


HOW TO BUILD
tiny
ELECTRONIC
CIRCUITS

Morris Moses

\$5.85
(in the U.S.)



**how to build
tiny electronic
circuits**

BY MORRIS MOSES

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Library of Congress Catalog Card No. 63-21054



contents

CHAPTER

page

1

History of subminiaturization 7

Think "small". Those prefixes "sub" and "micro". History of subminiature electronics. Enter microminiaturization. The VARO program. The DOFL program. DOFL techniques. RCA microminiaturization program. Texas Instruments program. TI semiconductor solid components. The future—molecular electronics. Miniature, subminiature and microminiature techniques and the amateur. Sturdiness.

2

Subminiature components 19

Carbon-composition resistors. Deposited-film resistors. Wirewound resistors (fixed). Painted resistors. Variable resistors. Square trimmer resistors. Capacitors. Electrolytic capacitors. Aluminum electrolytics. Tantalum electrolytics. Solid tantalum electrolytics. Etched-foil tantalum electrolytics. Tubular sintered (wet-slug) tantalum electrolytics. Wire solid-tantalum electrolytics. What tantalums when? Ceramics. Monolithic ceramics. Paper capacitors. Mylar capacitors (polyester film). Mica capacitors. Painted capacitors. Glass capacitors. Variable capacitors. Inductive components. Subminiature and microminiature inductors. I.f. transformers. Subminiature and microminiature transformers. Rf coils. Printed or painted inductors. Miniature, and subminiature-acoustic transducers. Subminiature relays. Subminiature printed-circuit relay. Specialized transistors—microminiature. Semiconductor diodes. Micro-diodes. Sockets. Subminiature plugs and jacks. Micromodule sockets and plugs. Switches. Meters. Thermistors. Microminiature lamps. Photoelectric-subminiature devices. Crystals. Subminiature tubes. The Nuvistor. Cells and batteries. The Leclanche cell. Mercury cells. How to figure discharge time and currents. Other subminiaturized components.

3

Subminiaturized equipment 54

Radio "pills". Digital circuit modules. Low-frequency receiver. Sunglass radio. Subminiaturized oscillator wristwatch. Progress in subminiaturized amplifiers.

4

Techniques 65

Printed-circuit shortcuts. Using tapes for photo set-ups. Etching with ammonium persulfate. Fotoceram boards. Potting electronic assemblies. Potting with transparent dielectric "gel". The "module" idea. Paraplate module. Plus module. MECA module. Ceramic-base circuit plates. Tinkertoy modules. Homemade Tinkertoy modules. Circular Tinkertoy type modules. Miniature wiring arrangements. Micromodule system. Converting to micromodules. Leads and wafer positions. Homemade "micromodules". Subminiature multivibrator flasher. Micromodule three-stage amplifier. Additional micromodule techniques. "Homemade" micromodule accessories.

5

Practical miniature projects 92

Single-stage amplifiers. Direct-coupled n-p-n/p-n-p amplifier. Cascade voltage amplifier. "Aspirin-box" amplifier. I.f. amplifier. Two-stage i.f. amplifier. Meter extender. Microampere input relay. Rf relay. Phase splitter. Balanced transformerless phase splitter. Audio signal squitter. Audio/i.f. signal tracer. Single-frequency sine-wave generator. Matchbox code oscillator. Multiple-frequency oscillator. Phase-shift audio oscillator. Light-powered pillbox code oscillator. Self-excited 100-kc oscillator. 100-kc oscillator. 20-kc crystal oscillator. Transistor organ. Sine-wave clipper. Coincidence pulse circuit. Field-strength meter. Comparison photocell detector.

6

Practical subminiature devices 126

Sound-level meter. Subminiature tone generator. Two-transistor pocket radio. High-impedance input preamp. Class B push-pull amplifier. Three-stage R-C coupled amplifier. High-frequency receiver. FM tunnel-diode transmitter. Delayed action photoelectric relay. Thermistor thermometer. Transistor "vtvm's". Subminiaturized 3-transistor radio-control receiver. Testing the receiver. Pocket superhet. Superhet alignment without a signal generator. Aligning with an rf signal generator. Troubleshooting the set. Try making it smaller.

7

Construction and repair hints 158

Hand tools. Pliers. Soldering irons. Tweezers. Optical accessories. Knives and cutting tools. Abrasives for smoothing and polishing. Files. Probing and picking tools. Saws and saw blades. Clamps and clamping devices. Chemicals. Cements. Hand drills. Small power tools. Taps and reamers. Screwdrivers. Wrenches. Printed-circuit and subminiature repairs. Locating troubles. Precautions with components. Printed circuit and subminiature electronic soldering techniques. Desoldering. Care of soldering iron tips. Resistance soldering irons. Resistance-soldering techniques. Conduction vs resistance soldering—pro's and con's. Coil winding. Silver plating.

Introduction

For many centuries, it has been the custom of certain South American natives to shrink their enemies' heads. The electronic art has recently "gone native." Reducing the size of an electronic component is not as simple as shrinking heads, and boiling the components in hot water or scalding them with steam has seldom been known to produce any useful effects. Electronic component manufacturers have had to resort to many ingenious techniques to manufacture Lilliputian circuit components and hardware for miniaturization work.

Some confusion still exists in definitions for miniature, sub-miniature and microminiature electronics. About the only practical yardstick for comparison is the relative component densities—the number of components in their circuits that can be put into a cubic inch. Miniature electronics seems to cover less than one component per cubic inch. Subminiature electronics would fall in the range of one to ten components per cubic inch, and microminiature electronics encompasses component densities well over thousands per cubic inch.

This work is intended to bring "miniaturized" electronics home to the amateur, experimenter and service technician, and to take the mystery out of "making it smaller." In short, it is a volume on the "how to do it" of electronic miniaturization. Many of the circuits in this book will be familiar to you. And it is my hope that

you will no longer feel that small components and small circuit packages are costly oddities—especially after building many of the projects in this book. If I have succeeded in making you aware that subminiature electronics can be constructed without elaborate equipment—on a kitchen table, basement bench or in a garage shop—I will be amply rewarded.

As in the previous companion work on "Printed Circuits," a book is rarely the result of one person's efforts. Those contributing material are too numerous to mention. Special acknowledgment is due the valuable assistance of Mr. L. S. Preskill of Allied Radio, Mr. Harold Maltz of Lafayette Radio, Mr. Robert Callihan of Goodyear Atomic Corp. and Dr. Bertil Jacobson of the Karolinska Institute, Stockholm, Sweden.

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W8UVC

Chapter 1

History of Subminiaturization

Think "small"

Within the past 5 years, there has been a startling revolution in the electronics field. Components and circuits are rapidly shrinking, and the fields of subminiaturization and microminiaturization are opening up undreamt of vistas. Cigarette-package size superheterodynes are no longer "Buck Rogers" stuff, but reality.

The reader will be guided in this book through the wonderland of Lilliputian electronics, and he will be shown how it is entirely possible and practical to shrink electronic heads, so to speak.

Those prefixes "sub" and "micro"

Throughout the book, the terms "miniaturized," "subminiaturized" and "microminiaturized" will appear quite frequently. There is yet no die-hard, black-and-white definition for the point where one begins and the other ends. In March, 1957, at the IRE National Convention, Dr. Cleo Brunetti of the Stanford Research Institute defined microminiaturization as "the design of electronic equipment using solid-state and other nonthermionic devices to obtain another order of magnitude reduction in size and weight." In everyday use today, subminiaturization might include microminiaturization. Most electronics workers associate subminiaturization with the subminiature type flat-press hearing-aid tubes and circuits whose component densities are in

the order of 1 to 10 components per cubic inch. Later on, in Chapter 4, we will see how practical *microminiature* circuits can be constructed, and in Chapters 5 and 6, the reader will be shown how many of his favorite circuits can be reduced to subminiature size using easily obtained commercial parts.

History of subminiature electronics

Some of the earliest subminiature components were probably cousins to the "galena" button detector used in crystal radios in the early 1920's. About the late 1930's, the silicon diode had

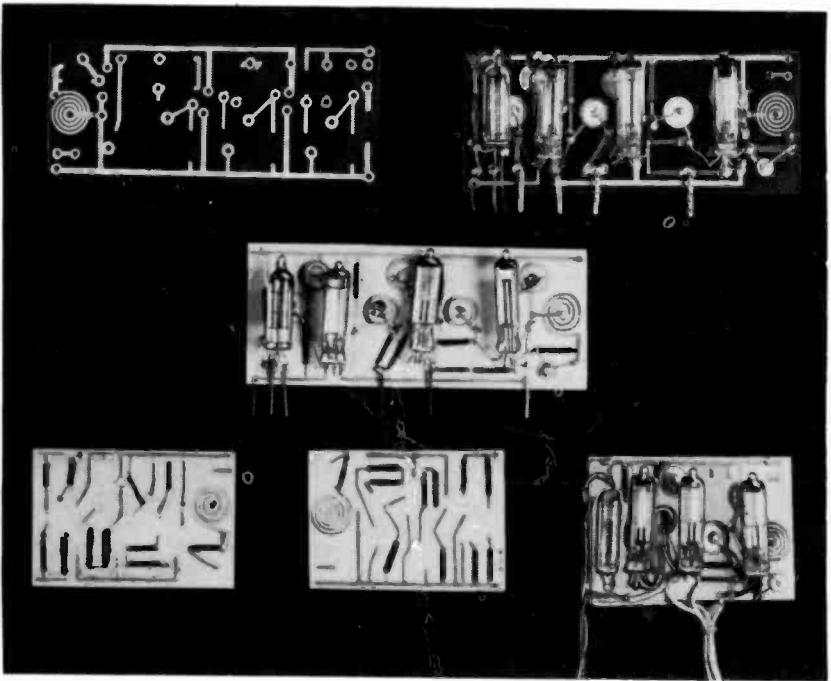


Fig. 101. *Miniature-tube circuits have spirals for inductors and painted resistors.*

found its way into early radars, and the subminiature hearing-aid tube made its first appearance about the time of World War II. Various electronic devices of World War II, notably the radio proximity fuze, spurred development of miniaturized components and their kindred technique, printed circuitry. Subminiature transmitters, amplifiers and receivers (Fig. 101) were developed in the late 1940's at the National Bureau of Standards.

Perhaps the biggest impetus to the subminiaturization effort came with the introduction of the transistor in 1949, and its large-scale manufacture in the early 1950's. Although many subminiaturized components were manufactured in small quantities in 1950, very few were produced in production runs of over 100 to 1,000 a year. Prices of early subminiatures were too high for the average manufacturer, experimenter and service technician, as witness the first point-contact transistors which sold for \$50 to \$100.

The 1950's brought new developments in manufacturing techniques. The idea of using magnesium, titanium, and zirconium compounds as dielectrics was exploited—even though work along these lines had been done in the early 1900's in Germany and in



Fig. 102. The problem of miniaturizing if transformers was made easier by having only one winding tunable.

1940's in the United States. Tantalum compounds were explored in detail by the Fansteel Co. of Chicago, pioneers in commercial production of this metal, and this led to developments in extremely small electrolytic capacitors.

High-quality ferromagnetics, including superpermeability silicon steels and ferrites, led to smaller and smaller inductive components such as the thumb-nail sized if transformer of Fig. 102.

The electronic industry here was going full blast on subminiature components by the late 1950's, and about 1955 the first signs of a quality subminiature component program appeared in Japan. Long recognized in the fields of electronics and electrical engineering, the Japanese caught on to inspection and quality control techniques. This, coupled with their large and extremely competitive labor forces, has made them a prominent factor in the subminiaturization program.

The stage was set—subminiaturization had arrived in an indisputably big way. Anyone could now buy a junction transistor for only a dollar or two.

Enter microminiaturization

Space in military electronic equipment has always been at a premium, and several electronics firms and various branches of the government embarked in the 1950's on an effort to shrink components one step further.

The VARO program

As early as 1951, the Varo Manufacturing Co. had the idea that subminiature electronics could be reduced even further in size and, from 1955 on, worked with government agencies and

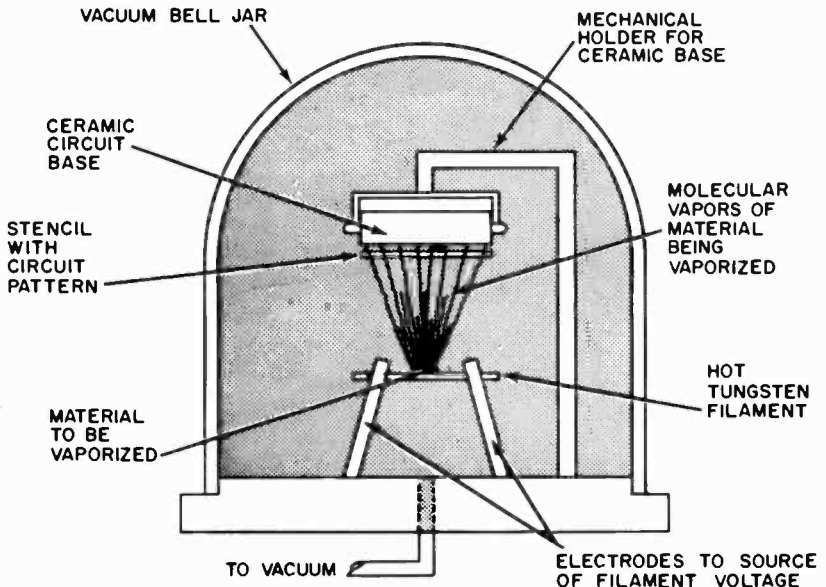


Fig. 103. Depositing thin films through a stencil is similar to spray painting. Metallic vapor settles on base plate and stencil. When stencil is removed from base, lines and other patterns on the base material form the circuits.

other private firms in this field. Earliest approaches were along the lines of vacuum deposition, thin films of conductors being built up to form patterns (Fig. 103). Gold and resistance alloys were used for conductors and resistors, and later on Mylar* films were used for insulators and dielectrics.

