective component.

(B) Preparing new component.

(C) Installing new component.

Fig. 2-14. Method of replacing defective component.

leads to the component being replaced are clipped close to the component body, leaving the two leads sticking up from the board. The leads from the replacement component are clipped close to its body as shown in Fig. 2-14B. The leads of the replacement component are hooked around the leads extending from the board, and soldered in place as shown in Fig. 2-14C.

If the leads connecting the component to the board are too short to use the above technique, the joint where the defective component leads contact the foil should be heated just enough to soften the solder. The component can then be lifted from the board.

When a component has a number of leads connecting it to an etched-circuit board, it is a difficult task to remove it,

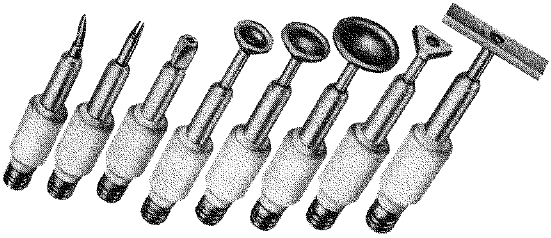


Fig. 2-15. Desoldering tips.

as all leads must be heated simultaneously. Handy devices to help solve this problem are shown in Fig. 2-15. Called desoldering tips, they provide a large surfaced, plate-type tip which will simultaneously heat up several component leads at the point where they are soldered to the foil, so that the component can be readily removed.

METALWORKING TOOLS

Since almost all electronic equipment, with the exception of etched circuits, is assembled on a metal chassis, a good understanding of how to prepare a metal chassis for component mounting is essential.

Drills

Mounting holes up to ½-inch are easily made with ordinary twist drills. These drills are available in sets offering drill sizes ranging from $\frac{1}{16}$-inch to ½-inch. When selecting a drill set, the old saying "penny wise is pound foolish" certainly applies. An inexpensive set of drills will quickly dull and will have to be replaced after only little use. On the other hand, a quality set of drills will last a long time and will be well worth its initial cost.

An electric hand drill is well worth its cost in terms of saving labor and time.

A drill with a ¼-inch chuck will usually be satisfactory for most work. Although drills with ⅜-inch or ½-inch chucks are available, their increased cost is not warranted.

Twist drills up to ½-inch are now available with ¼-inch shanks so that they will fit drills with ¼-inch chucks.

Power hand drills with built-in solid-state variable-speed controls are now available. In operation, depressing the trigger switch varies the drill speed smoothly from zero to their rated rpm—generally, 1800 rpm. The slow starting speed obtainable with such a drill alleviates the need of using a center punch to form a pilot mark on the chassis.

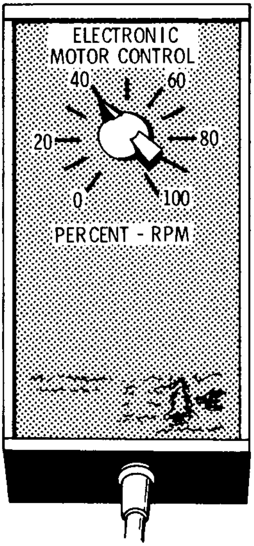


Fig. 2-16. Variable speed control.

If you already have a hand electric drill, but it is of the constant-speed type, you can obtain an inexpensive solid-state speed control, such as shown in Fig. 2-16, for your brand of drill. Although less convenient than the trigger-activated types which are on variable-speed drills, these external speed controls are still very handy.

CHAPTER 3

Electronic Components— Mounting and Wiring Techniques

In this chapter, we will discuss the components commonly used in electronic projects. Included are the basic electrical and mechanical characteristics of the components, as well as how they are mounted and connected into the circuit.

RESISTORS

Perhaps the most common component used in an electronic circuit is the resistor. Resistors are available in a wide range of resistance values, tolerances, and power ratings, and in either wirewound or composition (carbon) units.

The composition, or carbon, resistor is the most commonly used resistor. Standard carbon resistor values range from less than 1 ohm to 22 megohms. There are specialized carbon resistors of much higher resistance values, but these are rarely used in the average construction project.

Resistor Color Code

The resistance value of a carbon resistor is denoted with colored bands placed around one end of the resistor body. Table 3-1 is a listing of the resistor and capacitor color

Table 3-1. Resistor-Capacitor Color Code

Color	Significant Figure	Decimal Multiplier	Tolerance (%)	Voltage Rating*
Black	0	1	—	—
Brown	1	10	1*	100
Red	2	100	2*	200
Orange	3	1,000	3*	300
Yellow	4	10,000	4*	400
Green	5	100,000	5*	500
Blue	6	1,000,000	6*	600
Violet	7	10,000,000	7*	700
Gray	8	100,000,000	8*	800
White	9	1,000,000,000	9*	900
Gold	—	0.1	5	1000
Silver	—	0.01	10	2000
No color	—	—	20	500

*Applies to capacitors only.

code for ¼-, ½-, 1-, and 2-watt carbon resistors and color-coded capacitors. As an example of how these colored bands indicate the resistance value, let us assume a resistor is marked with brown, black, and red bands as read from the end of the resistor (see Fig. 3-1). The first band (brown) = 1; the second band (black) = 0; and the third (multiplier) band (red) = two zeros, indicate a value of 1000 ohms.

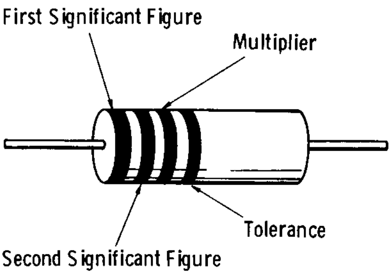


Fig. 3-1. Arrangement of color coding bands.

Resistor Tolerance

Composition (carbon) resistors are generally marked with a fourth band to indicate the tolerance. If the fourth band is silver, the resistor's tolerance is ±10 percent. A gold band indicates a tolerance of ±5 percent. Thus, if the nominal value of a resistor is 10,000 ohms, and it has a silver band, its actual resistance value ranges between 9,000 and 11,000 ohms. If the resistor has no tolerance band, its tolerance is assumed to be ±20 percent.

When a carbon resistor is used in a new circuit design, the actual power dissipated by the resistor should be about one half the rated wattage of the resistor.

Composition (carbon) resistors are furnished with axial tinned copper leads to connect the resistor into the circuit. These leads allow the resistor to be self-supporting.

Precision Carbon-Film Resistors

This type of resistor is intended for applications requiring extremely close resistance tolerance—±1 percent or better. The carbon film resistor is generally a low wattage (½ to 2 watts) unit, and is used primarily in precision test equipment.

Wirewound Resistors

When higher power dissipation is required, wirewound resistors are used. These resistors consist of a ceramic tube over which a layer of resistance wire is wound. The resistance winding is in turn covered by a layer of ceramic to protect the winding (see Fig. 3-2).

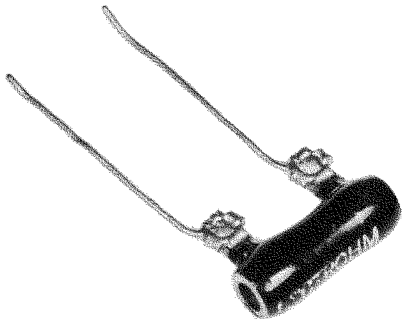


Fig. 3-2. Fixed wirewound resistor.

Wirewound resistors are available with resistance values ranging from a fraction of an ohm to approximately 100K ohms. Power ratings range from 2 to 500 watts.

Unlike a composition resistor, which has its resistance values indicated by colored bands, a wirewound resistor has its resistance values printed on its side.

The normal tolerance value of the wirewound resistor is ± 10 percent, although closer tolerance units are available.

Adjustable wirewound resistors are also available in which the resistance may be varied with an adjustable slider moved along an exposed portion of the winding, as shown in Fig. 3-3.

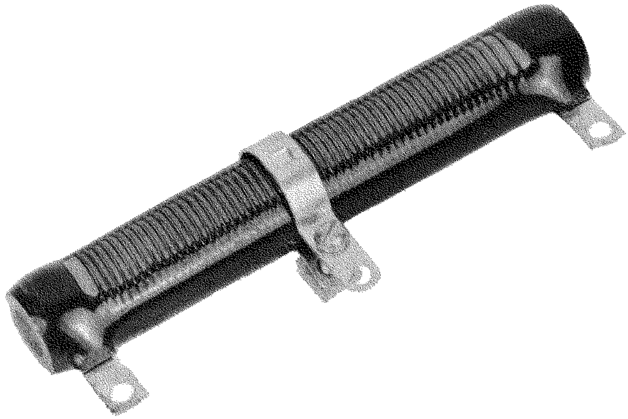


Fig. 3-3. Adjustable wirewound resistor.

Low wattage (2-20 watts) wirewound resistors are generally provided with wire leads for their connection into the circuit. Due to the relatively light weight of these resistors, these connecting leads also provide mechanical support for the resistor. Resistors with higher wattage (25-500 watts) are generally provided with brackets for mounting and solder lugs at each end of the resistor body for electrical connections.

POTENTIOMETERS

A potentiometer (Fig. 3-4) is a continuously variable resistor used in such applications as volume and tuning controls.

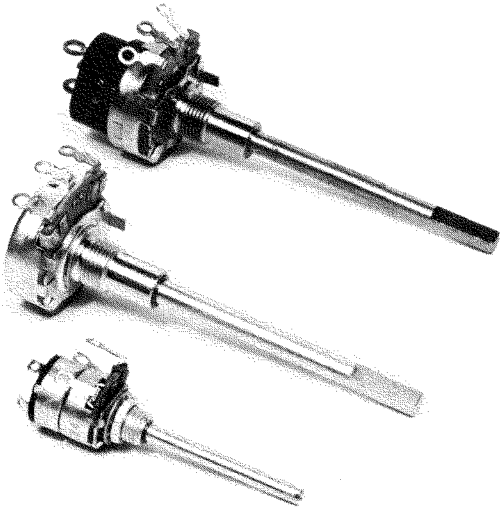


Fig. 3-4. Potentiometers.

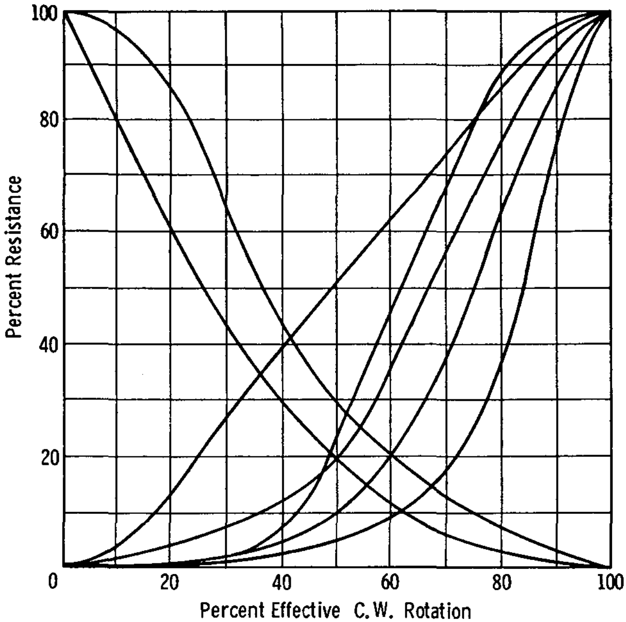


Fig. 3-5. Potentiometer resistance tapers.

Standard potentiometers are available in two basic types; composition (carbon) and wirewound. The composition potentiometer is a low wattage unit (½ to 2 watts). Wirewound potentiometers are available in wattages ranging from 2 to 300 watts or more.

Potentiometer Tapers

Potentiometers of the composition type are available with various resistance tapers, as shown by the graph in Fig. 3-5. A potentiometer with a linear taper means that its resistance will vary linearly (from zero to maximum) with respect to its shaft rotation. A potentiometer with a logarithmic taper means that its resistance will vary from zero to maximnm in a logarithmic manner with respect to its shaft rotation. The latter type of taper, often referred to as an "audio taper," is used in volume controls.

CAPACITORS

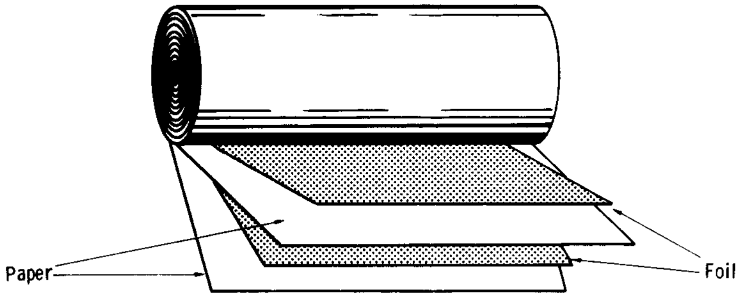
Capacitors, as well as resistors, form the "backbone" of electronic circuitry, and are available in a wide variety of physical and electrical configurations to suit the particular application.

Paper Capacitors

Perhaps the most common of all capacitors is the paper capacitor. Used extensively in coupling and bypass applications, paper capacitors are available in a wide range of capacitance values and voltage ratings. Typical capacitance values range from .0001 μF to 1.0 μF, with voltage ratings ranging from 200 to 10,000 volts and more for specialized units.

A paper capacitor is made by rolling alternate layers of aluminum foil and chemically treated paper into a cylindrical shape as shown in Fig. 3-6. Connecting leads are attached to alternate foil sides.

Paper capacitors should not be used in radio-frequency tuned circuits because they are not electrically stable enough.