*Registered trademark, DuPont Corp.

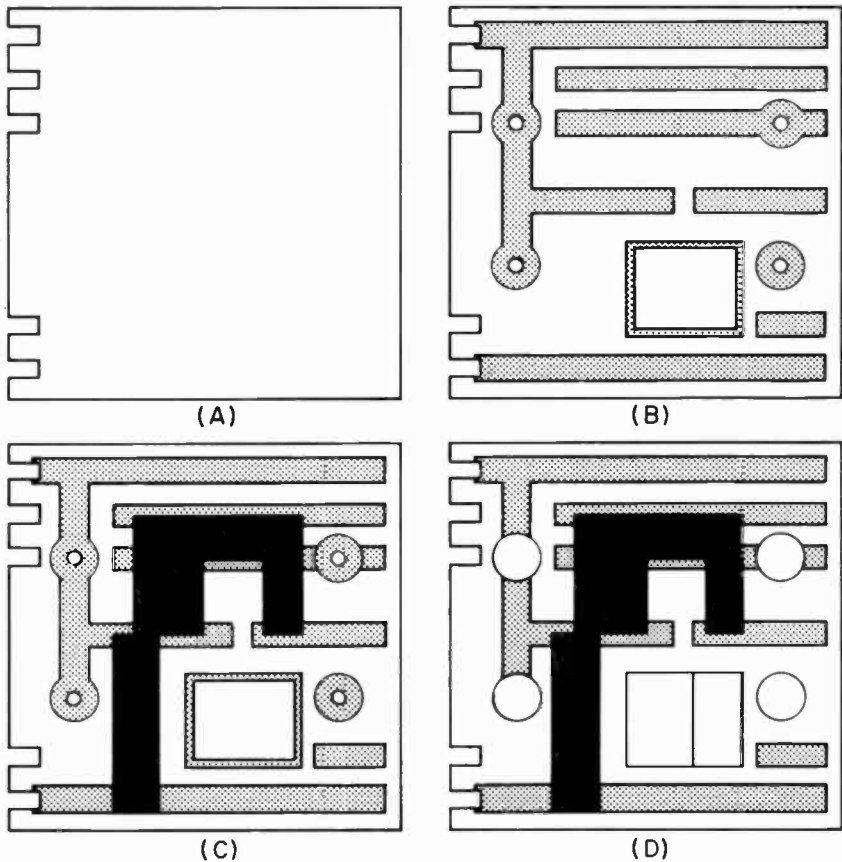


Fig. 104. Greatly enlarged, the basic wafer (A) has a circuit pattern applied (B). Additional processes (C) and (D) can be used to form circuit components like resistors and capacitors or just to apply capacitor dielectrics and insulating layers.

The DOFL program

Diamond Ordnance Fuze Laboratories, a branch of the Army Ordnance Corps, began work on an electronic parts "head-shrinking" program in early 1957. Conventional component and transistor manufacturers worked with the DOFL on new concepts in making electronic devices smaller. Wherever possible, component cases and supports were eliminated in the interest of "getting it smaller and lighter." Older printed-circuit techniques, similar to the Centralab AMPEC units were examined again for new ideas in ultra-small electronics packaging. The basic techniques of photoresist, vacuum, chemical and electro-

chemical deposition, silk-screen printing, machining, ceramic sintering and molding, cutting, etching and cementing were all brought into play on the challenging problem of component size reduction.

DOFL techniques

Base materials or substrates had to be found that would hold their dimensions and that were easily machined or formed. Among them were alumina, quartz, barium titanate and steatite.

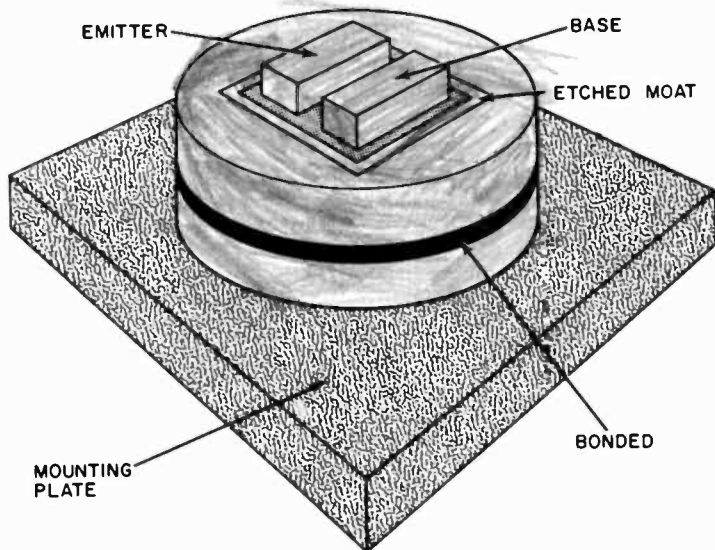


Fig. 105. The mesa transistor helped to reduce size. Any automatic machine process increases production, reduces costs and possible contamination of units that normally occurs in manual operations.

Steatite had already been used in units similar to Centralab's AMPEC's, but it was now cut into thin sheets resembling wafers—each wafer $\frac{1}{2}$ inch square and less than $\frac{1}{32}$ inch thick. These wafers were then notched at five points on one side and treated to produce microminiature circuits (Fig. 104).

Wires were silk-screened or painted on to the base material with silver ink and then fired on permanently in an oven. The problem of silver migration due to moisture on the plates was solved by hermetically sealing off the conductors with various plastics and waxes that would not let moisture through.

Resistors were silk-screened onto the base plates using plastic inks containing carbon black. If resistance values were too low, they were increased by roughing with a scribing tool. Resistors

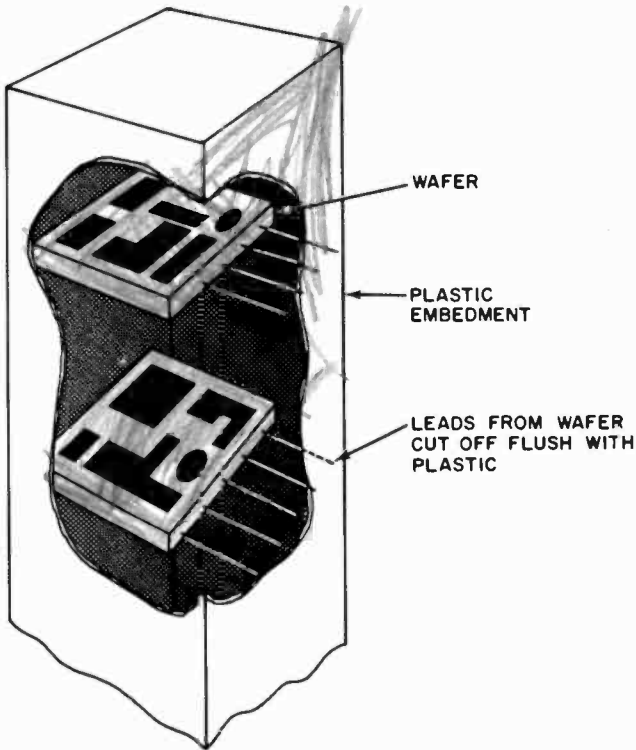


Fig. 106. Completed sterile unit is encapsulated as a complete circuit or stage. Defective units are easier to discard than repair.

that were too high were decreased in value with a hot air stream. Resistors were also injection-molded onto the base material.

Capacitors were made up using powdered barium titanates in a cement mixture which was rolled out like bread dough into a sheet just under $\frac{1}{32}$ inch thick. Drying shrank the sheet to about half this thickness, and it was then cut up into squares a little less than $\frac{1}{2}$ inch on a side. After several firings in an oven, these dielectric squares became capacitors with attached silver electrodes. The squares were then broken up into smaller squares about $\frac{1}{10}$ inch on a side. A typical $.01\text{-}\mu\text{f}$ capacitor was about

$\frac{3}{10}$ inch on each side—about 1/1,000 cubic inch in volume. These capacitors were put into the circuit using conductive cements.

Transistors, as we know them in three-dimensional form, were in for their share of shrinking also. A type of transistor known as a mesa (Fig. 105) was developed for use on the DOFL bases. The entire transistor was separated from the base material by a moat or groove over which the leads were made using vacuum deposits of aluminum.

After the components had been placed on each wafer, the wafers were connected with five lead wires in the five notches. A conductive cement was used again. Interconnecting each base unit or wafer was a problem, since the leads had to be brought close together if a compact assembly were to be produced. Fig. 106 shows how this problem was solved. Several wafers were encapsulated in plastic with the leads protruding. Then the leads were cut off, ground down flush with the surface of the plastic, and copperplated onto the exposed lead ends. This deposit was etched to produce the required circuit connections between lead ends.

RCA microminiaturization program

Early in 1958, the Army Signal Corps and RCA began a joint program toward the development of micromodules. This early work, begun primarily as a defense activity, has become a commercial civilian activity.

Practical aspects of the RCA micromodular technique are shown in Chapter 4, where the workings of a microminiaturization kit are explained in detail.

The basis of the RCA program was production of micro-elements which in turn were assembled to form complete micro-miniature working circuits. Resistors were designed for the range of 50 to 200,000 ohms with metallic oxide and deposited metal-alloy techniques. Capacitors were built for the micromicrofarad ranges, and tantalum electrolytics were developed for values in the low-voltage medium- μf range. Inductors with inductances between 1 μh and 2 millihenries were used as rf chokes and transformers, pulse transformers and L-C tank assemblies. A quartz crystal micro-element was designed for 45 mc. A diode equivalent to the type 1N277 was built as a micro-element along with the micro-element prototype transistors 2N109, 2N140 and 2N404.

The module assemblies first built included a 4.3-mc mixer,

49.4-mc rf amplifier, 4.3-mc if amplifier and limiter, 8-kc sawtooth generator and 45.1-mc crystal oscillator. To date, nearly 20 types of assemblies are commercially available.

Some of the objectives of the RCA micromodule program as it became commercially feasible were:

1. Reduction of size by an appreciable amount over present miniature equipment.
2. High-volume efficiency in packaging.
3. Variety of materials in the module.
4. Isolation of components.
5. Adaptability to mass production.
6. Money saving conventional and miniature components.
7. Better performance and higher reliability.

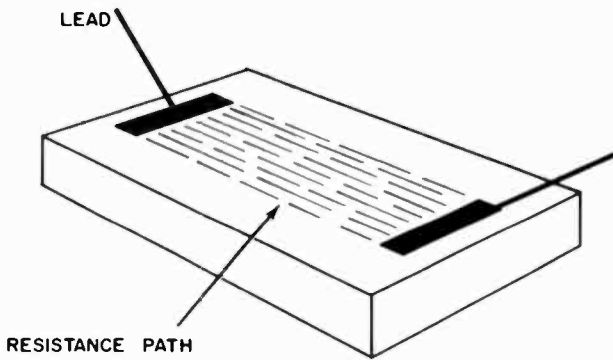


Fig. 107. *Semiconductor material (greatly enlarged) can be used for resistors and capacitors as well as transistors.*

Texas Instruments program

Early in 1959, Texas Instruments Co. developed the concept of "semiconductor solid circuits."* The idea was to set up and shape paths on a semiconductor wafer in such a way as to form amplifiers, oscillators, rectifiers and other conventional circuit elements—all on one integral base. The very obvious advantage is that it supplies an entire circuit with virtually no interconnecting wires between components!

TI semiconductor solid components

Resistors are made up by the bulk resistance of the semiconductor itself, using the basic resistance relation that a resistor's

*Registered trademark, Texas Instruments.

value is equal to the resistivity (ohms per cubic inch) times length, divided by cross-sectional area. Another way to put it is that longer wafers give higher resistor values, thicker ones, lower values (Fig. 107).

Capacitors are formed by using the capacitance effect in a p-n junction (Fig. 108). These p-n capacitors are also "half" tran-

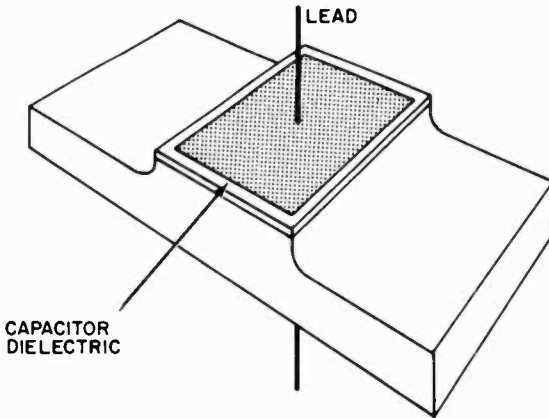


Fig. 108. Simple capacitor is actually a p-n semiconductor diode (junction).

sistors or diodes, so polarity must be watched just as with electrolytic capacitors, if they are to work properly.

There are some limitations on the ranges of present component values if extreme microminiaturization is desired. For instance, the upper range of resistance is near 20,000 or 30,000 ohms, and capacitors are held to a few thousand $\mu\mu\text{f}$ for highest component densities.

R-C combinations (Fig. 109) combine the techniques of Figs. 107 and 108.

Diffusing other elements onto a base material will produce a mesa transistor which has very good high-frequency properties.

One major bottleneck in the solid-base semiconductor technique is finding a way to produce capacitors in the μf range. These are needed for most audio amplifiers. Rf applications are still very limited because of the inductances required and the space taken by them.

One advantage claimed for the TI approach is uniformity in mass production which makes for higher reliability.

The future—molecular electronics

Perhaps the ultimate in electronic “circuit shrinking” will be the molecular electronic devices in which *complete* circuits are “grown” as one semiconductor body. A large crystal of silicon

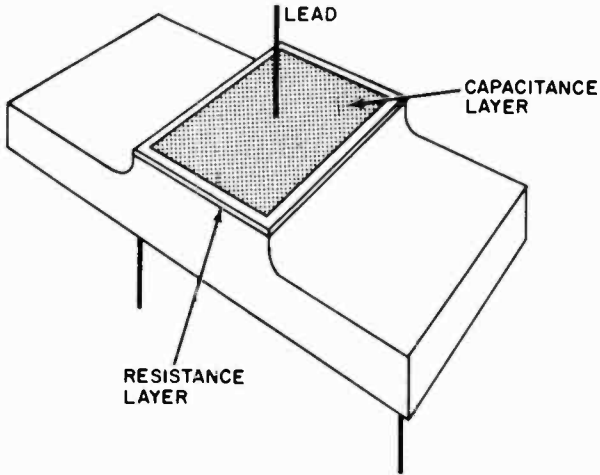


Fig. 109. In this enlarged view we see the make up of an R-C component. This technique is limited to low-capacitance values.

or gallium arsenide is pulled from a machine and impurities are added at various points to produce p-n junctions, thermoelectric effects (current generated from heat) and other electronic functions. Portions of the basic crystal may be etched, plated, alloyed and machined.

With no wires used for internal connections and “parts” integral with the basic crystal (no soldering, no cements), Westinghouse Corp. and the Air Force have produced dozens of “molecular circuits.”

Miniature, subminiature and microminiature techniques and the amateur

In general, present-day microminiature techniques are beyond practical use for everyone except the very advanced worker, but RCA has recently introduced a microminiaturization “do-it-yourself” kit (Chapter 4).

Of immediate interest to the amateur, experimenter and tech-

nician are the miniature and subminiature approaches described in Chapters 5 and 6. The miniature and subminiature components are *commercially* available and offer a reduction in size that is practical for the experimenter.

Sturdiness

Miniature and subminiature devices are not "sissified" nor fragile, and some of the assemblies of Chapters 5 and 6 can be dropped without serious injury because of the low mass of the components.

It is entirely possible that by the time the amateur and experimenter has become familiar with miniature and subminiature techniques, microminiature techniques will be available in kits within the economical reach of all who are interested in working with the electronics of the future.

Chapter 2

Subminiature Components

Many varieties of miniature and subminiature electronic components are commercially available to the amateur and experimenter. In some cases, these components have been on the market for several years, others are less than a year old.

Resistor types include carbon composition, film, wirewound and painted. Capacitors can be ceramic, mica, painted and electrolytic. Inductors include af, if and rf transformers and rf chokes as well as antenna and oscillator coils.

In addition, available hardware and accessories are described in detail. These include connectors, mounting clips, acoustic devices, tubes and batteries.

A chapter on components would be bare without descriptions of the newest and most popular semiconductor types. Data on diodes, transistors, photocells, meters, thermistors and other components are included to round out the picture.

Carbon-composition resistors

The heart of a carbon-composition resistor is a mixture of carbon and resins which is formed into different shapes. The two basic arrangements of material in a carbon-composition resistor are shown in Fig. 201. The one in Fig. 201-a is known in the trade as a slug or rod type. The resistor in Fig. 201-b is often referred to as a coated-cylinder.

The slug or rod carbon-composition resistor is made by mold-

ing or extruding a combination of carbon and resins into a small slug or cylinder. Leads are inserted into the cylinder while it is still molten. A layer of plastic is then applied over the slug and leads.

The coated-cylinder carbon-composition resistor is a tube of glass with a carbon coating on its surface. The glass tube is drawn continuously through the desired carbon-resin mix to produce the necessary resistance property in the finished resistor. After

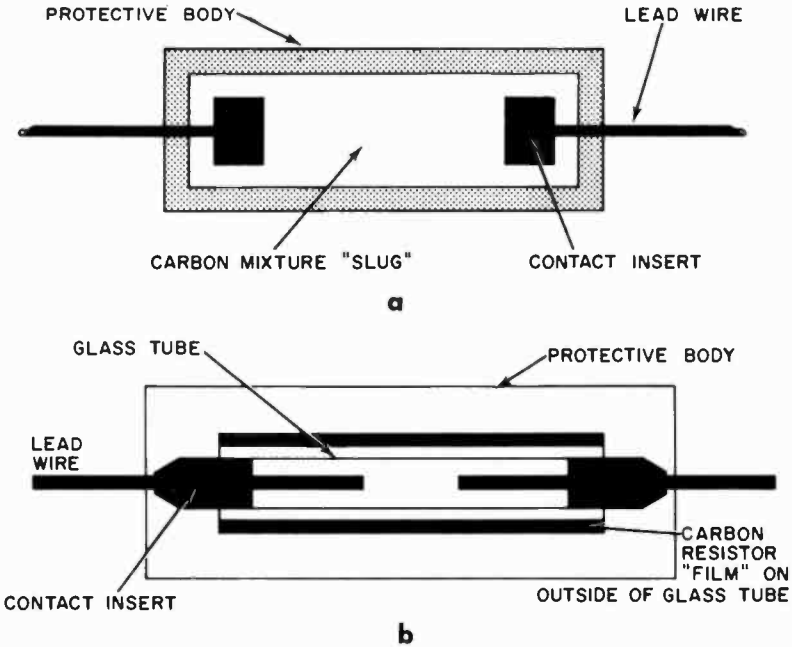


Fig. 201. Two popular methods of manufacturing resistors for electronic equipment. The carbon-film or coated cylinder types (b) are generally more expensive and have better tolerances than the molded carbon units (a).

being coated, the tube is cut into small pieces, and leads are inserted in each end with conductive cement. Then a plastic case is put over the lead-and-tube assembly to complete the resistor.

Both types are coded with the familiar three- or four-banded color-coding systems.

Carbon-composition resistors are subject to one or two "bugs" in use, sometimes caused by improper manufacture and by improper use. Leads occasionally become loose in the body of the resistor if they are not anchored firmly. Another is from overheating, which can occur if the circuit design is faulty or if

another current-limiting component fails. Carbon-composition resistors also generate *noise* which changes with the applied voltage.

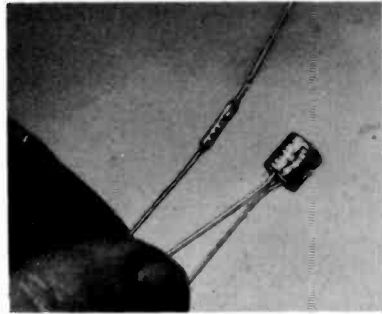
In general, the carbon-composition resistor is the most common all-round one to use where resistance can be within its type tolerance range and stability over several years is not a problem.

Deposited-film resistors

The deposited-film type is made by applying a carbon or metal film to the body material of the resistor. The body material is usually ceramic or glass, since the film must be *fired* or baked on at high temperatures.

One process uses hydrocarbon gases which are played onto the surface of the ceramic resistor bodies. The bodies are heated in

Fig. 202. Miniature wirewound resistors may resemble diodes or transistors. Wattage ratings are considerably lower than those used in TV receivers. These units are used for their exactness of value—not power rating.



a furnace to about 1,600°F. A wide range of film properties is obtained by changing the type of gas, temperature, time and other conditions.

Another deposited-film resistor is the *metalized* variety in which a rod is coated on the outside with either metal or metallic oxide films. Sometimes a hollow cylindrical tube is used, and the film is deposited on the inside.

Usually both carbon and metal-film resistors have to be adjusted to final resistance values by mechanically changing the film patterns after initial manufacture. This is usually some sort of abrasion or grinding process.

The uses for deposited-film resistors fall somewhere between carbon-composition and wirewound units. Very stable, they show up quite often in kit type electronic equipment for metering range work. They are very useful in rf applications because of their low inductance and low shunt-capacitance.

Wirewound resistors (fixed)

Wirewounds are made by winding a resistance wire on a non-conducting core. The most common core materials are forms of Fiberglas, and the range of resistance values is usually lower than that available in carbon-composition and deposited-film units.

The wirewound has some inductance and is not used much in rf work. The inductance ranges from a fraction of a μh to about $10 \mu\text{h}$ in the smaller sizes.

A typical subminiature axial-lead wirewound is shown in Fig. 202 with a larger radial-lead type.

Wirewounds show up commonly as cathode bias resistors as



Fig. 203. Conducting paints are used to connect resistive coatings to the wafer terminals.

well as in meter calibration circuits, precision attenuators and decade boxes.

Another form of wirewound subminiature resistor is the bobbinless type. These are available in several sizes, and are encased in transistor-like cans. In the bobbinless type of wirewound resistor the two ends of the winding are welded to leads which are hermetically sealed and insulated from the metal enclosure. The unit floats in a viscous fluid which acts as both shock absorber and insulator. Inductance is cut down by reversing turns and using fine wire. The fine wire size also reduces distributed capacitance in the resistor. This type of resistor is made in ranges of $\frac{1}{10}$ to 750,000 ohms, and ratings of $\frac{1}{3}$ watt.

Painted resistors

A painted resistor is made by brushing or painting a resistive paste or liquid mixture on the area where the resistance is desired. Most of these mixtures consist of carbon black, graphite, resins and solvents. They are commercially available from the Micro-Circuits Co. in several resistance ranges. A $\frac{1}{8}$ by $\frac{1}{4}$ -inch resistor area can be varied to produce from 250 to 150,000 ohms resistance at about $\frac{1}{4}$ -watt power rating.

In the construction of a painted resistor the outline of the resistor is first made with a soft lead pencil or by using black

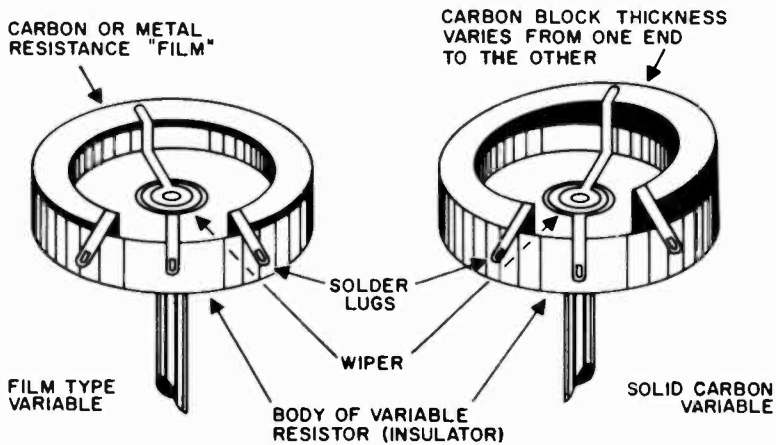


Fig. 204. Resistance variation for degree of rotation can be modified by changing the shape of the resistance element

India ink. Then the resistance paint is used to fill in. Lower resistances can be made by adding more coats of paint, since resistance is inversely proportional to thickness. Fig. 203 shows the ends being painted in with a silver conducting paint.¹ The experimenter can also use copper conducting¹ and epoxy-silver paints² for the end terminals. Connections to the end terminals can be made by tiny eyelets or medium-gage wire such as No. 24 to No. 26.

For best results, the paints should be mixed thoroughly before and occasionally during use. The base material should also be

¹Made by GC Electronics Co., Div. Textron Electronics, Inc., 400 S. Wyman St., Rockford, Ill.

²Made by Furane Plastics Co., 4511 Brazil St., Los Angeles, Calif., and Emerson & Cuming Co., Westover, Mass.

cleaned carefully with detergent and water, or solvent, as the case may be. Resistor thickness should be as even as possible to prevent hot spots. The resistors can be allowed to dry naturally before use, or can be baked under a sun lamp. For best results, they should be air-dried from $\frac{1}{4}$ to $\frac{1}{2}$ hour before baking, or they may "bubble up" from the excess trapped solvent. The final resistance is the one measured when the resistor is thoroughly dry.

Full details for making painted carbon resistors are given in Chapter 2 of *Printed Circuits*, No. 81 in the Gernsback Library series.

Variable resistors

Most variable resistors suitable for subminiature work have their resistive elements made by either film or solid carbon-composition methods. (Fig. 204).

The film construction usually starts off on a phenolic base material. Then the resistance mix is applied by spraying, dipping or silk-screen techniques. After the resistance material is applied, it is cured to a stable value by heating. Wiper contacts are usually beryllium copper.

In the solid-carbon method, the resistance element and support are molded as one unit and the contact material is usually carbon.

Resistance ranges of the film and solid carbon types are altered by changing the size of carbon particles and the kind of resins used to hold these particles together. Inert filling materials such as mica and talcum are also used to increase resistance values.

One property that is peculiar to *variable* resistors is the taper. The wattage rating of a variable resistor will depend on its taper and the wiper position. Manufacturer's charts enable the user to calculate the safe operating current for the control in any rotational position.

Variable resistors have rotational noise to reckon with. The manufacturer usually cuts the noise down by increasing contact pressures and polishing contact surfaces. The higher the contact pressure, however, the more the wear. A contact pressure, if too low, could cause arcing. The usual life of miniature and sub-miniature variables is in the order of 25,000 to 50,000 rotations under load.