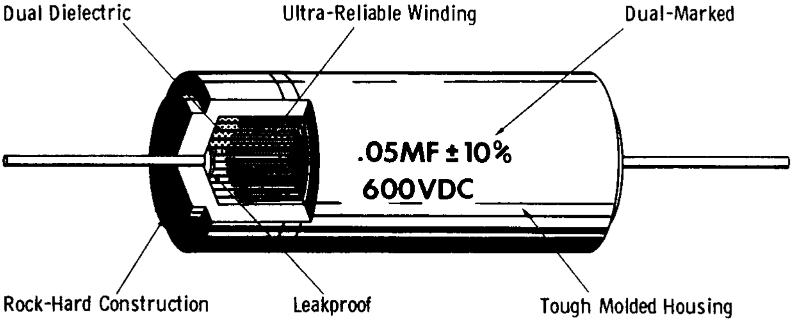


Fig. 3-6. Paper tubular capacitor.

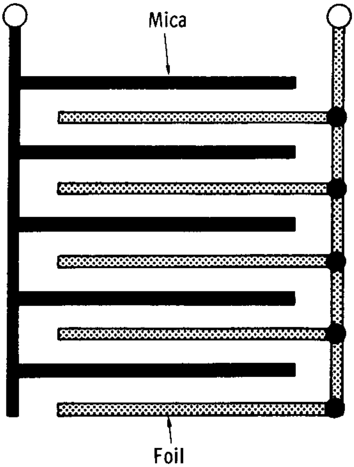
Mica Capacitors

Mica capacitors are used extensively in rf tuned circuits, since they are considerably more stable electrically than paper capacitors.

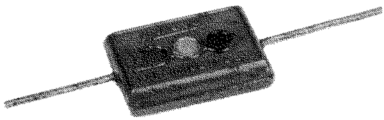
The construction of a typical mica capacitor is illustrated in Fig. 3-7, and consists of alternate thin sheets of aluminum foil separated by thin mica sheets. Leads are connected to the foil sheets, and the assembly is encased in a plastic housing.

Silver-mica capacitors have a silver coating (which acts as the conducting material) deposited on opposite faces of the mica sheets. Connecting leads are attached to the silver.

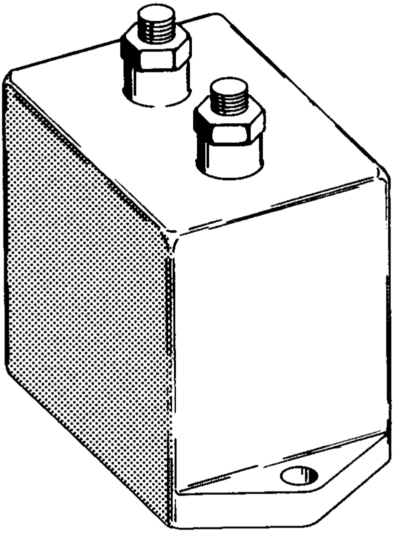
Silver-mica capacitors are more stable electrically than foil-type capacitors, and are used in high-stability frequency-determining circuits. Silver-mica capacitors are available in tolerances ranging from ± 5 percent to ± 1 percent or better.



(A) Construction of a typical mica capacitor.



(B) Flat mica capacitor.



(C) High-capacitance mica capacitor.

Fig. 3-7. Fixed mica capacitors.

Disc Capacitors

A disc capacitor (shown in Fig. 3-8) consists of a thin wafer of ceramic material with a thin coat of silver deposited on opposite sides. Leads are attached to these silver electrodes, and the wafer is encapsulated in a protective coating.

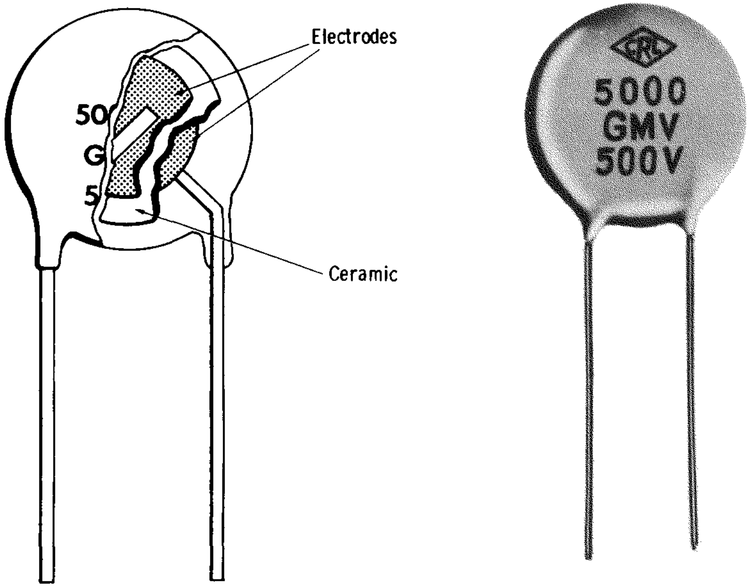


Fig. 3-8. Disc ceramic capacitor.

Disc ceramic capacitors are used primarily as coupling and bypass portions of radio frequency-circuits, rather than frequency-determining elements. Exceptions to this are special, close-tolerance, high-stability ceramic capacitors which are especially designed for use in resonant circuits.

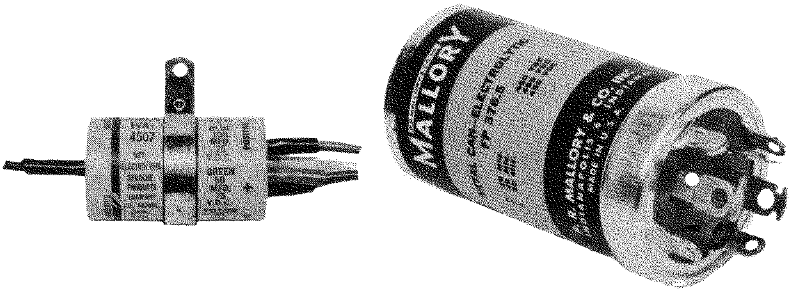
Disc ceramic capacitors are commonly available in capacitance values ranging from 47 pF to .05 μF. Voltage ratings range from 600 to 3000 volts.

Special low-voltage, high-capacitance disc capacitors are also available for use in transistor circuits. These capacitors have voltage ratings ranging from 12 to 100 volts. Capacitance ratings of these units range from .05 μF to .47 μF and higher.

Electrolytic Capacitors

Electrolytic capacitors have a high capacitance-to-size ratio, and are used extensively in the filter section of dc power supplies and transistor circuits.

Fig. 3-9 shows the can and tubular types, which are the most widely used electrolytic capacitors.



(A) Tubular capacitor. (B) Can type capacitor.

Fig. 3-9. Tubular and can electrolytic capacitor.

Electrolytic capacitors are available in capacitance values ranging from less than 1μF to 10,000 μF or more. Common voltage ratings range from 5 to 700 volts.

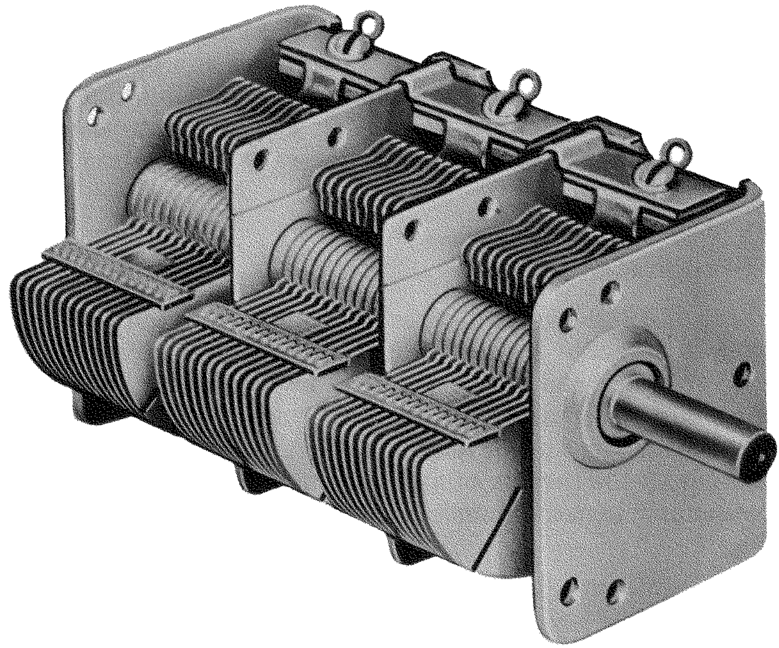
High heat tends to increase electrolytic capacitor leakage current, causing further internal heating of the capacitor—and the vicious circle continues. Increased leakage current shortens the life of the capacitor and degrades filtering action when it is used in power supply service.

When placing electrolytic capacitors in service, it is important that their polarity be observed. If connected incorrectly into a circuit, an electrolytic capacitor will be destroyed almost immediately.

Variable Capacitors

Variable capacitors are used primarily for varying the frequency of a resonant circuit. Receiver-type variable capacitors are generally available in capacitance ranges from 10 pF to 365 pF. Transmitting-type variable capacitors are available in similar capacitance values and with voltage breakdown ratings up to 20 kV and higher.

Variable capacitors are available in single, dual-, and three-section units. Fig. 3-10 shows a three-section unit. Two- and three-section variable capacitors are used primarily in the tuning sections of superheterodyne receivers, where it is necessary to simultaneously tune several resonant circuits.

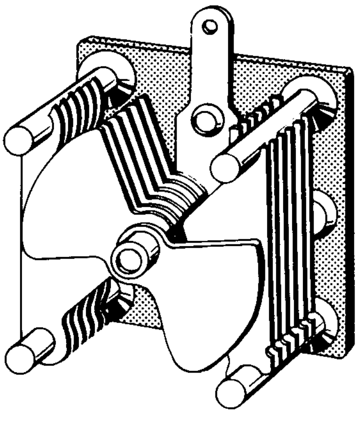


Courtesy J. W. Miller Co.

Fig. 3-10. Three-section variable capacitor.

Transmitting variable capacitors have an additional rating—voltage breakdown. This rating refers to the maximum voltage that may be applied to the capacitor before voltage breakdown occurs between the capacitor plates. Therefore,

Fig. 3-11. Butterfly capacitor.

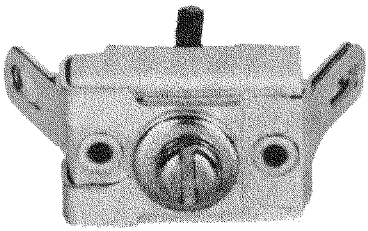


when purchasing a transmitting-type capacitor, be sure that the voltage rating of it is sufficient for the voltages encountered in the circuits. These voltages can be obtained from the tube manual or transmitter circuit diagrams.

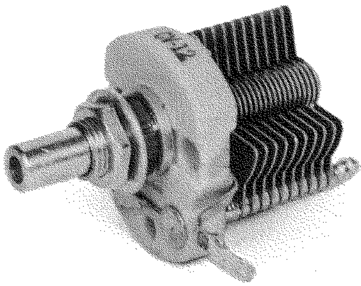
"Butterfly capacitors," shown in Fig. 3-11, are used in balanced rf circuits, where it is necessary to maintain electrical symmetry.

Trimmer Capacitors

Fig. 3-12 shows two types of trimmer capacitors. The trimmer capacitor shown in Fig. 3-12A is called a "compression" trimmer and consists of one or more metal (aluminum) sheets separated by sheets of mica. The aluminum sheets are under spring tension so that as they are squeezed together by the turning of an adjusting screw, their physical spacing and, hence, trimmer capacitance is varied.



(A) Compression type capacitor.



(B) Air-dielectric type capacitor.

Fig. 3-12. Trimmer capacitors.

Fig. 3-12B illustrates a trimmer capacitor with an air dielectric. Actually, this is a miniature version of the standard size air variable capacitor. Air trimmer capacitors usually have a screwdriver-adjustable short shaft in place of the longer shaft employed in standard air variables.

Trimmer capacitors are also referred to as "padder" capacitors.

Fig. 3-13 shows a variable capacitor known as a "piston" capacitor. One plate consists of an outer metal cup. A glass sleeve fits inside this cup, and a second metal cup ("piston") is fitted inside the glass sleeve. As the "piston" is moved up

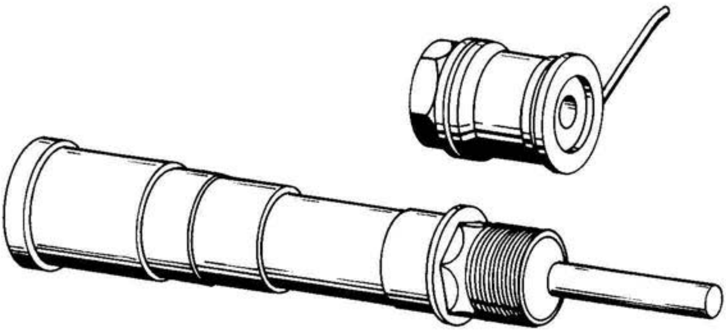


Fig. 3-13. Piston capacitors.

and down within the glass sleeve, the capacitance is varied. Due to the small physical area of the inner and outer metal parts of the piston capacitor, its maximum capacitance is quite low, usually less than 50 pF.

Trimmer capacitors are used primarily to add small amounts of capacitance to tuned circuits. In effect, they "trim" the capacitance to the required value.

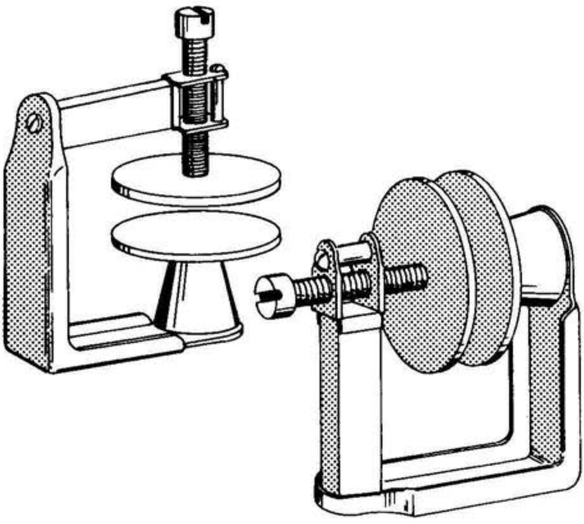


Fig. 3-14. Neutralizing capacitors.