Square trimmer resistors

Available in 1- and 2-watt ratings, and resistances from 50 to 50,000 ohms are the subminiature square trimmer pots in Fig.

205 which are about thumb-nail size. A side or top slot-head set-screw adjusts it to the exact resistance value required. One model measures $\frac{3}{8}$ inch square by $\frac{3}{16}$ inch high, and weighs $\frac{1}{30}$ ounce. To go from the lowest to the highest resistance, 25 setscrew turns are required, and more than 40 of these pots will fit into a 1-inch cube!

Capacitors

The demand for smaller components has brought about remarkable changes in the sizes—notably of the ceramic and electrolytic types.

Although the mica and paper capacitors are still finding uses,

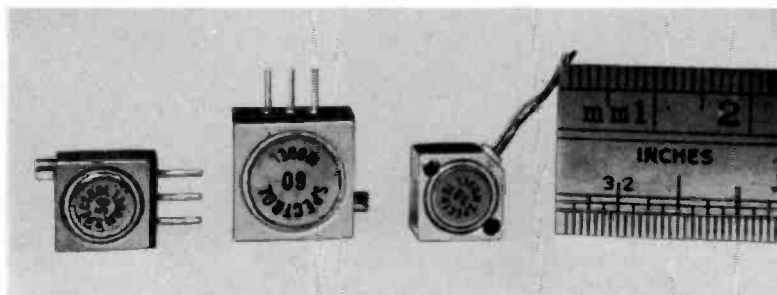


Fig. 205. Miniature variable resistors are used for making semi-permanent circuit adjustments. They are not generally used as frequently rotated controls such as those fitted with knobs.

they are slowly being edged out by the monolithic ceramic or vitreous enamel unit and the wire type tantalum.

Materials such as Mylar and epoxy resins have helped to produce better fractional- μf moderate-voltage capacitors.

The disk type ceramic has been improved to where a .025- μf 200-volt dc unit can be produced in a case size of under $\frac{1}{2}$ inch in diameter and $\frac{1}{8}$ inch thick.

Much progress has been made in subminiature variable capacitors, and the best for amateur and experimental use are polystyrene-cased variables in single, dual and triple sections. These average about 200 μmf /cubic inch and are limited to working voltages under 100 volts.

Electrolytic capacitors

Electrolytics give more microfarads per cubic inch than any other type. The common aluminum electrolytic has two electrodes, one of which (the anode) has a thin oxide film. This filmed anode

—a sheet or foil—is rolled up with another foil and made into an electrolytic. An electrolyte is put into the space between foils. Electrolytics can be polarized or nonpolarized; the polarized units are used for dc and the nonpolarized for ac.

Basic to all electrolytics is a form of chemical film which acts as a one-way barrier to current flow. In general, these films are oxides of metals.

Aluminum electrolytics

Although aluminum electrolytics do not have the capacity \times voltage figure that tantalum electrolytics have for given sizes, a

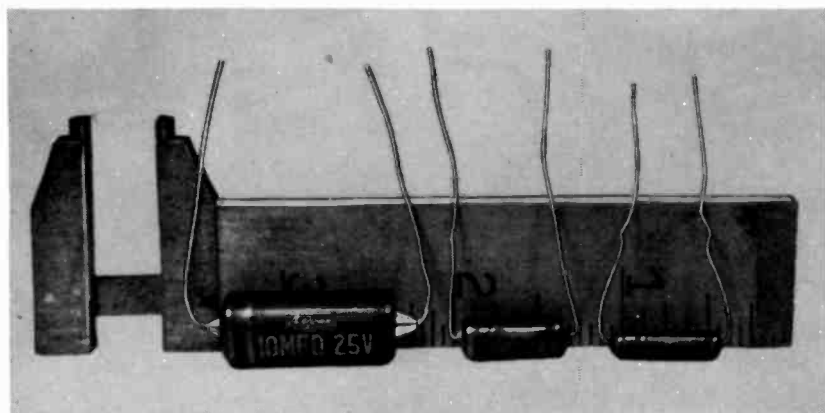


Fig. 206. *Electrolytic capacitors are available that are smaller than these aluminum types. Their economy makes them popular for breadboard purposes.*

lot can be said for aluminum electrolytics as far as cost is concerned.

Fig. 206 shows a typical selection of aluminum electrolytics.

Tantalum electrolytics

One of the most recent commercial components available in many varieties for subminiature work is the tantalum electrolytic. The physical variations include the *solid, etched-foil, wet-slug* and *wire* type. Tantalums offer highest capacitance value at the same voltage in least space. Table 2—1 shows the relative capacitances of tantalum, aluminum, paper and Mylar capacitors.

Solid tantalum electrolytics

The solid tantalum derives its name from the additional treatment it receives over that of a wet-slug type, described below.

The capacitor *gut* is a pellet of sintered tantalum soaked in a chemical compound containing manganese. This pellet is then fired in a furnace to form a layer of manganese dioxide over itself. A conductive material, commonly carbon or graphite, is then dusted over the pellet treated with manganese dioxide slug. A cathode of copper is then plated on the pellet, and the pellet is sealed in its case and leads are put on.

Etched-foil tantalum electrolytics

Here one piece of tantalum foil is chemically etched. The etching increases the surface area of the foil and, according to

Table 2 — 1 Volume vs capacitance

Capacitor	Relative Cu. In./ $\mu\text{f-V}$
Solid Tantalum	1.0
Wet Tantalum Slug**	.8
Etched Tantalum Foil**	4.5
Aluminum Electrolytic**	12
Metallized Mylar†	64
Metallized Paper	68
Paper*	130
Foil Mylar†	210

*Inserted Tab

**MIL quality, not hermetically sealed

†Registered DuPont Trademark

capacitor theory (capacitance is increased with increased surface area), will permit larger values in a given volume. The foil is then treated to oxidize the tantalum and produce a film of tantalum oxide on the foil's surface. This tantalum oxide is the dielectric material—similar to wax or mica in the purpose. The oxidized foil acts as the anode of the electrolytic. A cathode foil is placed on top of the anode foil, with paper or cloth spacers in between the two foils. Next, an electrolyte is poured into the spacer material. Finally, the anode and cathode foils are rolled up like a jelly roll, and put inside a case and sealed.

Tubular sintered (wet-slug) tantalum electrolytics

The basic construction of a cup type sintered tantalum electrolytic—sometimes called a wet-slug or anode-pellet type—is shown in Fig. 207.

The heart of the wet-slug tantalum is a plug or pellet of tantalum powder that has been mixed with a resin or binder ma-

terial. These pellets are put in an oven and baked to drive off the binder material, thus leaving a slug of highly refined tantalum. The pellets are then treated chemically and placed in their cases

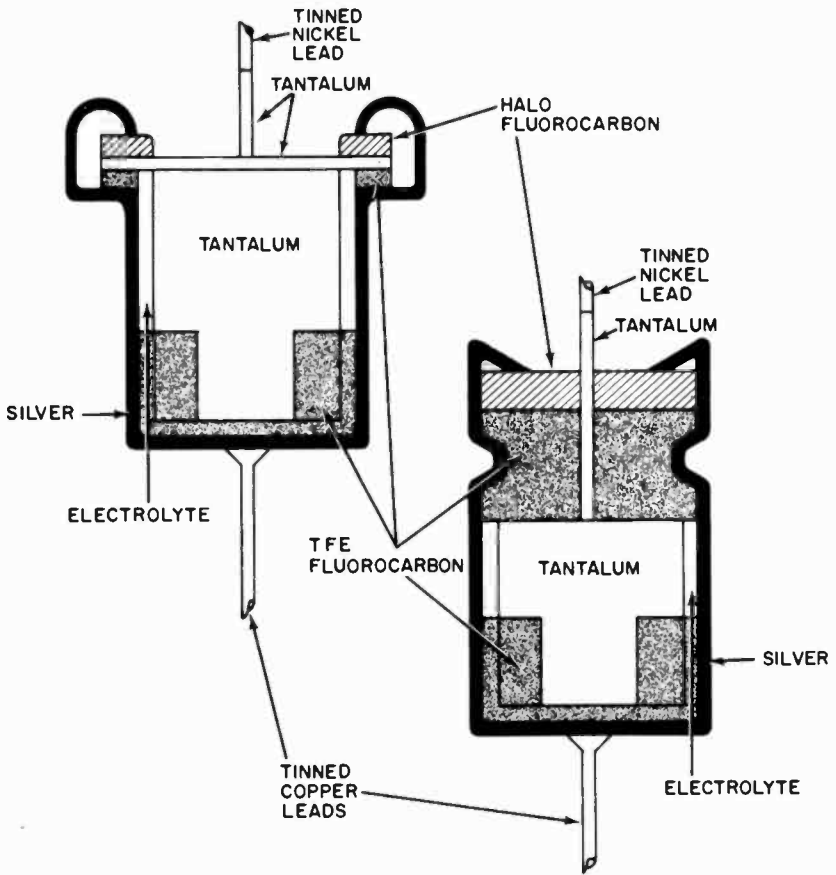


Fig. 207. This is a greatly enlarged cut-away view of the construction of a tantalum electrolytic capacitor. Capacitor plates are acid etched to roughen surface for greater surface area thus giving greater capacitance.

—tubes or cups, as the design calls for. The case is then filled with electrolyte and sealed. (The case is almost pure silver, accounting in part for the higher cost of tantalum electrolytics.) Various lead materials are used—a common combination being copper or tinned copper for the cathode, and nickel or tinned nickel for the anode. The capacitance per given volume can be changed considerably

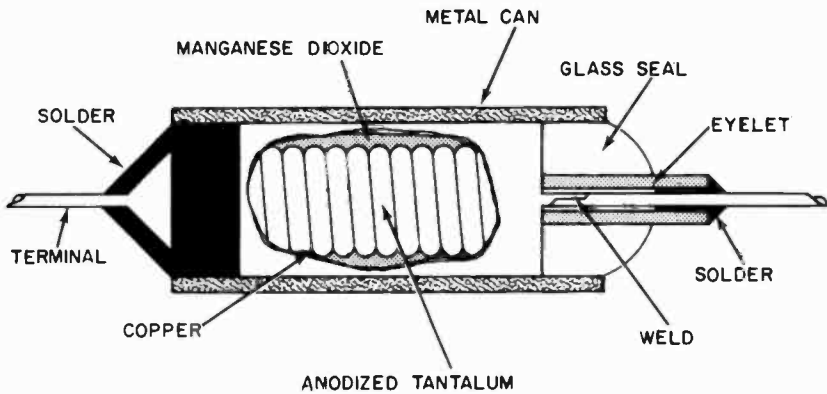


Fig. 208. Anodized tantalum wire is used as the internal electrode of the tantalum electrolytic capacitor. This wire is treated chemically so that an oxide forms on its surface. The wire and its oxide comprise the anode.

by changing the tantalum powder resin mix used to prepare the pellets.

Wire solid-tantalum electrolytics

The wire type solid-tantalum electrolytic was an early development in the tantalum family, and constructional details are shown in Fig. 208. It is related to the pellet or wet-slug tantalum.

In the wire tantalum, a spiral tantalum wire replaces the pellet. This wire is chemically treated to form the tantalum oxide layer on the surface of the wire. The wire is then surrounded with electrolyte—the most common is manganese dioxide. A copper cathode is wrapped around the wire and electrolyte, and the combination is sealed into a case and terminated.

Without etching the wire, the normal range of capacitances is about 1 or 2 μf , but later designs have used etched wire which can run the values up to 35 or 50 μf at low voltages.

The wire type tantalum has found wide use as a replacement for micas and ceramics in the fractional- μf ranges.

What tantalums when?

To the experimenter who is first using tantalums, the various types will probably cause untold confusion in picking the right one for the job. Let's look at some of the basic problems that come up in using tantalum electrolytics—mechanical size and

vibration, polarity headaches, voltage reversals, and sudden electrical surges probably cover most of the sintered units that the average constructor will encounter.

As far as vibration and mechanical problems are concerned, the tantalum was born out of the missile programs and is rugged enough for average use. This doesn't mean you can mount them

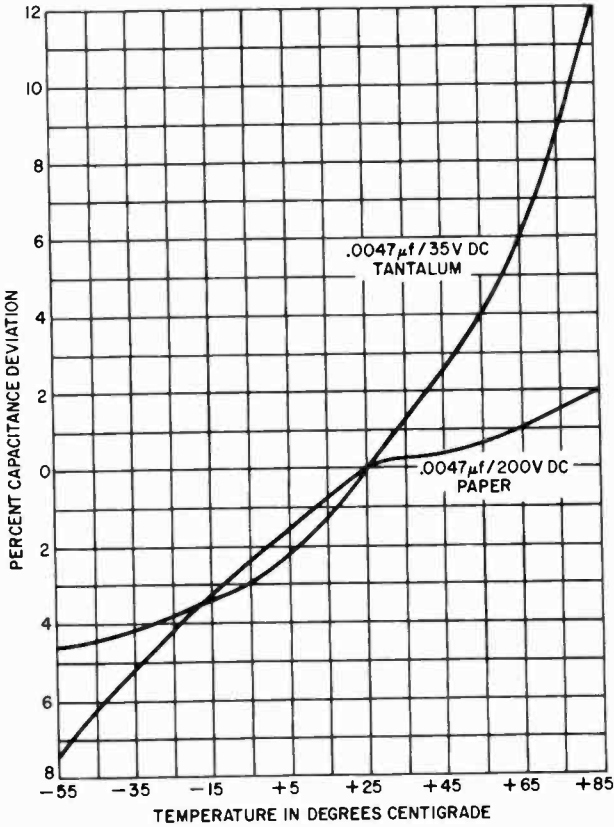


Fig. 209. A rise in temperature will increase the capacitance of a tantalum-type electrolytic capacitor.

with leads hanging all over the place. The leads should be short for jobs such as model airplanes since long leads will make the tantalum rock like a hammock and possibly break a lead from excess vibration.

Surge and ripple problems can be headaches if the experimenter

gets into critical circuits. In the construction chapters later on, the proper tantalum has been called out in the parts list, wherever tantalums are used instead of aluminum electrolytics. Tantalums are not the most efficient electrolytics on heavy dc power supplies such as a supply for a ham receiver or transmitter. They are pretty useful in signal circuits such as low-level audio or radio controls.

Temperature should not worry the average user—most tantalums are normally rated at 75° to 80°F. If you plan to bury your

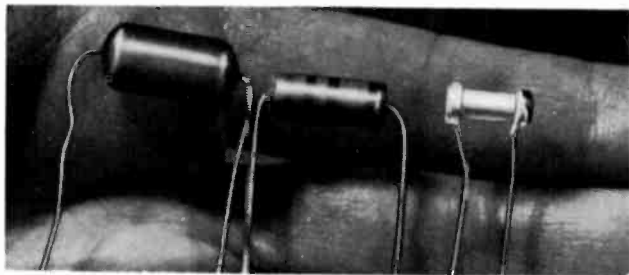


Fig. 210. *These tubular ceramic capacitors are covered with an insulating compound that protects the unit electrically and physically.*

circuit in ice or put it on a stove, remember that capacitance on these units falls off at low and goes up on high temperatures. A typical curve is shown in Fig. 209.

Ceramics

Ceramic capacitors have been developed to a point where capacitances range from 5 $\mu\mu\text{f}$ to 2.2 μf at voltages of 100 down to 3 volts, and a variety of shapes from tubular to square and disc shaped plates.

Several tubular designs are shown in Fig. 210. Typical diameters are $\frac{3}{10}$ inch and $\frac{4}{10}$ inch and lengths run from $\frac{4}{10}$ to about $\frac{7}{8}$ inch. Capacitances in this size range from about 100 to 5,500 $\mu\mu\text{f}$. By changing the composition of the dielectric, a temperature-compensated ceramic can be made. This is simply a capacitor whose value remains the same over wide ranges of temperature. Others are made whose capacitance value gets greater or smaller with a change in temperature. Working voltages are 500 volts, more than enough for subminiature circuits.

Some types of disc capacitor designs can vary from $\frac{2}{10}$ to $\frac{3}{4}$ inch in diameter and are all approximately $\frac{5}{32}$ inch thick. Capacitances range from 100 to 20,000 $\mu\mu\text{f}$ at 500 volts. By sacrificing working voltage, larger capacitances (0.22 μf to 2.2 μf) are available in

long. Working voltage is 100. The plastic coating on the case is only $\frac{1}{64}$ inch thick to conserve space.

Mica capacitors

The conventional mica has shrunk to a new size in the lower capacitances as shown in Fig. 214. Just under $\frac{1}{2}$ inch long and $\frac{3}{10}$ inch high, these micas are $\frac{3}{16}$ to $\frac{2}{10}$ inch thick and are made in capacitances of 10 to 820 $\mu\mu\text{f}$. Working voltages are 300 to

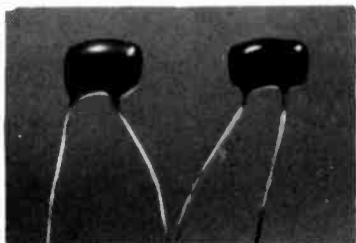


Fig. 214. The brownish color of these capacitors has caused them to be called chocolate drops. They are often found in $\pm 1\%$ values.

500 volts dc, well above the range for transistor and subminiature work. A crimped-lead design is available for printed-circuit work where the component is inserted in eyelets a fixed distance apart. Q for these tiny units runs between 500 to 1,000, and they are silvered mica for greater stability. The capacitor body is available in a single resin coat dip which results in a capacitor about 20% smaller in all dimensions.

Painted capacitors

Painted capacitors are made in a fashion similar to painted resistors, except that the painted areas are stacked up in a deck, and two sets of leads are brought out to the circuit connections. The total capacitance of such a deck or stack will be equal to the area of one painted square *times* the number of plates *minus* one plate *times* a factor (for this $k = .224$) *divided* by the thickness of the paper or dielectric material separating the painted areas.

Details for calculating the capacitance, number of plates, size of plates and voltage ratings of painted capacitors will be found in Chapter 2 of *Printed Circuits*, No. 81, Gernsback Library series.

Glass capacitors

Glass capacitors are closely related to the monolithic ceramics in the ability to maintain their capacitance with wide changes in temperature and not change unless actually broken physically. Working voltages for glass capacitors range from 300 to 500 dc.

One design of glass capacitor wafer is shown in Fig. 215. All thicknesses range from $\frac{1}{16}$ to $\frac{3}{32}$ inch and capacitances run from

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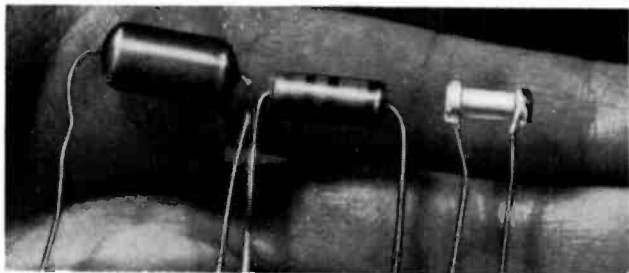


Fig. 210. These tabular ceramic capacitors are covered with an insulating compound that protects the unit electrically and physically.

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similar case sizes. These work between 3 and 10 volts and are ideal for transistor work. In many cases, they are very competitive to electrolytics.

Perhaps the smallest ceramic commercially available is the match-head unit in Fig. 211. These are available to $.001 \mu\text{f}$ and working voltages around 50. They are literally the size of a match-head, being about $\frac{2}{10}$ to $\frac{3}{10}$ inch in their largest dimension.

Monolithic ceramics

Another type of ceramics are referred to as *monolithic* units. These are made by alternately spraying ceramic dielectric and metal-on electrodes until the required capacitance is built up. The

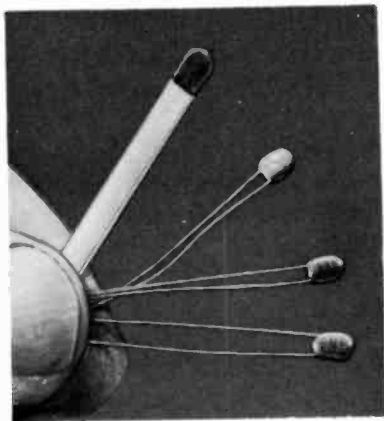


Fig. 211. These small disc ceramics resemble a match head when covered with an insulating compound.

final result is a solid unit that must actually be smashed with a hammer to destroy the capacitance value! This solid construction has the advantage of being immune to humidity, and permits capacitances of $2.2 \mu\text{f}$ at 25 volts in a $\frac{1}{2}$ inch square by $\frac{2}{10}$ inch thick package.

The smaller series of monolithic units shown in Fig. 212 is available in ranges of 47 to 10,000 $\mu\mu\text{f}$ and working voltages up to 200 dc. They have been standardized to $\frac{2}{10}$ - and $\frac{3}{10}$ -square-inch sizes and a $\frac{1}{10}$ -inch thickness. Variations on leads include one on each end (axial), on each side (radial) and combinations of these two.

Paper capacitors

Paper tubulars have been popular for years in miniature applications requiring capacitances of $.0001$ to $.05$ at voltages of 200 or less, which allows them to be made much smaller. The

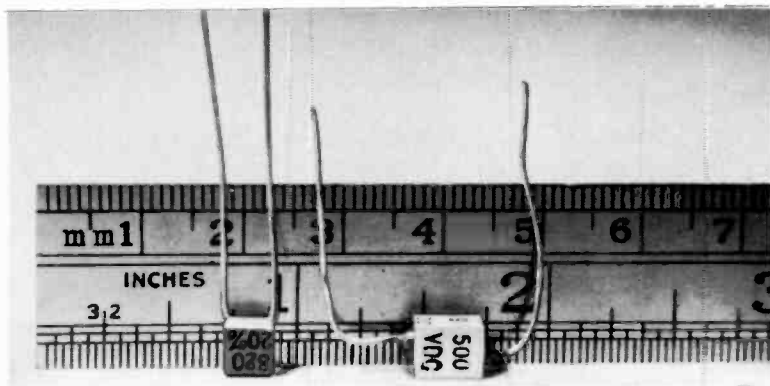


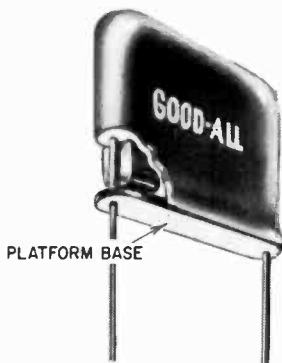
Fig. 212. These small units are quite sturdy. They may have either radial leads (left) or axial leads (right).

construction is wax paper and foil layers. Size ranges from $\frac{1}{8}$ inch in diameter by $\frac{1}{2}$ inch long to $1\frac{1}{4}$ inches long. This is a very inexpensive capacitor suited for voltages under 100.

Mylar capacitors (polyester film)

An advance over the paper-and-wax type construction is shown in Fig. 213 which has a Mylar* foil dielectric and is potted in epoxy resin, a very tough plastic. Typical sizes are $\frac{3}{10}$ inch wide

Fig. 213. This cutaway view shows one way radial leads are secured to the capacitor. This type mounting is best for printed circuits.



by $\frac{3}{4}$ inch high by $\frac{3}{10}$ inch thick for capacitances in the .01- to .05 μf range and a 50-volt rating. They are comparable to ceramic disc units in price.

Another Mylar* capacitor design is similar. These oval tubulars range in capacitances from .001 to .068 μf and in size from $\frac{3}{16}$ inch in diameter by $\frac{1}{2}$ inch long to $\frac{1}{4}$ inch in diameter by $\frac{3}{4}$ inch

*Registered trademark, DuPont Corp.

long. Working voltage is 100. The plastic coating on the case is only $\frac{1}{64}$ inch thick to conserve space.

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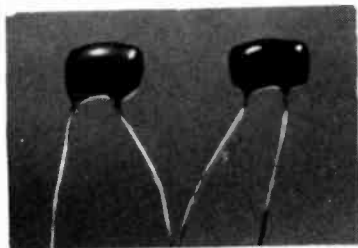


Fig. 214. The brownish color of these capacitors has caused them to be called chocolate drops. They are often found in $\pm 1\%$ values.

500 volts dc, well above the range for transistor and subminiature work. A crimped-lead design is available for printed-circuit work where the component is inserted in eyelets a fixed distance apart. Q for these tiny units runs between 500 to 1,000, and they are silvered mica for greater stability. The capacitor body is available in a single resin coat dip which results in a capacitor about 20% smaller in all dimensions.

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One design of glass capacitor wafer is shown in Fig. 215. All thicknesses range from $\frac{1}{16}$ to $\frac{3}{32}$ inch and capacitances run from

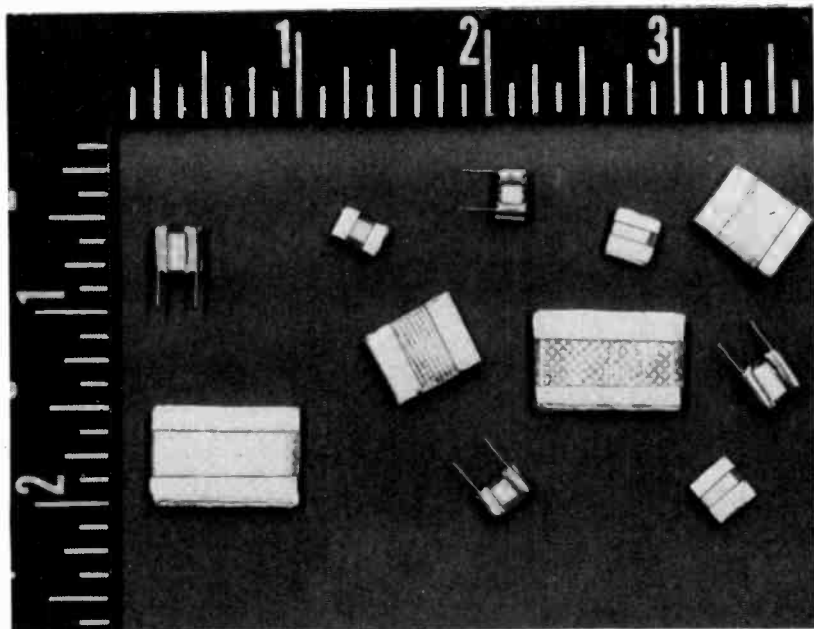


Fig. 215. Glass is also used as a capacitor dielectric. Construction is similar to that used for mica or monolithic ceramics. (Corning Electronic Components)

1 to 600 $\mu\mu\text{f}$ in $\frac{3}{10}$ by $\frac{2}{10}$ inch packages up to about $\frac{1}{2}$ by $\frac{3}{4}$ inch in 10,000- $\mu\mu\text{f}$ units. Wafer capacitors are available with and without leads.