Another type of capacitor, known as a neutralizing capacitor (Fig. 3-14), is used to provide the negative feedback capacitance in a triode rf amplifier stage. Without this neutralizing capacitance, the grid-plate interelectrode capacitance in the triode would cause oscillation of the amplifier.

The typical neutralizing capacitor consists of a fixed metal disc which forms one plate of the capacitor. The other plate is a movable metal disc whose position with respect to the fixed disc, is varied with a threaded drive screw. As the distance between the two discs is increased, the capacitance decreases.

TRANSFORMERS

Transformers represent another major category of electronic components. There are many types, including audio, power filament, pulse, and rf transformers.

Power Transformers

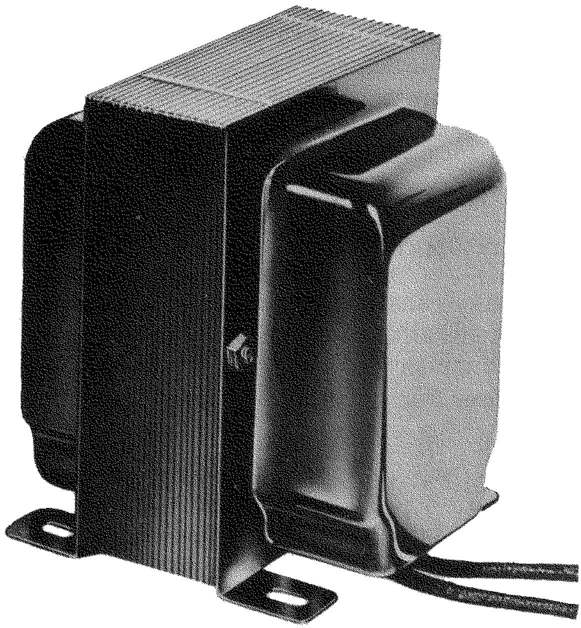
Perhaps the transformer you will encounter most in your work with electronics is the power transformer. The power transformer is designed to convert the 120-volt power-line voltage applied to its primary winding into one or more separate voltages. These voltages may be either higher or lower than the applied primary voltage. For example, a typical power transformer designed to power a vacuum-tube circuit will furnish a high voltage (200 volts and up) which is rectified to provide the proper dc plate voltage for the tubes in the circuit. In addition, one or more separate low-voltage windings (2.5, 3.5, 6.3, etc.) are provided to furnish voltage for the heaters of the tubes.

Chart 3-1 shows the accepted color code for the leads of the power transformers commonly used in electronic circuitry. The leads connected to the primary winding are black and red, or sometimes black and yellow. The high-voltage secondary end leads are identified with red, and the center tap lead with red-yellow.

Fig. 3-15 shows a typical power transformer. The power transformer's filament winding is identified by two green leads, and if the filament winding has a center tap, it is identified by a green-yellow lead. Rectifier filament winding leads are yellow, if included.

Primary Leads	Black
If tapped:	
Common	Black
Tap	Black and Yellow Striped
Finish	Black and Red Striped
High-Voltage Plate Winding	Red
Center-Tap	Red and Yellow Striped
Rectifier Filament Winding	Yellow
Center-Tap	Yellow and Blue Striped
Filament Winding No. 1	Green
Center-Tap	Green and Yellow Striped
Filament Winding No. 2	Brown
Center-Tap	Brown and Yellow Striped
Filament Winding No. 3	Slate
Center-Tap	Slate and Yellow Striped

Chart 3-1. Power Transformer Leads Color Code



Courtesy Stancor Products, Essex Wire Corp.

Fig. 3-15. Typical power transformer.

Typical receiver-type power transformers have secondary voltage ratings ranging from 125 to 600 volts. High-voltage secondary current ratings range from 10 to 200 mA.

Typical filament voltages are almost exclusively 6.3 volts, although some older power transformers offer 2.5-volt filament windings. Current ratings for filament windings range from 0.6 to 10 amperes or more. Rectifier filament winding voltages are usually 5 volts at current ratings of several amperes.

Power transformers designed to power semiconductor circuits usually have only a single secondary winding. The voltage rating of this winding will depend on the circuit requirements, usually ranging from 6 to 40 volts or more. The current rating may be from a few milliamperes to several amperes. Since these transformers are generally used to power a bridge-type semiconductor rectifier, the secondary winding is not centertapped.

Another type of power transformer is known as a "plate" transformer. This type has a single high-voltage secondary winding, and is designed to provide plate voltage for tubes in transmitting and industrial equipment. Secondary voltage ratings of plate transformers range from less than 1000 volts to 10 kV or more. Secondary current ratings range from 100 mA to several amperes.

Filament Transformers

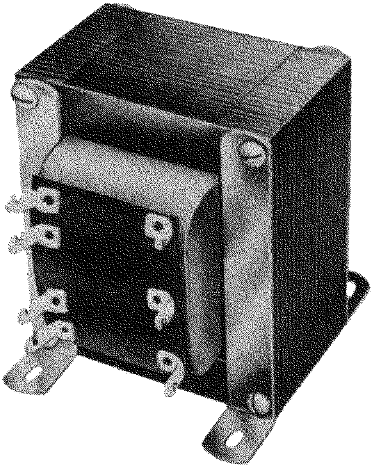
The filament transformer (a variation of the power transformer) generally has a single secondary winding, and is designed to furnish operating power to the filaments of vacuum tubes (see Fig. 3-16).

Tips on Using Power Transformers

When mounting power transformers—power, filament, plate, etc.— it is important that the transformer be mounted well away from any low-level portions of the circuit when the transformer is used to power audio-frequency equipment such as audio amplifiers. This is because the ac field radiated from the transformer can be picked up by a high-gain, low-level stage, thereby causing hum in the output signal of the amplifier.

When purchasing a transformer, note that the secondary voltage of the transformer is listed as, say, 300 VCT. This

Fig. 3-16. Typical filament transformer.



Courtesy Stancor Products, Essex Wire Corp.

denotes that when used with a full-wave rectifier, the output from the rectifier will be only 150 volts. This is because 150 volts appears on each half of the secondary winding with respect to the centertap. On the other hand, some transformer manufacturers list their secondary voltages as, say, 300-0-300 volts. This means that 300 volts appear on each side of the center tap, and thus, 300 volts will appear at the output of the full-wave rectifier connected to this winding.

When a higher voltage than is obtainable from a full-wave rectifier configuration is desired, a bridge rectifier may be used. This will yield twice the output voltage from the same secondary winding. For example, a power transformer with a secondary voltage of 300 volts, C.T. will provide 150 volts when used with a full-wave rectifier and 300 volts when used with a bridge rectifier. However, the total power delivered by the secondary must remain the same in both cases. Therefore, if the bridge rectifier is used, the current drawn from the secondary must be cut in half to keep within the VA rating of the transformer.

When selecting a filament transformer to furnish operating voltage for a rectifier, it is important that the primary-to-secondary insulation of the transformer be high enough so that there will be no voltage breakdown between the secondary and primary windings. The maximum voltage that may be applied between primary and secondary windings is generally given for filament transformers by the manufacturer.

Variable Transformers (Variacs)

Fig. 3-17 shows a handy device that enables one to continuously vary the applied voltage (120 volts ac) from 0 to

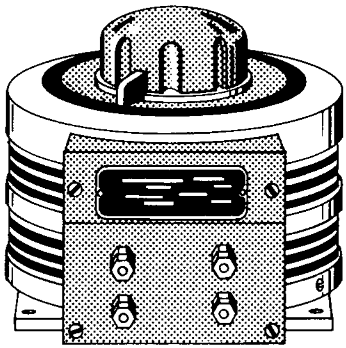


Fig. 3-17. Variable-voltage transformer.

maximum. Unlike a variable power rheostat, which drops voltages by means of heat loss, the variable transformer is extremely efficient. Variable transformers are available in current ratings ranging from less than 1 ampere to 20 amperes or more.

Voltage Adjusting Transformers

A variation of the variable transformer is shown in Fig. 3-18. Instead of a continuously variable output, the

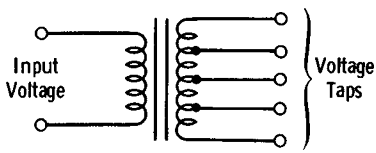


Fig. 3-18. Voltage-adjusting transformer.

voltage adjusting transformer has a series of taps on its secondary winding which provide different levels of secondary voltage. These taps are often provided so that the secondary voltage is slightly higher than the applied primary voltage. As an example of this, a voltage-adjusting transformer may be used to boost a lower-than-normal line voltage, say, 105 volts, up to 120 volts.

Audio Transformers

Transformers that fall into this category include audio input, audio interstage, and audio output transformers.

Audio Output Transformers

The audio output transformer is intended to couple the output of a vacuum-tube or transistor audio amplifier to a speaker.

Audio output transformers have definite characteristics, the most important of which are:

1. Proper impedance match between the source (amplifier plate or collector circuit) and load,
2. Adequate power handling capability, and
3. Adequate frequency response.

Proper impedance matching means that the proper load impedance should be reflected back to the amplifier output stage for the given load (speaker). Manufacturer specifications indicate the proper transformer for the particular amplifier output stage/load combination. "Universal" audio output transformers are available which greatly simplify the matching. Such a transformer is shown in Fig. 3-19. Multiple secondary taps permit a wide range of impedance-matching arrangements.

The power handling rating of the output transformer depends on the output power of the amplifier. For example,

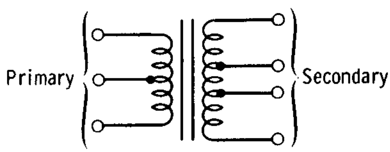
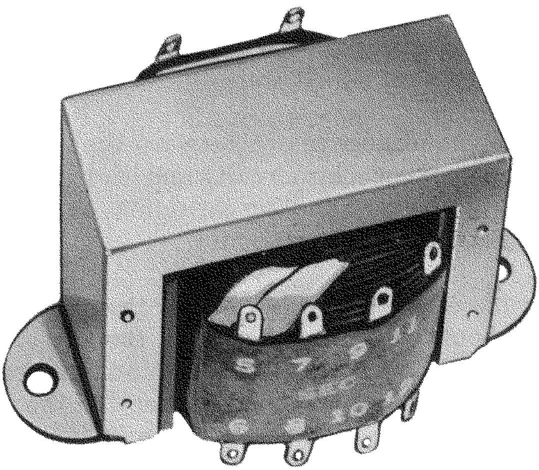


Fig. 3-19. Impedance-matching audio transformer.

a 15-watt audio amplifier should employ an output transformer capable of handling 15 watts, etc. There is one point to keep in mind: Most manufacturers of standard audio output transformers do not correctly rate their transformers. One of their transformers rated at, say 10 watts will actually handle about 5 watts without introducing excessive harmonic distortion. Therefore, as a rule of thumb, it is a good idea to select an output transformer with a power rating 5 or 10 watts higher than the rated output of the amplifier stage. (This does not apply to the higher quality "high fidelity" output transformers which are rated honestly as far as power handling capacity is concerned.) Fig. 3-20 shows a typical output transformer.



Courtesy Stancor Products, Essex Wire Corp.

Fig. 3-20. Typical audio-output transformer.

The frequency response of an audio output transformer is an important consideration when it is to be used in a high-fidelity amplifier. Generally speaking, the output transformer should have a frequency range of from at least 20 Hz to 20 kHz. If negative feedback is to be placed around the output transformer, the frequency bandwidth of the transformer should extend beyond this range.

Air-Core Coils and Transformers

Examples of air-core coils and transformers include intermediate frequency (i-f) transformers, radio-frequency (rf) chokes and traps, antenna and rf transformers, etc.

I-F Transformers

Fig. 3-21 illustrates one of the more common types of air-core transformers. It is known as an intermediate frequency transformer because it is used in the intermediate frequency amplifier sections of radio and tv receivers. It consists of two windings placed on a fiber or ceramic form. Generally, both the primary and secondary windings are

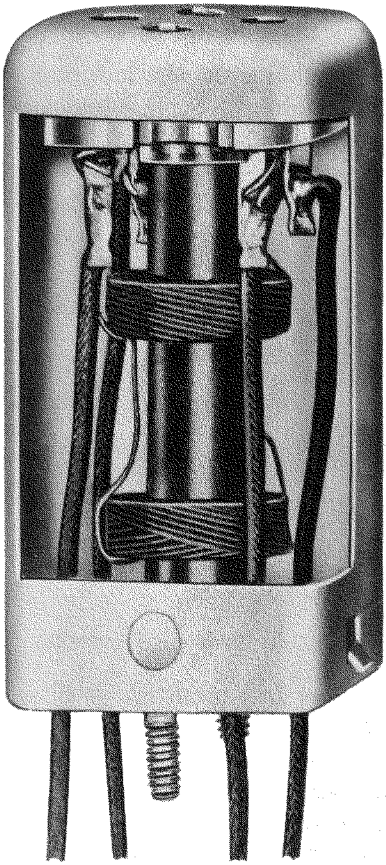


Fig. 3-21. Intermediate-frequency (i-f) transformer.

tuned to the operating frequency by mica compression trimmer capacitors.

In some i-f transformers, ferrite slugs are used to tune the windings to the desired frequency.

FILTER CHOKES

A filter choke (Fig. 3-22) is a device used in the filter section of a dc power supply. The two major ratings of a

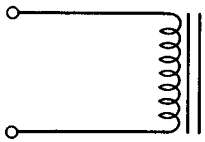


Fig. 3-22. Filter choke.

filter choke are the inductance and current rating. Fig. 3-23 is a photo of a typical low-current filter choke.