An additional improvement in the glass capacitor is that the capacitor body has been *fused* to the copper-iron-nickel lead for work in high-humidity and high-vibration circuits. This has made the capacitor take on a rounded shape and removed the square edges. Sizes are slightly smaller for the same capacitances.

Variable capacitors

Depending on whether a change of 1 or 2 or several hundred $\mu\mu\text{f}$ is wanted, variable capacitors are commercially available for subminiature work.

At the low-capacitance end of the scale are the glass and metal piston units with ranges of about 1 to 15 $\mu\mu\text{f}$ and working voltages up to 200. Q's are high, going from 1,000 at 1 mc to about 400 at 100 mc. The same type of unit is made with quartz, instead of glass, for high Q's and higher temperatures.

On the other end of the scale are the plastic film dielectric

variables, which are larger in size. These are very useful for pocket radios and are made in single section- and multiple-gang types. Those sealed in plastic cases prevent dust from entering, and extra shielding plates between sections and at the back cut down stray and body capacitance effects. The rotation is mechanically limited to prevent the plates from falling out of mesh with each other. Rated for 50 volts dc maximum service, they are



Fig. 216. Multi-turn compression-type variable capacitors may be called either trimmers or padders. Shaft can be fitted with a knob or adjusted with a screwdriver.

Fig. 217. Shafts can be added to many types of miniature adjustable components. Avoid heat whenever possible. Various cements can be used to do the job solder might be selected for. Use them sparingly and carefully.



matched to i.f.'s, oscillators and antenna loops shown elsewhere in this chapter. In addition, each section has tiny trimmers for alignment.

Bridging the capacitance value range of the two units above is a variety of mica trimmer designs. One of them is a conventional size mica, about $\frac{3}{4}$ inch square. Another is a half-size, about $\frac{3}{8}$ by $\frac{1}{16}$ inch. The standard trimmer is made with a shaft as shown in Fig. 216. A half-size unit, fitted with a home-made tuning shaft, is shown in Fig. 217. Capacitances for these trimmers fall between 1 to 12 and 140 to 750 $\mu\mu\text{f}$. One feature of a trimmer to remember is that the capacitance is *not* linear with rotation. In other words, a trimmer will drop off to about half its capacitance in the first or second turn, depending on the number of plates.

Inductive components

Great advances have been made in subminiature inductive components. Both af and if transformers have been reduced through various stages of design to an assortment of pigmy units.

Slowly catching up to transformers, in matching sizes, are

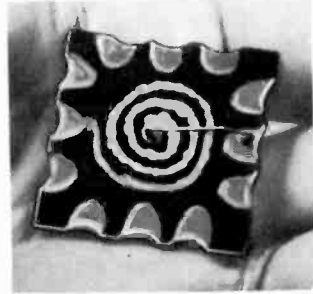
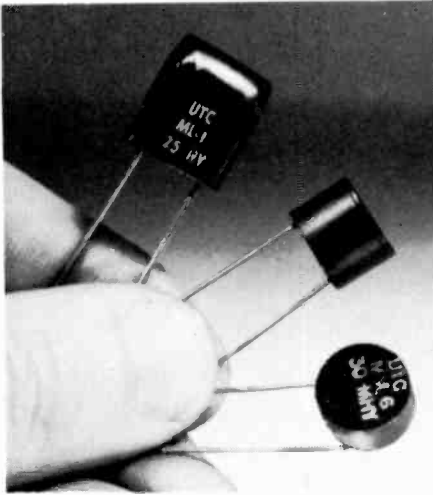


Fig. 218. Chokes or inductors must also be made small for compact circuitry. Very fine wire sizes are used to get high inductance. Current carrying capacity is reduced to very low values.

chokes in the millihenry ranges and various rf inductors, some of which have ferrite or iron-cored construction.

The following section traces developments in commercially available inductive components for miniature and subminiature use.

Subminiature and microminiature inductors

Shown in Fig. 218 are several styles of subminiature inductors well suited to the transistor and subminiature-tube circuitry.

The first type, ML, is $\frac{13}{32} \times \frac{15}{32} \times \frac{9}{16}$ inch high and is shaped similar to a small mailbox. It is available in inductances of .25 to 60 henries, and ranges from 9 to .2 milliamperes in current. Furthermore, the ML is shielded in a hipermalloy (highly permeable) case.

The second type, the MM and MH, is a squat-circular unit, approximately $\frac{7}{16}$ inch in diameter by $\frac{1}{4}$ inch high and is constructed in ranges of 0.6 to 12.5 millihenries and in an average current capacitance of 25 ma. The members of the MH series are designed to peak at higher frequencies. The MM and MH types have toroids or doughnut type windings.

Slightly larger units, but still small, are made in either vertical- or horizontal-mounting styles and range from .1 to 5,000 μ h. The chief feature of these inductors is their variability over $\pm 15\%$ in range.

One of the smallest rf-inductors available is less than $\frac{5}{32}$ inch in diameter and $\frac{3}{8}$ inch long. The size is such that about 115 of these inductors will fit into one cubic inch. They are shielded so that they can be placed side by side with no coupling effects.

i.f. transformers

The common-miniature i.f. used with miniature tubes is about $\frac{3}{4}$ inch square and 2 inches high. Demand for smaller components led to the development of the units shown in Fig. 219 which

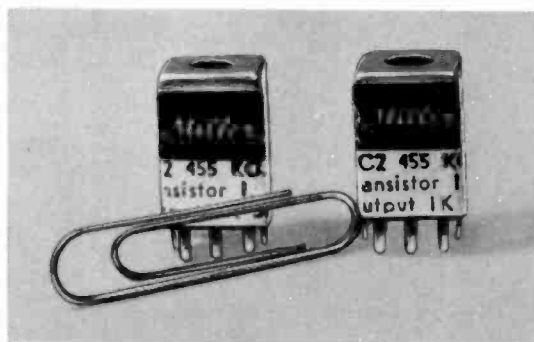


Fig. 219. Miniature or pocket receivers use i.f. transformers as small as those shown here.

are $\frac{1}{2}$ inch square by $\frac{3}{4}$ inch high and are available as inputs and outputs in the 10,000 to 100,000 ohm impedance ranges for transistor- and subminiature-tube circuitry. Primaries are tapped and may be used in either tapped or untapped primary circuits.

Another series of subminiature-i.f.-transformers are $\frac{3}{8}$ inch square by $\frac{5}{8}$ inch high and are manufactured in two types suitable for transistor applications. The first is an input-type, matching 25,000 to 600 ohms, and the second output-unit, matching 25,000 to 1,000 ohms. The cup core construction allows the use of very small shields without any effects on the i.f.'s performance.

Subminiature and microminiature transformers

Perhaps the first major step in reduction of transformer sizes was the UTC Ouncer series, introduced about 1947, as a result of World War II development. Included in this line are input,

mixer, interstage, output and reactor types, with an average power level ranging from about 10 to 100 milliwatts.

Subminiature-tube and early-transistor circuitry led to development of the still smaller Subouncer models. The Subouncer units are $1\frac{9}{32}$ inch by $4\frac{3}{64}$ inch by $\frac{7}{8}$ inch and weigh less than $\frac{1}{2}$ ounce. Available in many varieties, the design of the Subouncers permits power levels in the 100 to 250 milliwatt ranges. They are also constructed with channel mounting which adds about 50% to the basic dimensions.

Further need for smaller units led to a Sub-subouncer size. These models have special nickel-iron cores and come with 4 inch color-coded leads. The size is approximately $\frac{7}{16}$ inch by $\frac{3}{4}$ inch



Fig. 220. Some of the smaller iron-core transformers are more like tie-tacks or shirt buttons. The smaller these transformers are made the more difficult it is to make bandpass wide. Low frequencies often suffer when size is reduced.

by $4\frac{3}{64}$ inch and weight is about $\frac{3}{8}$ ounce. There are many varieties in the current line. The average-power level is 100 milliwatts. Included are reactor or choke units, rated from 3.5 henries, and handling between 1 and 5 milliamperes dc.

A still smaller size in rectangular-transformer development is the ultraminiature type shown in Fig. 220. Made in several styles, it is $\frac{3}{8}$ inch on a side.

Additional subminiature-transformer advances produced the DO-T and the DI-T styles. Both are hermetically sealed in a metal case and are available in single-ended or double-ended lead arrangements. The DO-T is $\frac{5}{16}$ inch in diameter and $1\frac{3}{32}$ inch

long and weighs $\frac{1}{10}$ ounce. The DI-T is $\frac{5}{16}$ inch in diameter, but only $\frac{1}{4}$ inch long and is half the weight of the DO-T.

A complete line of economical subminiature transformers is manufactured in case sizes about $\frac{3}{4}$ inch by $\frac{3}{4}$ inch by $\frac{7}{8}$ inch and weighs approximately one ounce. These models are for applications in cases where the space savings of the Sub-subouncers and smaller components are not required, but where a miniature

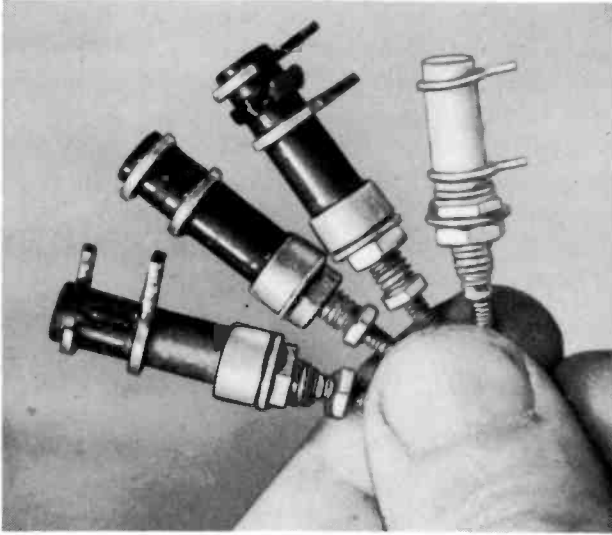


Fig. 221. Slug-tuned coil forms are more practical than printed (etched) inductors for the lower rf frequencies.

or subminiature result is desired. Although not as expensive, these transformers yield good results for such applications as input, interstage and output work. In addition, they come with manufactured brackets, which can be stripped off to save space where needed.

Rf coils

Subminiature-rf coils are available in both fixed-and-variable designs. The most useful of the variable types are shown in Fig. 221. Sizes vary from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch in diameter and $\frac{5}{8}$ inch to $\frac{7}{8}$ long. Typical inductances in these rf coils range from .2 to 300 μh , and Q's vary from 35 to 80. The variety of coil-form materials includes silicone-filled ceramics, nylon, phenolics and fibre. Some

coils incorporate a spring-loaded feature which minimizes accidental shifts in the adjustable-core positions.

Some rf-choke units have a maximum diameter of $\frac{5}{32}$ inch, and a maximum length of $\frac{1}{4}$ inch. Inductances range from 1 to $80 \mu\text{h}$ and the tuning ranges vary from 160 to 9 megacycles. Q's are concentrated between 50 and 65 at an average frequency of 5 megacycles. Current handling ability of one particular unit is 50 milliamperes.

Printed or painted inductors

Fig. 222 shows a painted-subminiature inductor, which was made with a No. 1 camel's hair-brush on a piece of phenolic $\frac{3}{4}$ inch square and has an inductance of approximately $.1 \mu\text{h}$. Although



Fig. 222. Painted subminiature inductors are useful for low values of inductance.

painted inductors are fairly easy to construct, they are limited to values that can be exceeded with wire-type inductors of the same volume. Painted inductors are also limited to higher frequencies, and are occasionally useful with circuits in the miniature, rather than subminiature or microminiature class. They are sometimes used with subminiature tube circuits. The experimenter can find detailed methods for calculating such inductors in *Printed Circuits* No. 81, Gernsback Library.

Miniature-and-subminiature-acoustic transducers

Fig. 223 shows several reluctance-type subminiature microphones. The first (center) is a circular type with an impedance of 1,000 ohms, a frequency response of over 400 to 4,000 cps, and an output of -75 db. Somewhat more than 1 inch in diameter, the unit is $\frac{25}{64}$ inch thick, and has an external mu-metal shield for hum reduction.

At the right is a $\frac{5}{8}$ inch by $\frac{5}{16}$ inch by $\frac{15}{16}$ inch long package with approximately the same electrical characteristics and slightly more extended response than 4,500 cps.

The smallest in the series (left) measures $\frac{1}{2}$ inch square by more

than $\frac{1}{4}$ inch thick, and has an input impedance of approximately 1,900 ohms. The frequency response covers 400 to 3,500 cps and the external shield is mu-metal.

Subminiature relays

Fig. 224 shows a relay that is available in coil resistances of 5,000 and 7,250 ohms, for operation on currents of 1 to 1.5 milliamperes. The contacts are capable of handling 0.2 ampere at 115 volts ac or low voltages up to 28 volts dc.

There are other varieties of the same basic design. One version

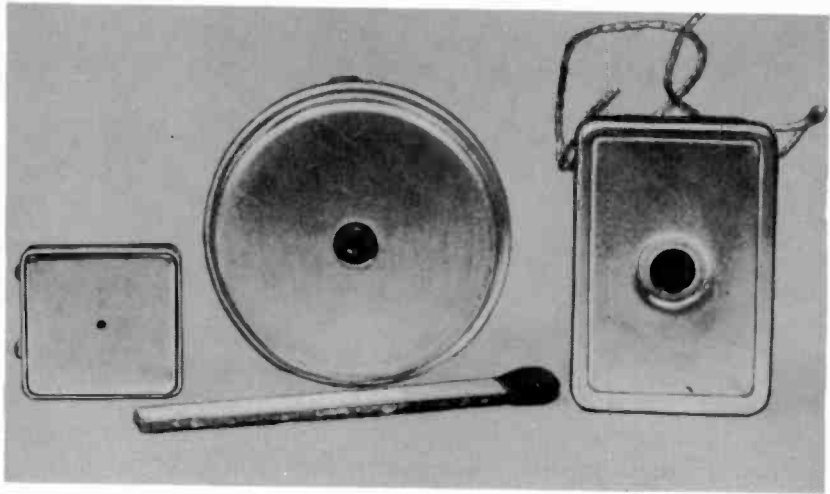


Fig. 223. *Reluctance-type subminiature microphones.*

has fixed contact spacing, whereas another has a set screw adjustment for altering contact spacing. Sensitivity is between 10 and 100 milliwatts, depending on coil resistance. Contacts are silver, and the units weigh under $\frac{1}{2}$ ounce.

Still another subminiature-power relay requires 1 watt to operate. Its contacts will handle about 1 ampere at 115 volts ac or 2 amperes at low voltages up to 28 volts dc. It is a dual-position-locking type, and weighs about $\frac{1}{2}$ ounce. It can be used to back-up the current-handling ability of the relays we have just described by operating it from the secondary contacts of one of the sensitive relays.

Subminiature printed-circuit relay

A moving bar armature with contacts is the heart of a novel subminiature relay. Measuring approximately $\frac{7}{8}$ inch on each

side, the contact spacing is such that the relay can plug-in and be fastened directly over the printed-circuitry on the board. The usual armature-return spring has been replaced by a permanent ceramic magnet, and the relay is made in 1-to-3-pole, single- and double-throw-contact arrangements. Voltages for operation range from 3 to 24 volts dc, and relay life is rated between 100,000 and



Fig. 224. The small coil of this relay draws only about one milliamperere. The wire-like contacts can handle about 200 ma.

several million operations, depending on the load current carried by the contacts.

Specialized transistors — microminiature

A look at “tomorrow’s transistor today” is shown in Fig. 225. Described by its manufacturer as so small, “it looked like a



Fig. 225. This transistor looks more like a spot of paint on a broom straw than an electronic component.

speck of dirt on a wire,” the transistor body is about $\frac{1}{16}$ inch long by $\frac{1}{32}$ inch square — just barely larger than a pinhead! Flat leads, about $\frac{1}{100}$ inch wide, .003 inch thick, and $\frac{5}{8}$ inch long permit the tiny device to be soldered into the circuit.

Semiconductor diodes

The variety of diodes first made for subminiature use has originated from the basic units — germanium and silicon general purpose diodes — to at least four widely used types — computer diodes, tunnel diodes, voltage regulator and zener diodes, and varactor diodes.

Basic general purpose diodes consist of a tiny wafer of germanium or silicon attached to one electrode, and a cat's whisker attached to the other electrode. They are today's descendants of the radio crystal. These combination-semiconductor wafer and whisker units are encased in glass or plastic.

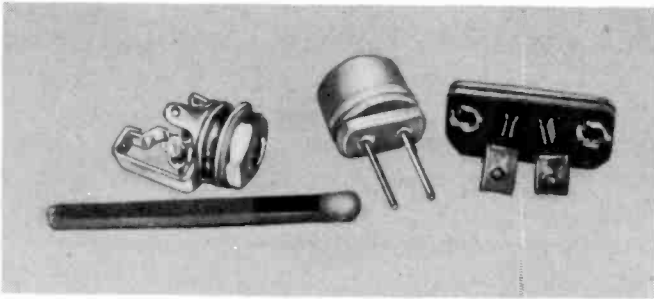


Fig. 226. Effect of applying miniaturization to jacks and plugs.

Micro-diodes

A companion to the micro-transistor described previously is the micro-diode. The body is $\frac{1}{16}$ inch long by $\frac{1}{16}$ diameter with $\frac{1}{2}$ inch leads. About 1,400 of these would weigh one ounce! The semiconductor material is silicon, and the diode junction is potted in a glass sleeve with resin.

Sockets

In many cases, the experimenter may prefer to solder the leads of components directly into the circuit. This is especially true of components such as resistors, inductors and capacitors.

However, there are occasions when quick replacement or substitution for testing purposes is desirable, such as with subminiature tubes, transistors, diodes and photo-electric devices.

Subminiature sockets, similar to those used for transistors, were among the earliest to appear commercially. These vary from 3-contact to 7-contact universal types in a wide assortment of mounting arrangements. Some mount simply by pressing the

socket into a tight-fit hole; others use a mounting spring or ring retainer. Some have mounting plates and tabs for holding a shield.

Subminiature plugs and jacks

Fig. 226 shows an assortment of tiny plug and jack combinations. A single contact plug and jack set are about $\frac{1}{2}$ inch by $\frac{3}{4}$ inch. The matching 2-pin jack is $1\frac{1}{4}$ inches long by $\frac{3}{8}$ inch wide. The jack has a phenolic base with $\frac{3}{32}$ inch mounting holes. The plug and jack combination on the right has a $\frac{3}{8}$ inch sphere housing the plug, and the jack is about one inch in its longest dimension.

Micromodule sockets and plugs

A matching socket and plug for microminature work is shown in Fig. 227. These are just under $\frac{4}{10}$ inch square and have 12 gold-plated beryllium-copper contacts on 0.075 inch centers. These

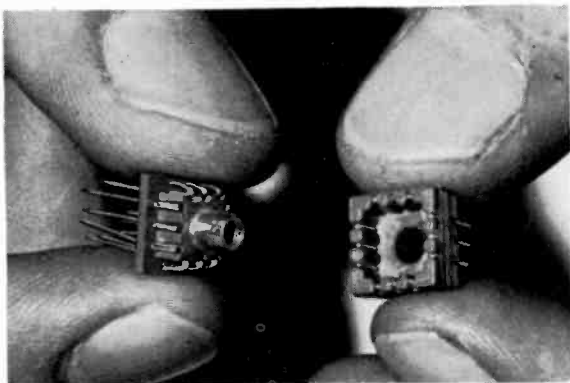


Fig. 227. Gold-plated beryllium copper used on pressure contacts increases reliability as well as cost. Gold does not tarnish or corrode.

weigh about $\frac{1}{40}$ of an ounce, and can be used as a plug and jack or in board-to-board applications.

Switches

Switches have long resisted the trend towards subminiaturization. Since any switch must of necessity contain at least one moving part, space was always at a premium in such a component.

The common-toggle switch has been shrunk to the tiny dimensions of $\frac{1}{4}$ inch by $\frac{5}{16}$ inch by $\frac{3}{4}$ inch. See Fig. 228. Available in both spdt and dpdt construction, both switches are less than

$\frac{1}{4}$ inch thick, and the largest (dpdt) is only $\frac{1}{2}$ inch long. The handles are about as long as the switch body. Capable of handling 5 amperes at 115 volts ac, they will carry a 100% overload for several minutes, and have a life cycle of 80,000 operations.

Meters

Subminiature meters have made a slow appearance. The delicate nature of a meter movement has kept many manufacturers from venturing into such items.

One of the earliest miniature meters to appear was a 1 inch meter with a zero adjustment. Available in a wide range of basic movements, the most popular is the 0-1 ma full scale. The ac-

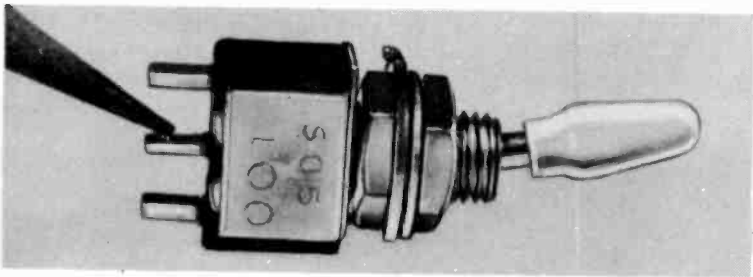


Fig. 228. Switches can be a problem too. They can not be made so small that they are difficult to operate or easily broken.

curacy of most subminiature meters is usually from 2% to 5%. Connections are made by soldering to lugs on the rear of the meter.

Current versions of 1 inch-size meters available include both one inch square and one inch round styles. Stock dc ranges include 0-100 microamperes, 0-1 milliamperes, 0-500 milliamperes, 0-100 volts, and 0-1,000 volts. Several zero-center microammeters are also available. Both styles have zero-set adjusters and screw terminals on the back. Other models include an S-meter and a VU-meter for -20 to +3 db.

Perhaps the most novel group of subminiature meters include a $\frac{7}{16}$ inch round meter, a $\frac{1}{2}$ inch square meter, and a $\frac{3}{4}$ inch by $\frac{3}{4}$ inch by $\frac{7}{8}$ inch meter. The $\frac{7}{16}$ inch round meter is made as an indicator with either a flag or pointer dial. The movement is available in 500 microampere-1-milliamperes coils. The $\frac{1}{2}$ inch square meter is available in a 0-1 milliamperes movement and several higher milliamperes ranges. The cover can be removed for zero-setting.

Thermistors

Thermistors are resistors which change resistance sharply with a change in temperature. They have a *negative temperature coefficient of resistance*—which means the warmer they are, the lower their resistance. Most metals behave just the opposite — the warmer they are, the higher their resistance.

Made of ceramic and metallic oxide, thermistors are available

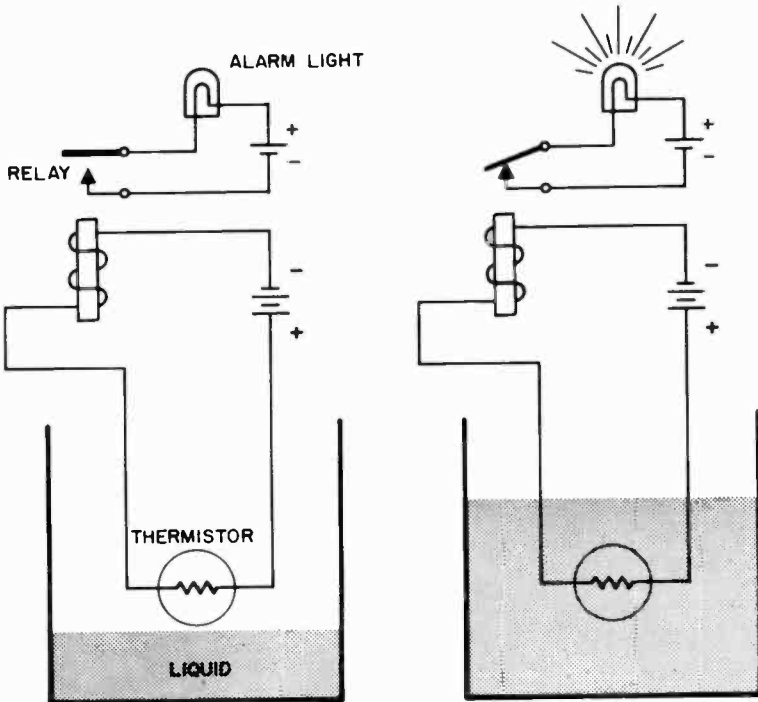


Fig. 229. In the illustration at the left, the low resistance of the thermistor results in a heavy relay current. The relay is actuated and the armature is kept pulled away from its relay contact. In the illustration at the right, the cooling action of the liquid raises the resistance of the thermistor. This decreases the relay current, and a spring (not shown) pulls the armature against its relay contact. This closes the circuit to the alarm light.

in several forms — discs, rods, washers, beads and probes. The probe is a bead sealed in glass. A rod is unique in its length to diameter ratio. The washer has a hole in its center for mounting with a bolt or machine screw. Resistances of 200 ohms to 100 megohms are commonly obtainable.

Thermistors can be used in several different applications, one of which is temperature measurement, indication or alarm. A

practical temperature measuring device for construction by the home experimenter is described in chapter 5.

A second use of thermistors employs this heating effect. In another application (Fig. 229), a certain amount of series current is run through the thermistor. If the thermistor dissipates this heat to the air, the resistance is low and a relay can be actuated. However, if the thermistor is immersed in water, it will be cooled, the resistance will rise and the relay action can be reversed. A practical use of the thermistor in this case is as a liquid level indicator or alarm.

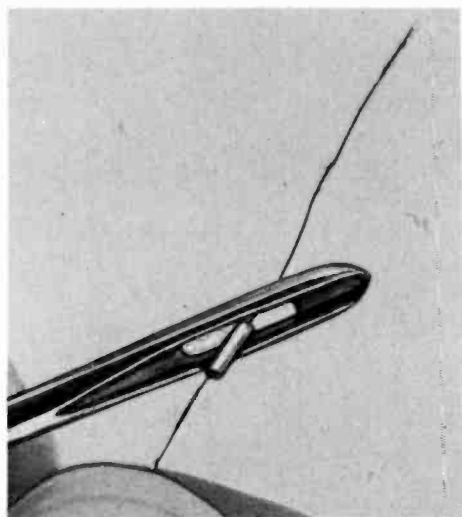


Fig. 230. *This indicator lamp can be put through the eye of a needle.*

Microminiature lamps

One of the smallest lamps is the microminiature lamp in Fig. 230. It measures only 0.045 inch in diameter, $\frac{1}{8}$ inch in length, and the leads are $\frac{7}{8}$ inch. Both axial leads and single-ended leads are available. The lamp draws a maximum of 30 milliamperes at 1.3 volts dc and can be seen twenty feet away in a normally-lit room.