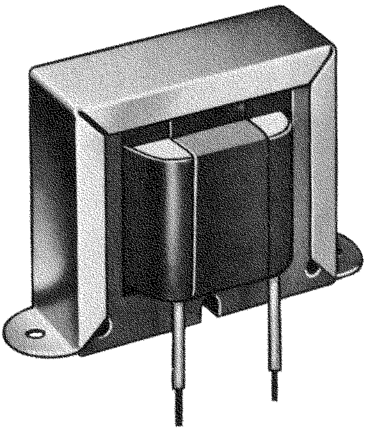


Fig. 3-23. Typical low-current filter choke.

Courtesy J. W. Miller Co.

The inductance of a filter choke is expressed in henrys, and may range from less than 1 henry to 50 or more.

The current rating of a choke may range from a few milliamperes to several amperes. It is important that the maximum current rating of the choke not be exceeded. If more than the rated value of current is drawn through the choke, the inductance will decrease, which in turn will decrease the effectiveness of the choke in the filtering circuit.

When used in high-voltage circuits, the insulation between the winding and mounting frame of the choke must be sufficient to prevent voltage breakdown.

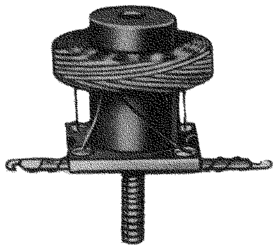


Fig. 3-24. Radio-frequency (rf) choke.

Courtesy J. W. Miller Co.

RF Chokes

An rf choke (Fig. 3-24) consists of a winding placed over a fiber or ceramic form. Often, the winding is arranged in a "pie" to reduce the distributed capacitance of the choke.

Frequently, in an effort to increase the inductance of an rf choke, a ferrite core is employed.

CHAPTER 4

The Electronic Breadboard

The use of the electronic breadboard permits easy access to circuit components for measuring circuit parameters, such as voltage, current, and resistance. Also, the components can be easily replaced or rearranged until the optimum circuit performance has been obtained.

In the pages that follow, we will take a look at a number of breadboard techniques that are simple and inexpensive. Breadboards for both vacuum-tube and transistor circuits are covered. Finally, two unique "integral-power supply" breadboards are described.

BREADBOARDS FOR VACUUM TUBE CIRCUITS

One of the simplest breadboard arrangements for vacuum-tube circuitry is shown in Fig. 4-1. A sheet of aluminum, the size of which depends on the number of components—tubes, capacitors, transformers, etc.—to be used, is selected. According to the design, the required number of tube socket holes, transformer mounting holes, and filter capacitor holes are cut or punched into the sheet.

Holes are drilled to accommodate insulated tip jacks which are placed around the components—a tip jack for each terminal of each component. For example, an 8-contact octal tube base will have eight tip jacks placed around it as shown.

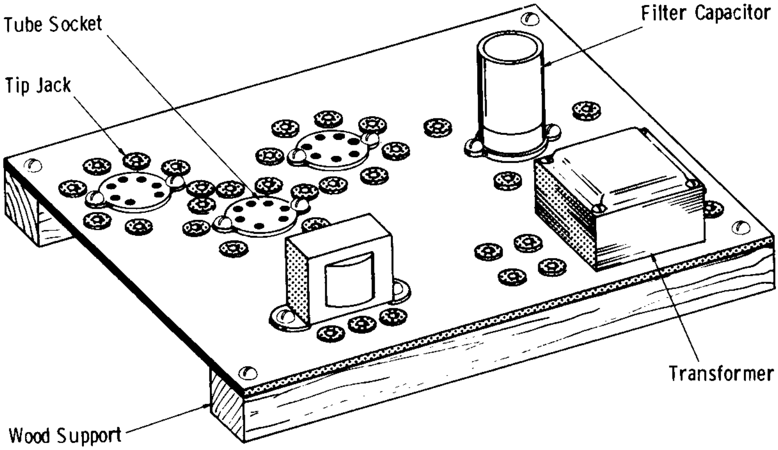
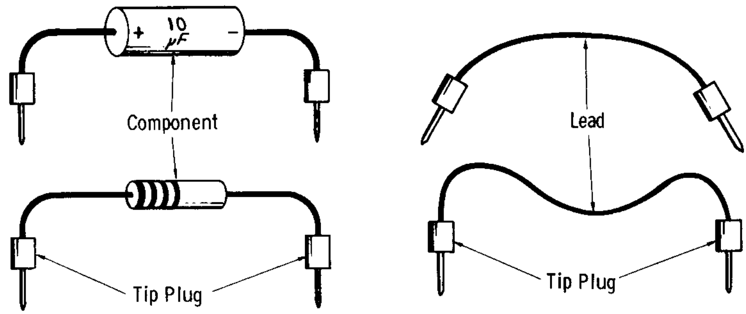


Fig. 4-1. Simple breadboard chassis.

The components are then mounted on the plate, and leads are run from the component terminals, transformers, etc. to their respective tip jacks.

Finally, the ends of the chassis plate are supported on small wood blocks so that the component terminal on the bottom of the chassis will not rest on the work surface.

We now have a unit with which we can, by using the tip jacks, connect in any desired arrangement, the components mounted on the chassis breadboard. The required smaller components, such as carbon resistors and tubular capacitors, are supplied with pin plugs for insertion into the tip jacks, as shown in Fig. 4-2. Various length leads for connections between tip jacks are made as shown in Fig. 4-2B.



(A) Components.

(B) Leads.

Fig. 4-2. Tip plugs on component leads.

A Wooden Breadboard

Fig. 4-3 shows a simple electronic breadboard. This type of breadboard is used to quickly assemble an experimental circuit without the necessity of punching and drilling holes in a metal chassis.

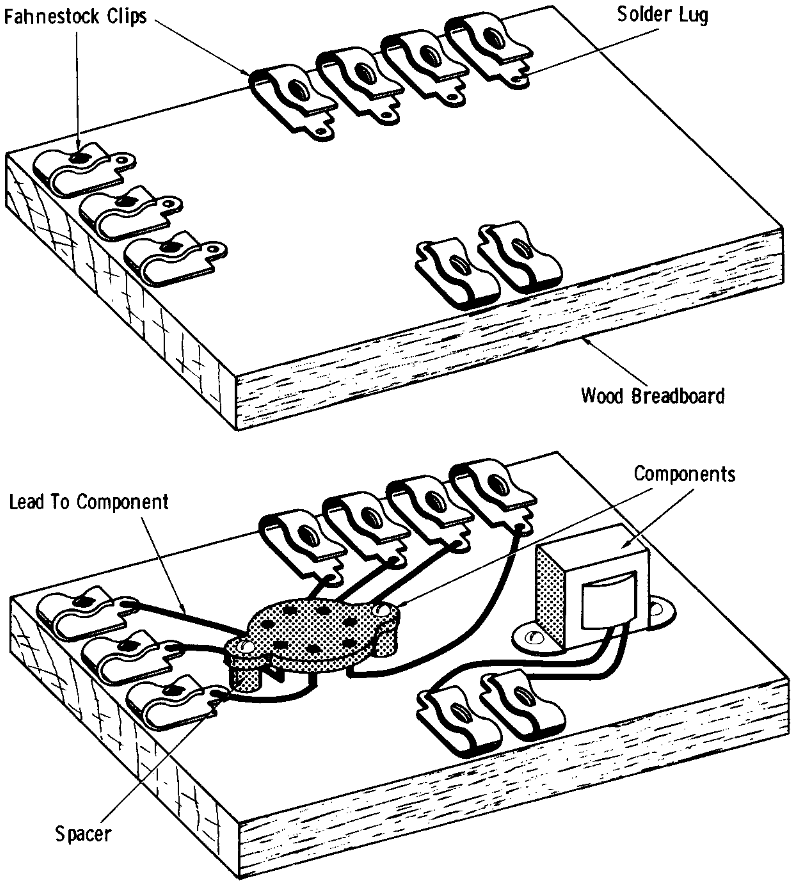


Fig. 4-3. Wooden breadboards.

Fahnestock clips, rather than pin jacks, are used to make connections to the various component tie points. These clips are simply screwed to the board with small round-head wood screws. A solder lug is placed under the head of each screw to provide the electrical connection to the Fahnestock clip.

The tube sockets and all other components that have either leads or terminals coming from their undersides are mounted to the board with metal spacers.

Still another approach to the electronic breadboard is shown in Fig. 4-4. Several tube sockets, as well as any trans-

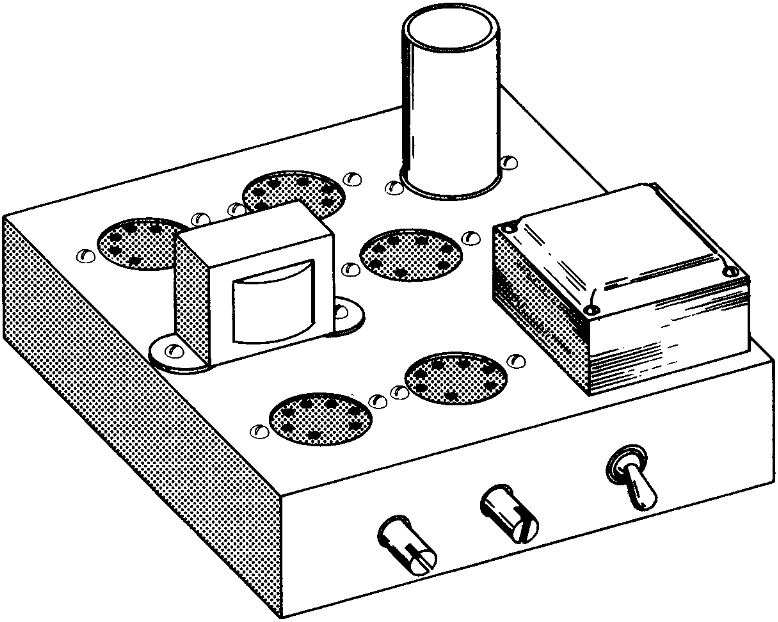


Fig. 4-4. Permanent breadboards.

formers, chokes, filter capacitors, etc., which are anticipated in any circuit project are mounted on the chassis. The result is a chassis with a sufficient number of components to assemble any present or anticipated project.

This type of breadboard permits the use of short, direct connections between components—a necessity when working with high-frequency or high-gain audio circuits.

Fig. 4-5 is an example of component wiring, showing the underneath side of the chassis in Fig. 4-4.

An Integral-Power Supply Breadboard for Vacuum-Tube Projects

Here is a rather novel type of electronic breadboard which contains an integral regulated power supply to

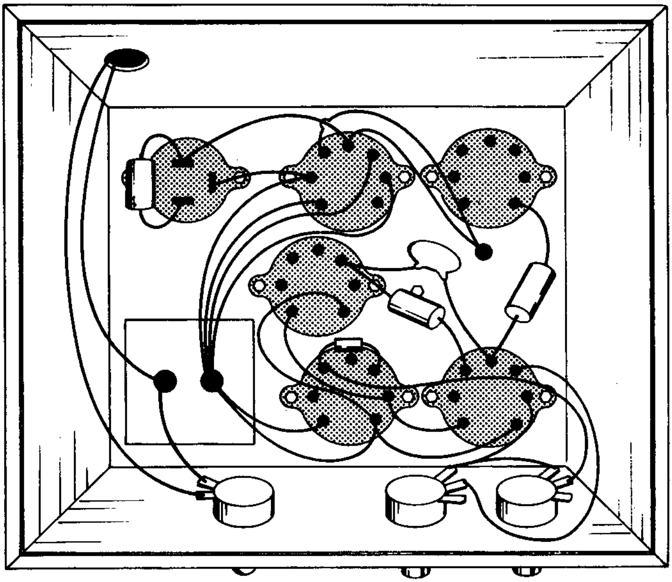


Fig. 4-5. Example of component wiring.

furnish all necessary operating voltages, heater, plate, and bias for experimental vacuum-tube circuits.

Fig. 4-6 shows the physical arrangement of the regulated power supply breadboard. A standard 13″ × 17″ × 3″ aluminum metal chassis is used as the basic breadboard. A portion of the chassis is cut out as shown, leaving an opening on which an aluminum plate may be installed. This removable plate serves as the breadboard on which the developmental circuit is assembled. The completed breadboard plate may be removed from the basic foundation chassis and a new plate substituted.

The regulated power supply is capable of supplying 6.3 volts at 2 amperes, 300 volts at 50 mA, regulated and variable, and 400 volts at 200 mA. The two high-voltage dc outputs cannot be drawn simultaneously.

Fig. 4-7 is the schematic diagram of the regulated power supply. The supply consists of three basic sections—a power transformer and filter, voltage regulator, and bias supply.

The operation of the supply is as follows: When 120 volts is applied to the primary of T1, a high voltage is developed across the secondary winding which is applied to

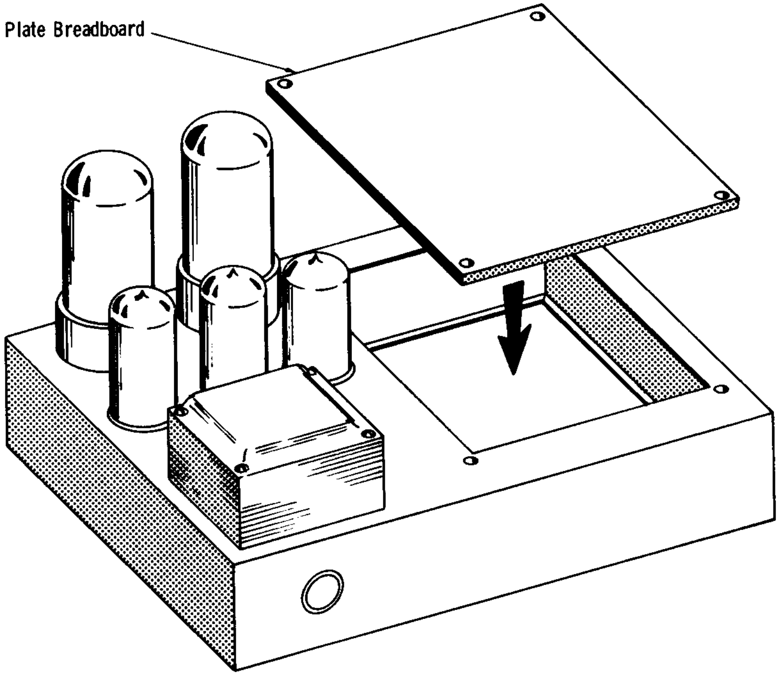


Fig. 4-6. Integral power-supply breadboard.

the full-wave rectifier V1. There is also a 6.3-volt winding which is applied to the 6.3-volt output terminals of the supply, and a 5-volt winding which supplies heater power for the full-wave rectifier.

The rectified output from V1 is applied to the choke-input filter made up of L1 and C1. (A choke-input filter was chosen to enhance the regulation of the +400-volt output.)

The output from the filter is applied to both the 400-volt output terminal and to the plate of the series regulator tube, V2. The cathode of V2 is connected to the +Regulated output terminal.

A voltage divider, consisting of R1, R2, and R3, is placed from the cathode of V2 to ground (common).

The voltage-control potentiometer, R1, selects a portion of the voltage developed across the voltage divider and applies it to the control grid of the error amplifier, V3.

The cathode of V3 is held at a constant voltage by the gaseous voltage regulator, V4.

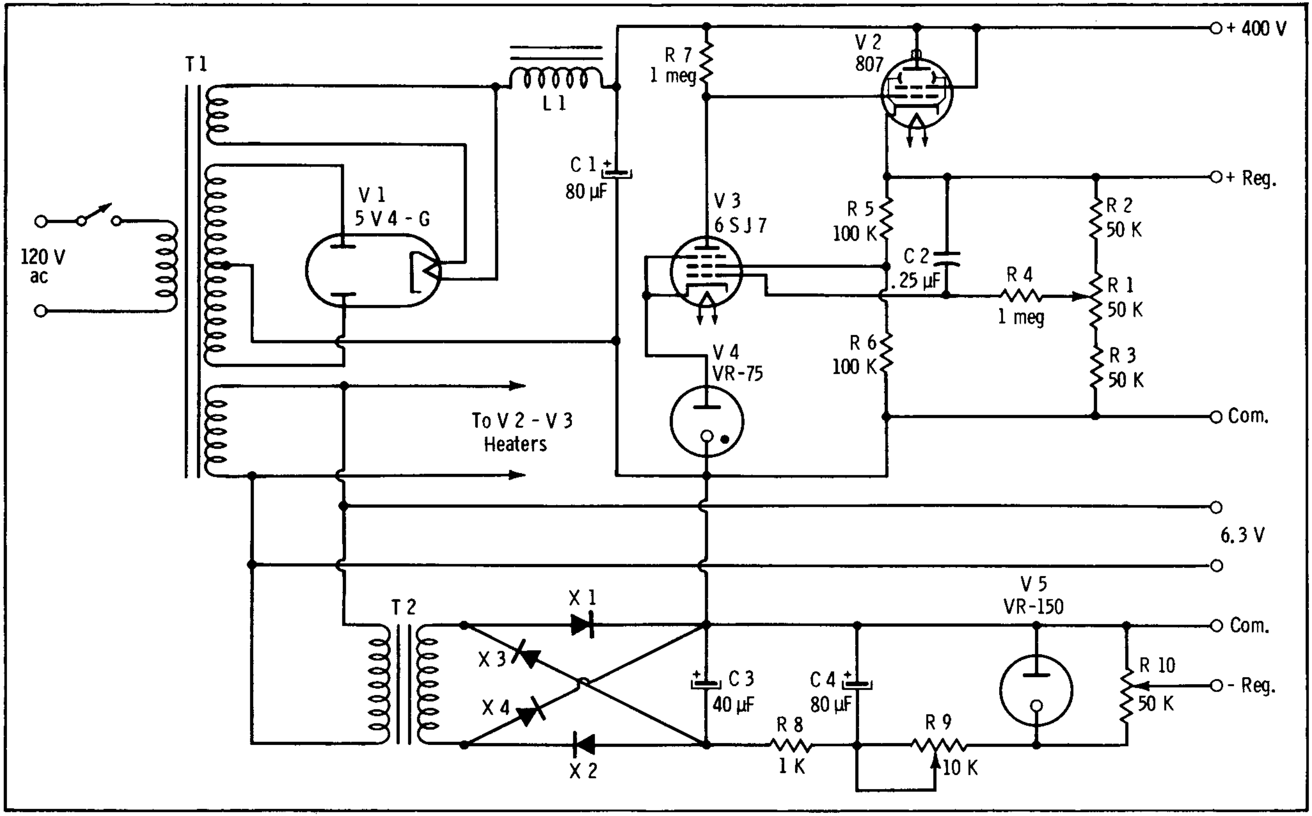


Fig. 4-7. Schematic of regulated power supply.

Table 4-1. Parts List for Fig. 4-7

Item No.	Description
C1	80 μF, 450 volt electrolytic capacitor
C2	.25 μF, 600 volt paper capacitor
C3	40 μF, 150 volt electrolytic capacitor
C4	80 μF, 150 volt electrolytic capacitor
RESISTORS	
R1	50K, 1 watt carbon potentiometer (linear taper)
R2	50K, 1 watt carbon fixed resistor
R3	50K, 1 watt carbon fixed resistor
R4	1 meg, 1 watt carbon fixed resistor
R5	100K, 1 watt carbon fixed resistor
R6	100K, 1 watt carbon fixed resistor
R7	1 meg, 1 watt carbon fixed resistor
R8	1K, 5 watt wirewound resistor
R9	10K, 5 watt potentiometer
R10	50K, 5 watt potentiometer
TUBES	
V1	5V4G tube
V2	807 tube
V3	6SJ7 tube
V4	VR-75 tube
V5	VR-150 tube
TRANSFORMERS	
T1	Power transformer (Stancor PC-8412, or equiv.)
T2	Low-voltage transformer (Stancor P-6134, or equiv.)
CHOKE	
L1	Filter choke (Stancor C-1001, or equiv.)
DIODES	
X1, X2, X3, X4	1N1222 silicon diode (or 1N4004)

The amplified error signal is applied to the control grid of the series tube, V2, where it controls the amount of current applied to the load.

In operation, if an increase in load current occurs, the voltage developed across the voltage divider, R1-R2-R3, will drop. Likewise, the voltage at the slider of the voltage-control potentiometer, R2, will drop, lowering the positive voltage applied to the control grid of the error amplifier, V3. Since the cathode of V3 is held at a constant voltage by the voltage reference tube, V4, the control grid of V3 becomes less positive with respect to its cathode. This will decrease the V3 plate current, resulting in a smaller voltage drop across plate load resistor R7. This decreased voltage drop across R7 will cause the plate of V3 to become more positive. Since the plate of V3 is directly connected to the control grid of V2, this control grid will become more positive with respect to its cathode, and V2 will allow more voltage to be developed across the load. Should the load voltage rise, the reverse of the foregoing action will occur.

BREADBOARDS FOR SEMICONDUCTOR CIRCUITS

The techniques involved in semiconductor breadboarding are necessarily different than those for vacuum tubes. The smaller physical size of semiconductors and their related components allows different breadboarding techniques.

Typical Semiconductor Breadboards

Fig. 4-8 shows a representative type of breadboard designed for use with semiconductor devices.

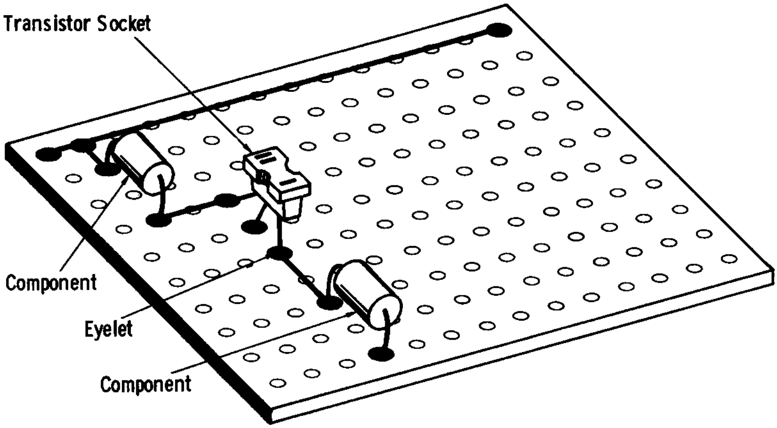


Fig. 4-8. Perforated-board breadboard.

The breadboard is usually made of perforated phenolic. Electrical and mechanical tie-points are formed with brass eyelets. Component leads are inserted through these eyelets and soldered in place. For minimum wear on transistor leads, transistor sockets may be used, with the socket terminals brought out to eyelets for making connections to the other circuit components.

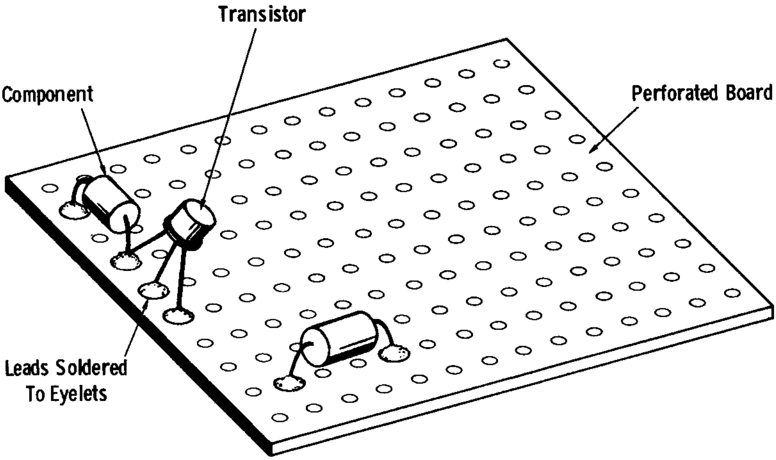


Fig. 4-9. Variation of Fig. 4-8.

Fig. 4-9, a variation of Fig. 4-8, shows the semiconductors soldered directly to the eyelet tie-points.

Commercially Available Breadboards

Several manufacturers market electronic breadboards at reasonable costs. Fig. 4-10 shows one example.

In addition to the complete breadboard kits, there are individual components designed especially for breadboarding steups. Fig. 4-11 shows a few of these.

An Integral Power Supply Breadboard For Semiconductors

This integral breadboard is similar to the vacuum-tube integral power supply breadboard described earlier. However, this breadboard is designed especially for semiconductor circuit development.

As shown in Fig. 4-12, the integral power supply breadboard consists of a variable low-voltage dc power supply mounted at one end of an aluminum chassis. A portion of the chassis opposite the supply is cut out so that a piece of perforated board may be mounted.

Fig. 4-13 is the schematic diagram of the regulated power supply. Let's briefly examine its operation.

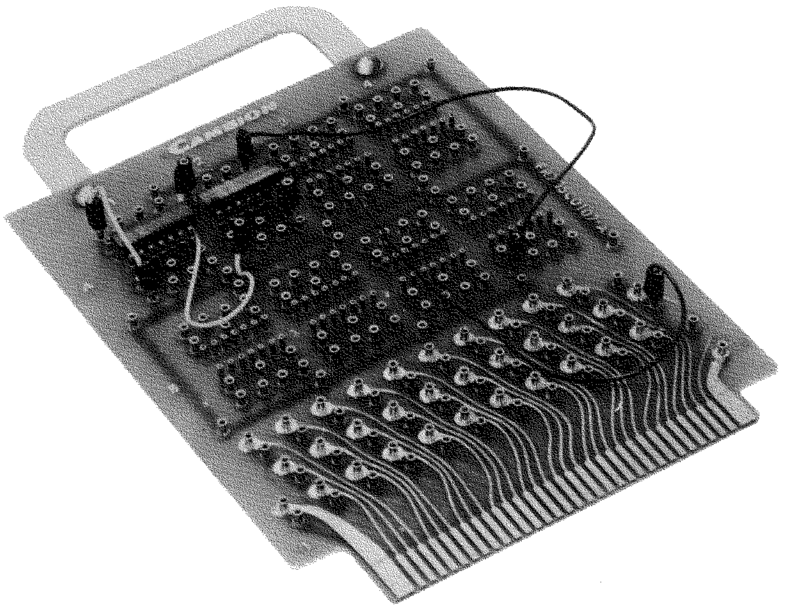


Fig. 4-10. Commercial breadboard.

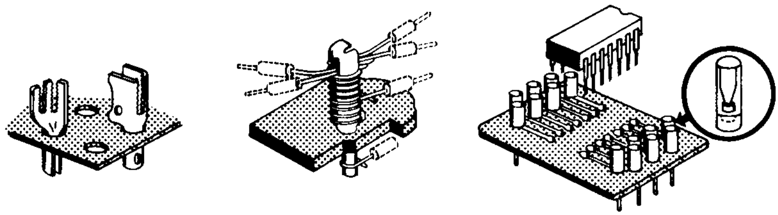


Fig 4-11 Commercial breadboard components.

When 120 volts are applied to the primary of the power/isolation transformer T1, 25 volts are developed across the secondary and applied to the full-wave bridge rectifier, consisting of X1, X2, X3, and X4. The pulsating direct-current output from the rectifier is filtered by C1.

The negative voltage output from the rectifier is applied to the collector of transistor Q1. The collector of Q1 is connected to the negative output terminal of the supply.

The negative output from the rectifier is also applied to the voltage divider, R1 and R2. A second filter capacitor (C2) is connected at the junction of R1 and R2 which further enhances the filtering. The slider of the voltage-

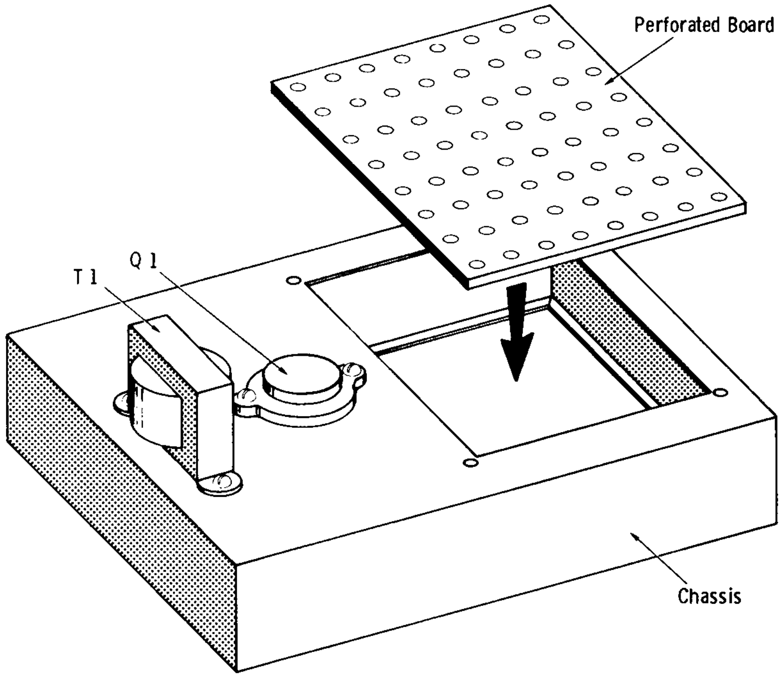


Fig. 4-12. Integral power-supply breadboard.

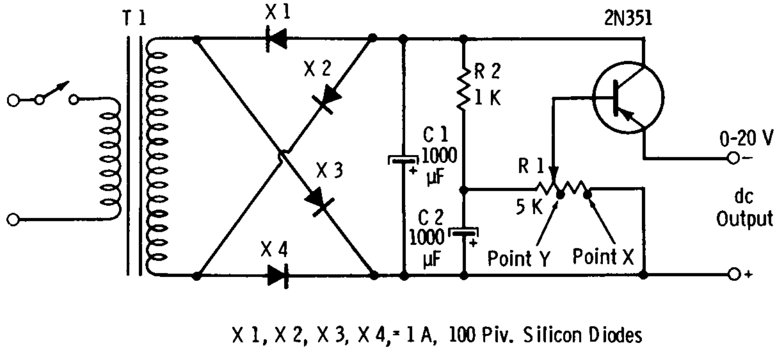


Fig. 4-13. Low-voltage power supply.

control-potentiometer, R1, is connected to the base of Q1. As the slider of R1 is varied, the voltage applied to the base of Q1 is also varied from 0 volts to approximately 23 volts.

In operation, when the slider of R1 is set at point X, the base of Q1 receives no current and Q1 is cut off. Since there is no current through Q1, there will be no voltage at the supply output terminals.

As the slider of R2 is moved toward point Y the base bias applied to Q1 will increase from 0 mA, and Q1 will become forward-biased. As a result, there will be collector current through Q1, and a voltage will be developed across the output terminals of the supply. The amount of base bias for Q1 and hence the supply's output is thus determined by the setting of R1.

The supply will furnish an output voltage ranging from 0 to 20 volts, at 200 mA, and somewhat higher at loads below 50 mA.

CHAPTER 5

Semiconductor Project Construction Techniques

The majority of hobby semiconductor projects use relatively low-power transistors. Since these transistors are equipped with wire leads, the simplest way of connecting them into the circuit is by simply soldering their leads directly into the circuit. When doing this, there are several precautions that should be observed. First, the leads to the transistor should be kept as long as possible, to minimize the heat that is conducted into the transistor when it is being soldered into place. Under no circumstances should the leads be cut shorter than ½-inch from the body of the transistor.

WORKING WITH TRANSISTORS

When soldering a transistor into the circuit, it is a good idea to grasp the lead being soldered with a pair of fine-nose pliers as shown in Fig. 5-1. The pliers act as a heat sink, conducting heat away from the transistor.

Fig. 5-2 shows a clip-on heat sink that can be used in place of a pair of pliers. Resembling an alligator clip with flat jaws, the heat sink is clipped to the lead being soldered, thus leaving the hands free to work.

When handling any semiconductor device, keep in mind that, while they are quite rugged mechanically, they can be damaged easily if they are dropped.

Semiconductor leads should not be flexed unnecessarily because they can break off. By the same token, when bend-

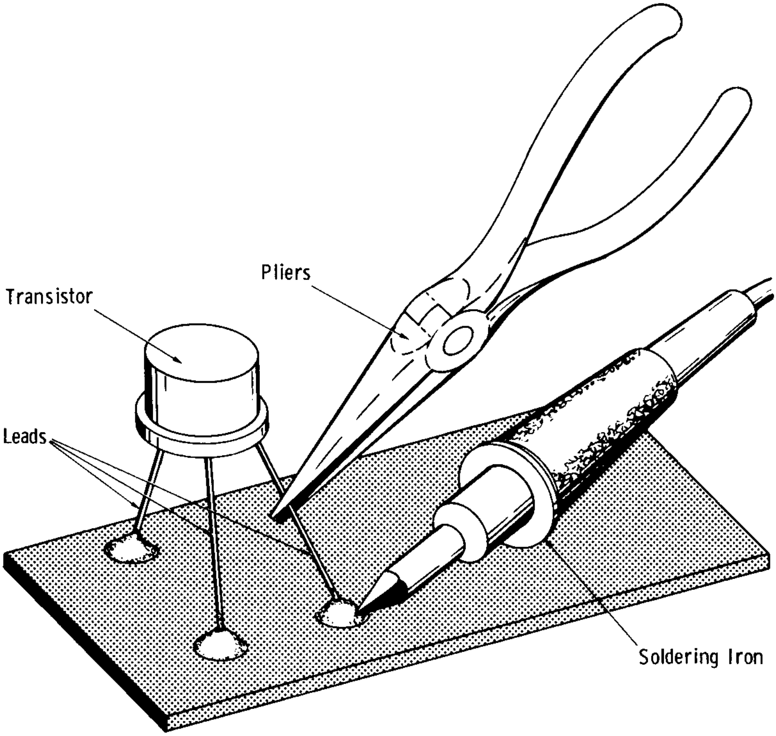


Fig. 5-1. Using pliers as a heat sink.

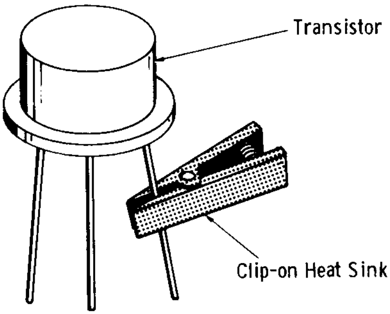
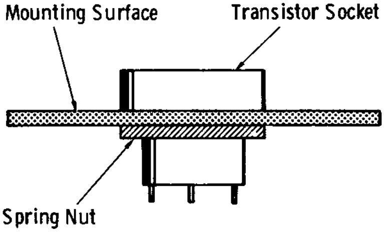


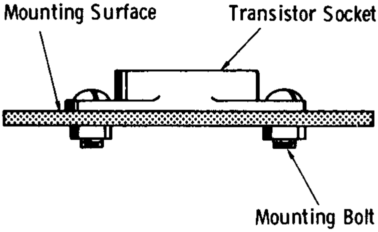
Fig. 5-2. Clip-on lead heat sink.

ing a semiconductor's lead, do not make the bend closer than $\frac{1}{8}$-inch from the point where the leads enter the body of the semiconductor. Otherwise, the seal where the lead enters the semiconductor may be broken, leading to early failure of the semiconductor.

If a number of different transistor types are to be checked for performance, the use of transistor sockets is highly recommended; thus, the resistor leads will not be subjected to continual heating and flexing during the soldering operation.



(A) Socket secured with spring-nut.



(B) Socket held with two small screws.

Fig. 5-3. Methods of mounting small transistor socket.

Fig. 5-3 illustrates how two of the more common sockets for small transistors are mounted. The socket type shown in Fig. 5-3A is mounted by passing the socket through a hole and securing it in place with a spring-nut.

The socket shown in Fig. 5-3B is mounted in a similar manner, with the exception that it is held in place by two small screws.

POWER TRANSISTOR MOUNTING

It is common practice to insert power transistors into sockets, since they are usually too heavy to be sturdily supported by their leads, and it is generally necessary to place the body of a power transistor against a metallic surface which will act as a heat sink.

Fig. 5-4 shows a common method of mounting a power transistor. Note the use of the mica insulating washer placed between the body of the transistor and heat sink. This is necessary since the collector of the transistor is internally connected to the transistor case, and thus, the case of the transistor must be insulated from the heat sink (which is generally at ground potential) to avoid a short circuit between the transistor collector and the heat sink.

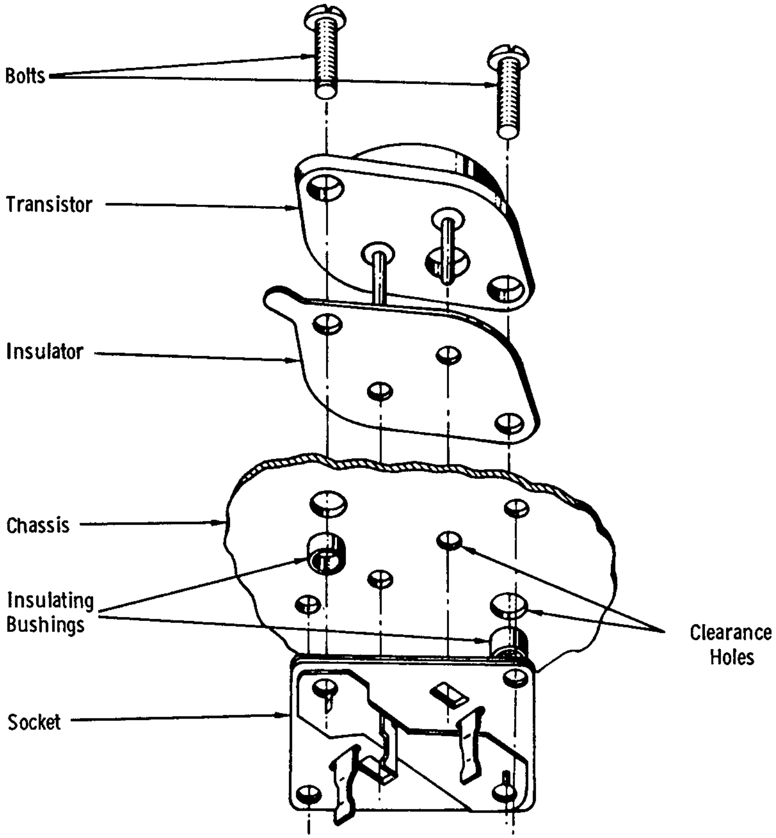


Fig. 5-4. Method of power transistor mounting.

In cases where the transistor collector is at the same potential as the heat sink, the insulating washer may, of course, be omitted.

Heat Sinks

When a transistor has a collector dissipation rating of over 500 mW, a heat sink is usually required. Power transistors are designed so that they may easily be attached to a metal plate or chassis of the equipment in which they are used. This relatively large metal surface then serves as the heat sink.

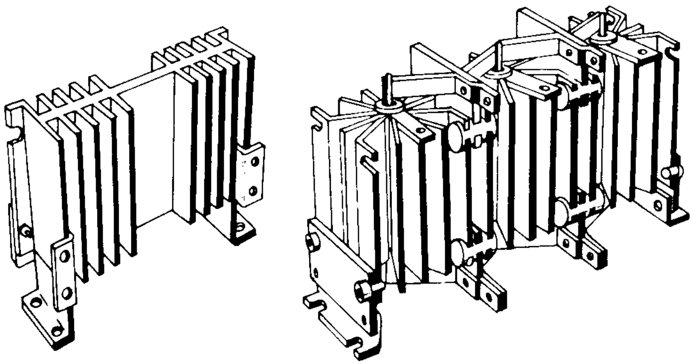


Fig. 5-5. Transistor heat sinks.

Fig. 5-5 shows two types of heat sinks which are commercially available. Note the fins that efficiently radiate heat absorbed from the transistor. These heat sinks may be purchased with holes already drilled for the acceptance of the more common types of power transistors.

When mounting a power transistor on a heat sink, it is a good idea to spread a thin layer of silicone grease on the area of the transistor where it touches the heat sink. This grease, which may be purchased especially for this purpose, aids in the transfer of heat from the transistor to the heat sink.

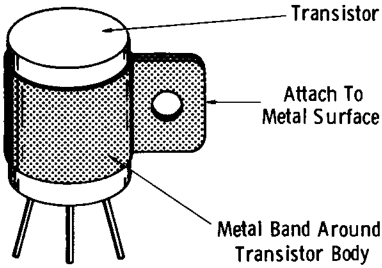


Fig. 5-6. Small transistor heat sink.

Fig. 5-6 shows a method of providing a heat sink for lower-power (250-500 milliwatt) transistors. A band of aluminum is fashioned to fit around the case of the transistor. The tab is then bolted to the metal chassis or other heat sink. Since the collectors of most of these small transistors are isolated from the case, no insulation is needed between the transistor case and band.

CHAPTER 6

Miniaturization and Microminiaturization Techniques

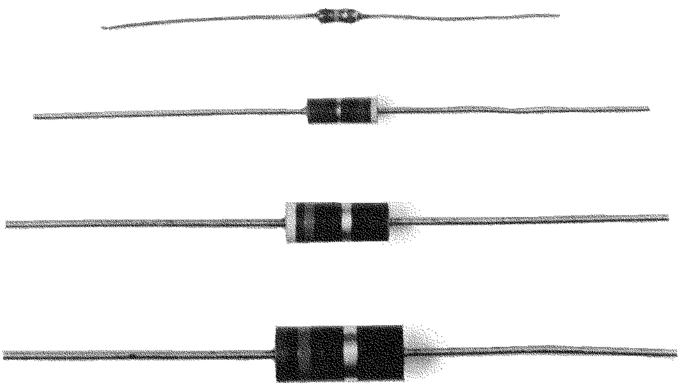
In this Chapter, we are going to examine the techniques used in the fabrication of miniature and microminiature electronic circuits. The advent of the transistor made possible the construction of extremely small electronic devices which were not feasible with the more bulky and mechanically fragile vacuum tube. The electronic experimenter can readily obtain miniature electronic components to assemble truly diminutive electronic gear.

MINIATURE ELECTRONIC COMPONENTS

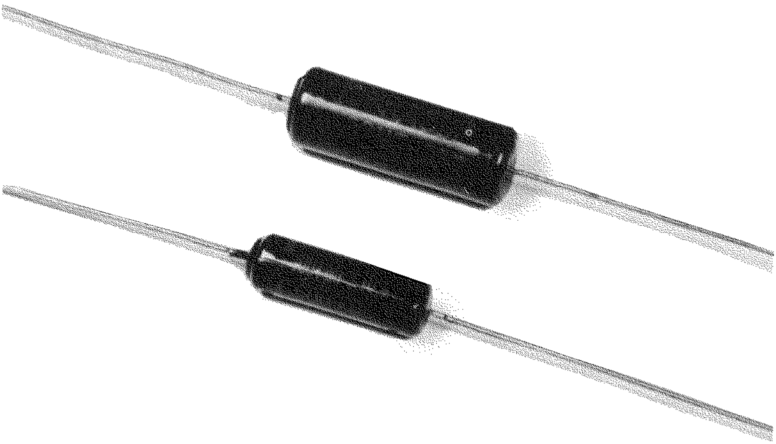
Resistors, capacitors, transformers, and speakers are some of the components available in miniature form, at reasonable cost.

Resistors

Resistors suitable for miniature and subminiature circuitry are available in a number of types including carbon composition and deposited metal film. Fig. 6-1 shows miniature carbon composition and carbon film resistors. The $\frac{1}{8}$ watt carbon resistors are commercially available with ohmic values ranging from 0.24 ohm to 22 megohms. Typical metal-film resistors are available in ohmic values ranging from



(A) Carbon-composition resistor.



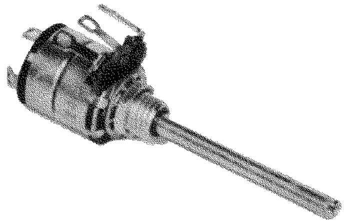
(B) Deposited-film resistor.

Fig. 6-1. Miniature resistors.

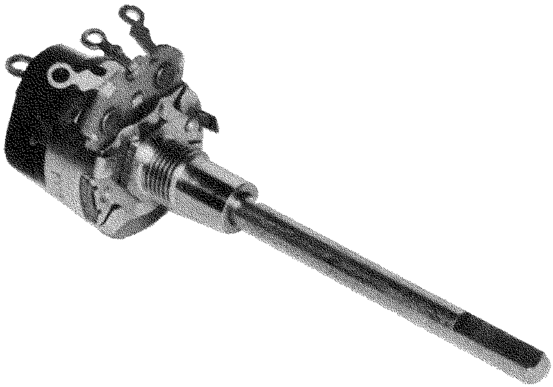
30.1 ohms to 1.5 megohms. Carbon composition resistors are satisfactory in most applications where precise long-term stability is not required. Deposited metal-film resistors offer closer ohmic tolerances and greater stability over long periods of time—at, of course, a higher cost.

Potentiometers

Variable resistors and potentiometers, as well as resistors, are in diminutive sizes.



(A) 1K to 1M potentiometer.



(B) 1K to 500K potentiometer.

Fig. 6-2. Miniature carbon-composition potentiometers.

Fig. 6-2 shows two types of miniature carbon composition potentiometers. The type shown in Fig. 6-12A is available in ohmic values ranging from 1K to 1M. Power dissipation for this type is ½ watt.

The potentiometer shown in Fig. 6-2B is available in ohmic values ranging from 1000 ohms to 500K. Power dissipation is $\frac{1}{2}$ watt.

Transformers

Fig. 6-3 shows one type of miniature transformer designed for the audio frequency portions of transistor circuitry.

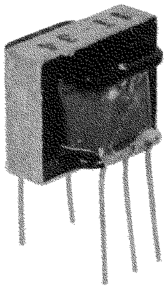


Fig. 6-3. Subminiature audio transformer.

These transformers are available with a wide range of characteristics. Typical of these are audio input, audio coupling, audio drive, and audio output. Impedance values range from 30k ohms for audio input and interstage transformers to 1k ohms to 4 ohms for drive and output transformers.

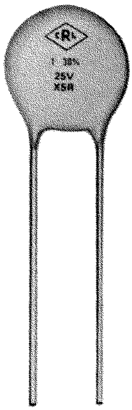
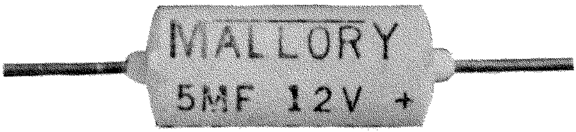


Fig. 6-4. Miniature high capacitance capacitor.

Courtesy Centralab Div., Globe-Union, Inc.

Capacitors

Fig. 6-4 shows a typical disc-ceramic capacitor that is commercially available for miniaturized transistor equipment. These capacitors are available in a wide range of capacitances, voltage ratings, tolerances, and temperature coefficients.



Courtesy Mallory Capacitor Co., Div., P. R. Mallory & Co., Inc.

Fig. 6-5. Miniature tubular electrolytic capacitor.

Fig. 6-5 illustrates a miniature electrolytic capacitor suitable for miniature circuitry. Capacitance values usually range from 1 μF to 200 μF with voltage ratings of between 3 and 150 volts.

RF Chokes (Radio-Frequency Chokes)

Fig. 6-6 shows an rf choke which is suitable for use in miniaturized equipment.

Fig. 6-6. Miniature rf choke.

The small size of these rf chokes is made possible by placing their windings on ferrite cores which greatly increase their inductance for a given number of turns.

Miniature Speakers

Fig. 6-7 shows a speaker suitable for use in miniature receivers, amplifiers, etc. The diameter of the cone is only 1½ inches.

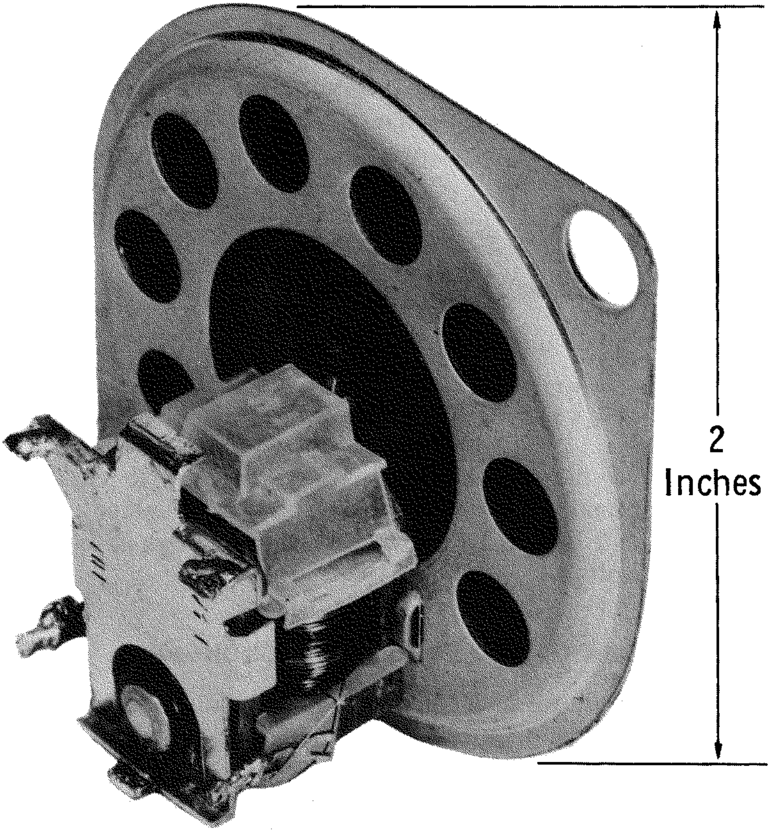


Fig. 6-7. Miniature speaker.

Miniature I-F Transformers

Fig. 6-8 shows one miniature i-f (intermediate-frequency) transformer. These transformers are suitable for use in miniaturized receivers.

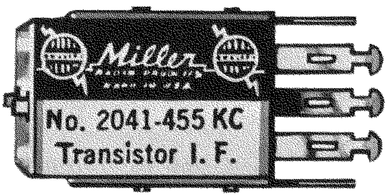
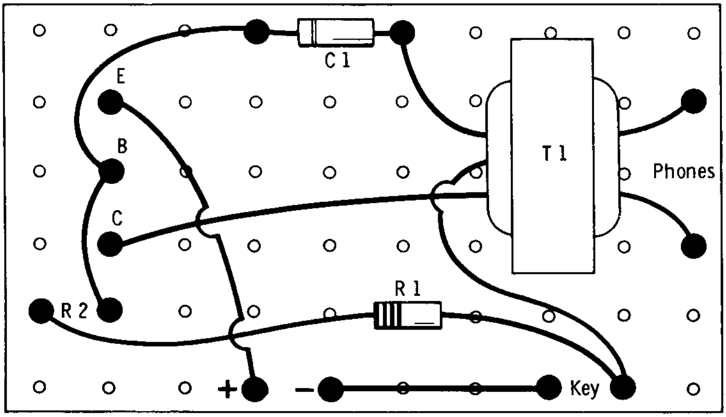


Fig. 6-8. Miniature i-f transformer.

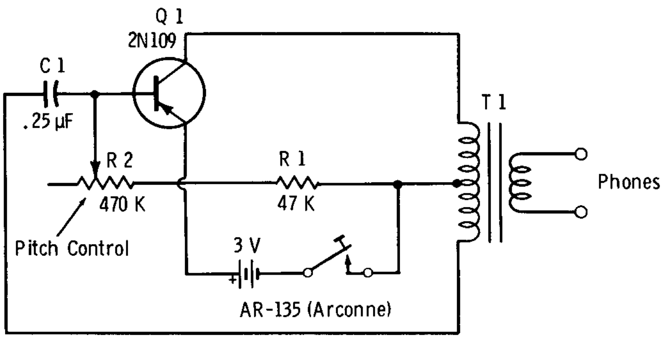
Courtesy J. W. Miller Co.

PHENOLIC PERFORATED BOARD AS CHASSIS FOR MINIATURE PROJECTS

One of the simplest methods of miniature project construction is shown in Fig. 6-9. A piece of perforated phenolic



(A) Circuit board layout.



(B) Schematic representation.

Fig 6-9. Miniature code oscillator.

board, just large enough to contain the project components, is used. The components are arranged as closely as possible to each other, with eyelets being used as the electrical and mechanical tie points ("flea clips" can also be used). The project shown in Fig. 6-9A is a miniature code practice oscillator. The schematic diagram of the oscillator is shown in Fig. 6-9B.

Phenolic perforated board makes an ideal chassis for miniature circuits as it can be easily cut to any desired shape, and its evenly spaced holes make component layout easy.

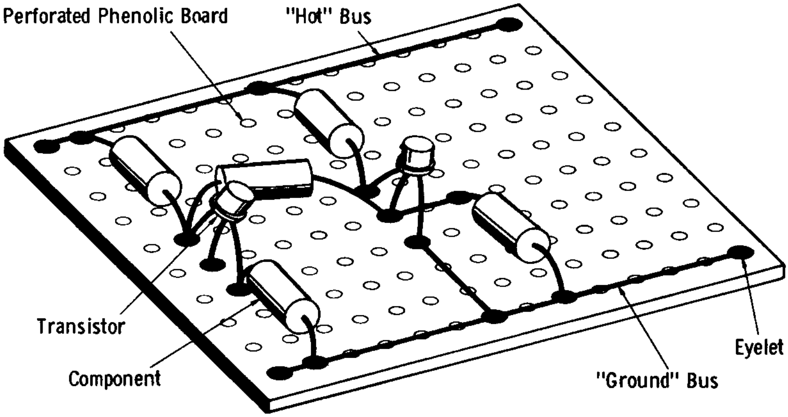


Fig. 6-10. Practical component layout.

Fig. 6-10 shows a method of component layout on perforated board which provides a logical compact arrangement for easy assembly and testing of the completed unit. As shown in Fig. 6-10, a length of heavy (No. 14 or No. 16) base copper wire is run along opposite sides of the board. One of these serves as a "common" or ground bus to which all circuit grounds are tied. All + or − supply voltage points in the circuit are connected to the other wire. Transistors are mounted midway between the two buses as shown, with circuit elements, such as emitter-bias resistors, collector-lead resistors, etc. being connected between their respective transistor terminals and the appropriate bus.

Stacked Perforated Board Miniature Assemblies

Fig. 6-11 shows an arrangement where individual perforated board miniature assemblies are stacked—one above the other. This permits an even greater component density, and is particularly adaptable when several circuit sub-

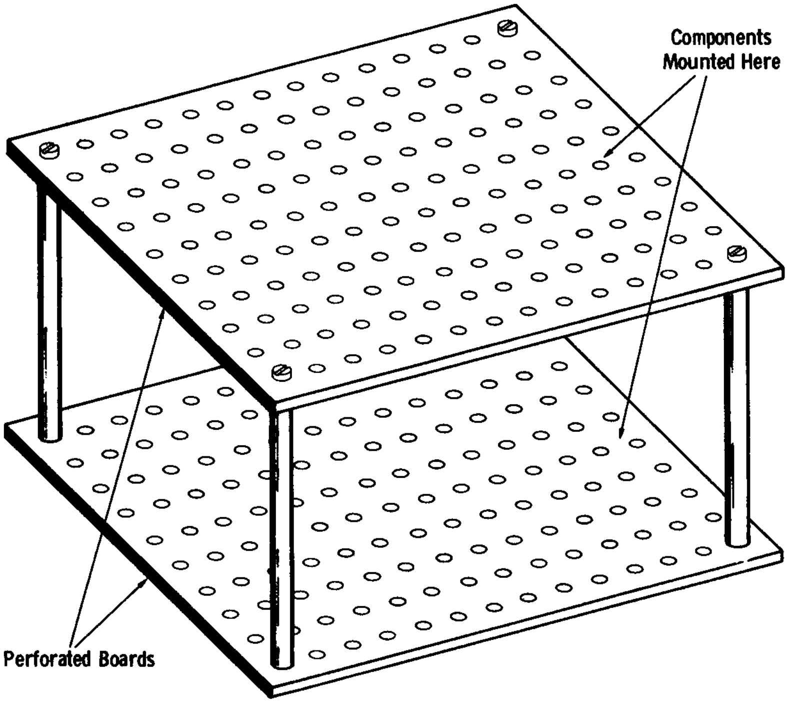


Fig. 6-11. Stacked perforated board.

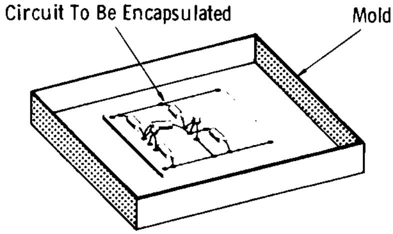
assemblies—one on each wafer—are combined to form a complete circuit.

The individual perforated board wafers are separated by a length of bus wire placed through a hole in each corner of the boards, and secured in place with a drop of epoxy cement.

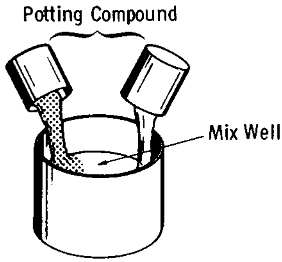
ENCAPSULATING MINIATURE CIRCUITS

It is often desirable to encapsulate a finished piece of miniaturized electronic equipment to offer protection from the surrounding environment as well as often adding to its appearance.

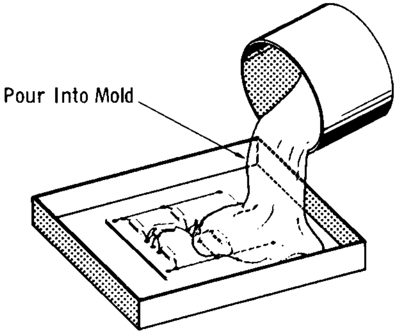
Fig. 6-12 shows a simple method of encapsulating a miniature electronic circuit. The circuit is placed in a container, such as a small plastic box, which is slightly larger than the circuit being encapsulated (Fig. 6-12A).



(A) Placing circuit in mold.



(B) Mixing potting compound.



(C) Pouring potting compound in mold.

Fig. 6-12. Encapsulating a miniature circuit.

Next, the encapsulating compound is prepared. A suitable compound for this purpose is *Silastic RTV,* manufactured by the Dow Corning Corp. This compound comes in two parts which are mixed together prior to pouring into the mold. When mixing the parts be sure that they are thoroughly blended (Fig. 6-12B). Pour the mixture slowly into the mold so as not to form air bubbles. See Fig. 6-12C.

Dow Corning manufactures several variations of the basic Silastic. One type will cure in approximately 30 minutes, while the other takes at least 24 hours to fully cure.

When the Silastic has thoroughly cured, the encapsulated assembly can be easily removed from its mold.

If a more rigid encapsulation is required, the circuit can be encapsulated in an epoxy compound. As in the case of the Silastic compound mentioned previously, most epoxys come in two parts, the epoxy resin and the catalyst. These two are mixed together and poured into a mold in which the circuit assembly has been placed.

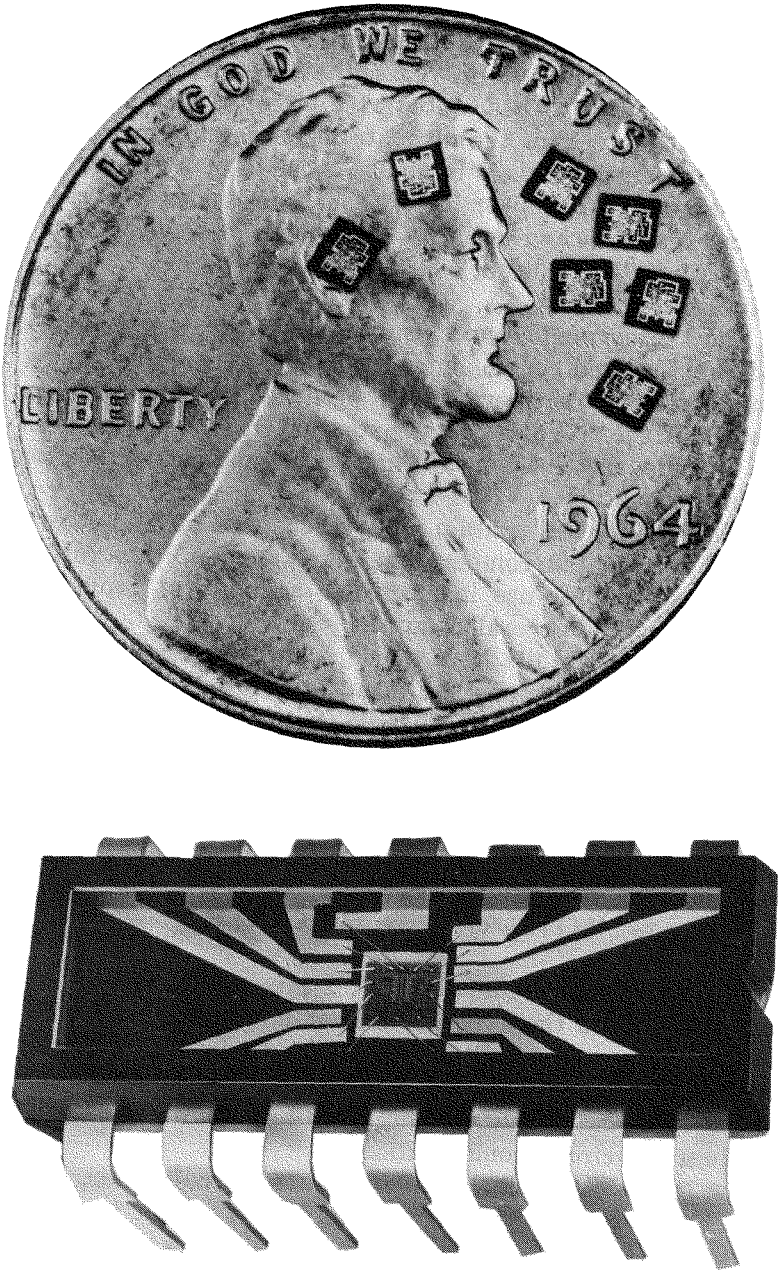


Fig. 6-13. Typical integrated circuits.

MICROMINIATURIZATION

During the last several years, the big word in the electronics industry has been integrated circuits. These devices offer what is perhaps the ultimate in microminiaturization.

An integrated circuit basically consists of a number of individual active semiconductors, such as diodes and transistors, found on and within a single chip of semiconductor material, such as silicon. Fig. 6-13 shows the basic idea of an integrated circuit.

Since integrated circuits contain a number of transistors and their related components, it is easy to conceive that a complete radio receiver can be produced in a small chip about half the size of a postage stamp. (Of course, this does not include the antennas, tuning and volume control, or loudspeaker.)

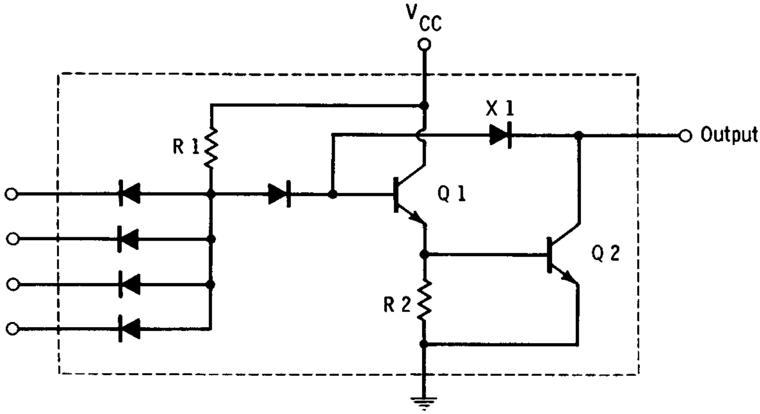
Since computers contain many thousands of transistors, diodes and related components, integrated circuits (originally designed for use in electronic computers) provide a great reduction in overall computer size.

Integrated circuits have more recently become available as linear circuit elements. Linear integrated circuits may be used as amplifiers, both audio-frequency and radio-frequency, and as a result, are finding their way into industrial and consumer products.

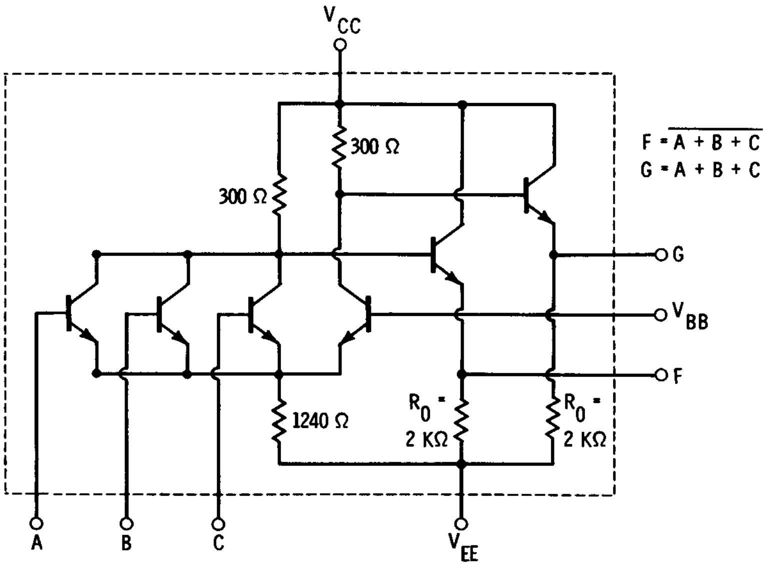
EXPERIMENTING WITH INTEGRATED CIRCUITS

Due to volume production, linear integrated circuits are now available to the experimenter at low cost. These inexpensive integrated circuits are available in several different physical configurations and lead arrangements, depending on the type and manufacturer. Fig. 6-14 shows two types of integrated circuit configurations.

Due to the close spacing of integrated circuit leads, care must be taken when soldering them into a circuit to avoid short circuits between leads. Fig. 6-15 shows a socket designed especially for integrated circuits. The use of this socket makes it easy to attach leads to the integrated cir-



(A) NOR circuit.



(B) OR-NOR circuit.

Fig. 6-14. Schematic of typical integrated circuits.

cuit terminals. It is also easy to substitute different integrated circuits in the socket to check performance.

Fig. 6-16 shows a handy setup which simplifies experimenting with integrated circuits. The leads which are attached to the integrated-circuit socket terminals are connected to Fahnestock clips for easy connection to other parts

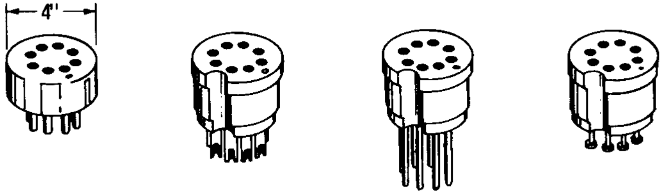


Fig. 6-15. Sockets for integrated circuits.

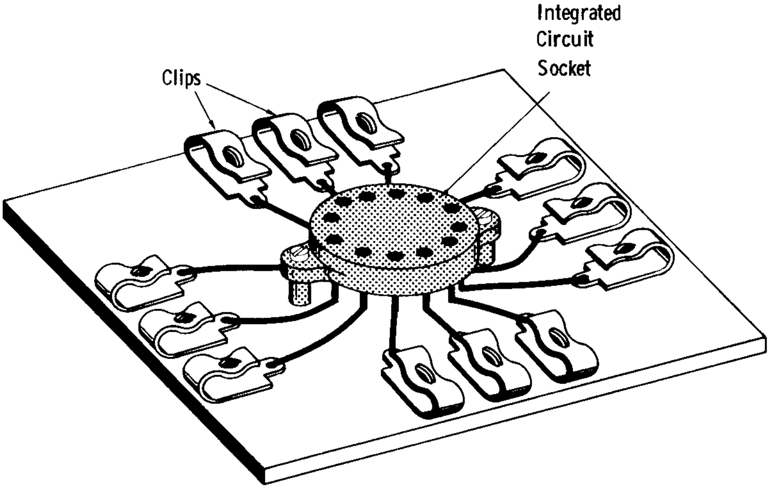


Fig. 6-16. Mounting integrated circuit socket for experimental use.

of the experimental project. The socket is secured to a small piece of wood, plastic, or other insulating material with epoxy cement.

When working with integrated circuits, it should be kept in mind that they are, with a few exceptions, very low power devices. As a result, be sure to check the maximum ratings of the integrated circuit carefully before using it.

Index

D

E

F

G

H

I

K

S

T

U

V

W