Life at 1.5 volts is 500 hours, and at 1 volt is approximately 2,500 hours. When pulsed at 60 pulses per second, with a 1.5 volt square wave, the light will produce 1,000,000 or more flashes until exhausted.

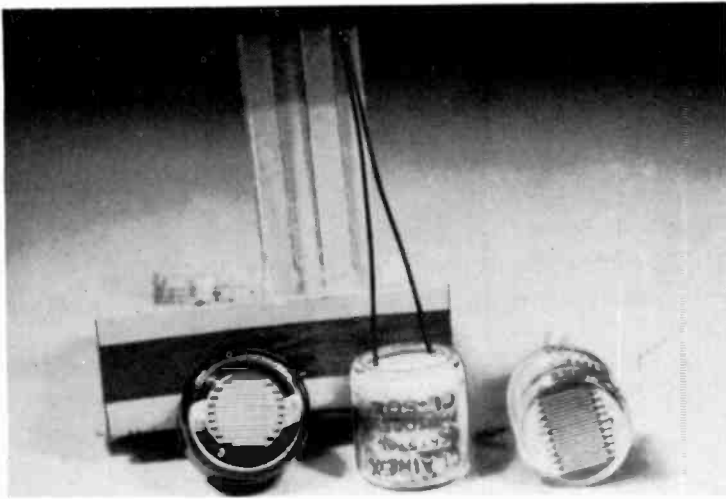


Fig. 231. These pencil eraser sized photoconductive cells change their resistance when exposed to light. Connected in series with a dry cell and a meter they are the active part of a sensitive photo light meter that works like an ohmmeter.

Photoelectric-subminiature devices

Fig. 231 shows a few subminiature photocells of the photoconductive type, which change their resistance, depending on the amount of light they "see." Two main varieties are the cadmium-sulfide and the cadmium-selenide type. The size is $\frac{1}{2}$ inch diameter by $\frac{1}{2}$ inch long. The cadmium-selenide unit is a more sensitive cell, and has a higher speed of response. Both kinds of cells are rated at 250 volts peak ac or dc, and will handle up to $\frac{1}{2}$ watt in a sensitive plate relay circuit without an amplifier. Normal light resistances range from 100 to 1,000 ohms, whereas the dark resistance ranges up to several megohms.

There are still smaller photoconductive cells in both high and low voltage units which measure approximately $\frac{1}{4}$ inch in diameter by $\frac{1}{2}$ inch long. The high-voltage types can be operated on 115 volt ac and dc circuits without need for amplification. The low-voltage types are designed to work with B batteries up to 60 volts dc or for use with transistor amplifiers.

Crystals

Miniature crystals are approximately $\frac{7}{16}$ inch wide by $\frac{3}{16}$ inch thick by $\frac{1}{2}$ inch high and are made in a frequency range of 5,000 kc to 100 mc. Both wire-lead and rigid-pin units can be obtained,

and clipped-lead types can be plugged into subminiature-tube sockets.

One variation in miniature crystals is the circular unit in Fig. 232. Measuring $\frac{9}{16}$ inch in diameter by $\frac{3}{6}$ inch deep, this unit is made in a frequency range of 15 to 50 mc and consists of $\frac{1}{16}$ inch diameter pin-leads.

Subminiature tubes

With the development of transistors, the subminiature tube was squeezed out of the midget-components picture. However, many subminiature-tube types are still in active production.

Among the popular tubes are the CK512AX voltage amplifier, CK526AX power amplifier, CK5676 hf oscillator and CK1054 thyatron. The primary use for subminiature tubes of this nature is for replacement in older equipment, originally designed around tubes.

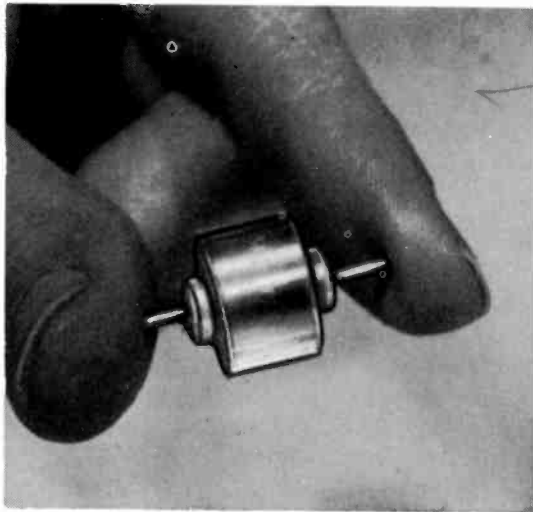


Fig. 232. Circular unit shown here is a miniature crystal.

Nuvistor

Fig. 233 shows a novel design in subminiature tubes — a 6-volt filament-type, 6CW4 triode. There is no glass envelope in the tube and it measures under $\frac{1}{2}$ inch in diameter and $\frac{8}{10}$ inch high. Fifteen tubes weigh one ounce. The tube is designed for plate voltages up to 75, and draws from 2 to 8 ma plate current. Heater- and plate-power requirements are less than 1 watt.

This metal-cased tube is used in vhf, TV and FM tuners, medical electronic equipment and compact electronic instruments. The mounting lugs around the outside of the base are of different widths for orientation of the tube in the socket.

Cells and batteries

Battery size still continues to lag behind other subminiature component developments, and the trend toward smaller batteries is a result of lighter current drain components. Presently known

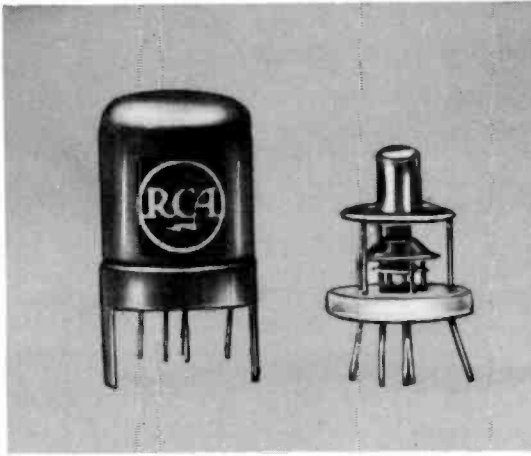


Fig. 233. This small sized tube is ideal for high-frequency circuits. Tabs on the metal case orient the tube properly in its socket.

electrochemical systems such as zinc-carbon, nickel-cadmium and silver-zinc have reached efficiencies in the high 90% ranges. Solar or sun batteries and thermo-electric batteries are still mostly experimental.

The Leclanche cell

The basic chemicals of the Leclanche dry cell are zinc, carbon and manganese-dioxide. This dry cell will not perform well in temperatures above 120°F. and has a shelf-life of approximately six months at temperatures of 70°F. to 90°F. The shelf-life can be extended to a year by storing the battery in a refrigerator or other cold location.

It is impossible to tell in advance how well this type of cell will perform unless the service is known. If the battery is to be used

continuously or on intermittent duty its life will be entirely different. A voltmeter check on the Leclanche cell is only a rough measure of the battery's condition.

The smallest Leclanche cell available to date is a unit designed to power a battery-operated wristwatch and is rated at 7-microamperes drain under a 200,000-ohm load for a life of 1 year. The initial voltage is 1.5 volts, which decreases to 1.3 volts at the end of one year's use. The cell is less than $\frac{1}{2}$ inch in diameter, slightly more than $\frac{1}{8}$ inch high.

One of the smallest practical and ready-available cells is the type N, which measures $1\frac{3}{16}$ inches high and less than $\frac{1}{2}$ inch in diameter. It is designed for a no-load emf of 1.5 volts, and a current of 20 milliamperes, maximum.

Mercury cells

The mercury cell has a higher first cost than the Leclanche-type but is a more efficient unit for the space it occupies. The main

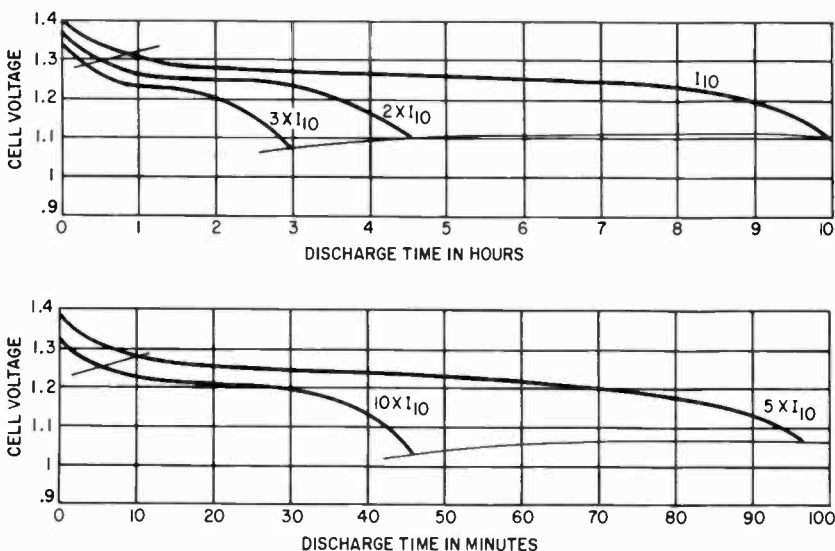


Fig. 234. The top set of curves show typical cell voltage at 1, 2 and 3 times the 10-hour (I_{10}) rate. The lower set are for the voltages at 5 and 10 times the 10-hour rate. For example: a 1 ampere-hour cell (1,000 mah) can be discharged for 10 hours at 100 ma ($1,000 \text{ mah} \div 10 \text{ h} = 100 (I_{10})$). If the 100 ma drain is doubled ($2 \times I_{10}$ or 200 ma in this case) the cell voltage will drop to 1.1 in about $4\frac{1}{2}$ hours. Intermediate current values can be estimated or the next higher rating curve can be used, giving a safety factor for discharge time. Increasing drain to 300 ma ($3 \times I_{10}$) the cell voltage will drop to 1.1 volts in about $2\frac{3}{4}$ hours. As the discharge rate increases the cell voltage drops faster. A 1 ah (1000 mah) cell will not give 1 ampere for 1 hour. The curve $10 \times I_{10}$ shows that the 1.1 volt level will be reached in a little more than 40 minutes.

chemicals in a mercury cell are mercuric oxide, powdered zinc and caustic-potash. The cell's voltage under a constant load is nearly flat, but terminates with a sharp voltage drop-off. It will take temperatures up to 150°F. without mechanical damage or significant changes in its electrical characteristics. The mercury cells also have the advantage of a 2 to 3 year shelf-life, and quick recovery to no-load voltage after a load has been put on the battery.

The smallest mercury cell is just over $\frac{7}{16}$ inch in diameter and $\frac{1}{8}$ inch high, and weighs only 0.04 of an ounce. The useful current range is 0-5 milliamperes and service capacity is about 75 milli-ampere-hours.

A slightly larger version of the mercury cell is $\frac{7}{16}$ inch in diameter by $\frac{2}{10}$ inch high unit, rated for 10 milliamperes service and duty of about 150 milliampere-hours. The weight is less than $\frac{1}{10}$ ounce.

How to figure discharge time and currents

Fig. 234 gives a set of *service-life* curves for nickel-cadmium cells. The vertical readings on the left are voltages under load, and the horizontal readings on the bottom are the discharge times in hours or minutes. A few examples (bottom of page 52) clarify how the curves are used.

Other subminiaturized components

Obviously, it is quite impossible to give you a description of every subminiaturized component. The trend toward making parts smaller and smaller is a continuing one, but we have given you enough examples in this chapter to give you some indication of what has been done. Apparently all components must yield, sooner or later, to some subminiaturization techniques. This also applies to units we would not normally associate with subminiaturization. For example, wiring can be made to occupy much less space by using a printed-circuit board. The printed-circuit board can be reduced in volume by having printed-circuit boards in depth — that is, several boards superimposed on each other, but occupying no more space than a single board.

Finally, there seems to be no sharp demarcation when the subject is size. Parts are made smaller, then they are miniaturized, then subminiaturized and finally microminiaturized. And if a microminiature part can be made smaller, what is it?

Chapter 3

Subminiaturized Equipment

The public became aware of miniaturization after World War II when small portables, about the size of cigar boxes, appeared on the market. Hearing aids were a little larger than decks of cards at that time, as hearing-aid manufacturers began to use subminiature and hearing-aid "flat-press" tubes. The transistor was yet to be a commercial practicality. (See Fig. 301.)

When the transistor appeared commercially it ushered in a long line of miniature and subminiature electronic devices. Radios shrank to coat-pocket and then to shirt-pocket size. Recorders diminished from bread-box bulk to dimensions small enough for inside breast-pocket concealment. Hearing aids were miniaturized to matchbook and pill-box size.

The age of miniaturization and subminiaturization was making its debut.

Radio "pills"

Doctors now have a radio pill capable of transmitting a low-frequency signal from within the human body. The pill — sometimes called an *endoradiosonde*—is less than 1 inch long and just under $\frac{3}{8}$ inch in diameter. An exploded view of a similar pill (measured against a scale in centimeters) is shown in Fig. 302.

A cutaway view of the pill is shown in Fig. 303. The entire device is sealed, and the transmitter is modulated with a pressure-sensitive inductive core. The pressure of the body organ under investigation is transferred through the rubber membrane to the spring-loaded ferrite core.

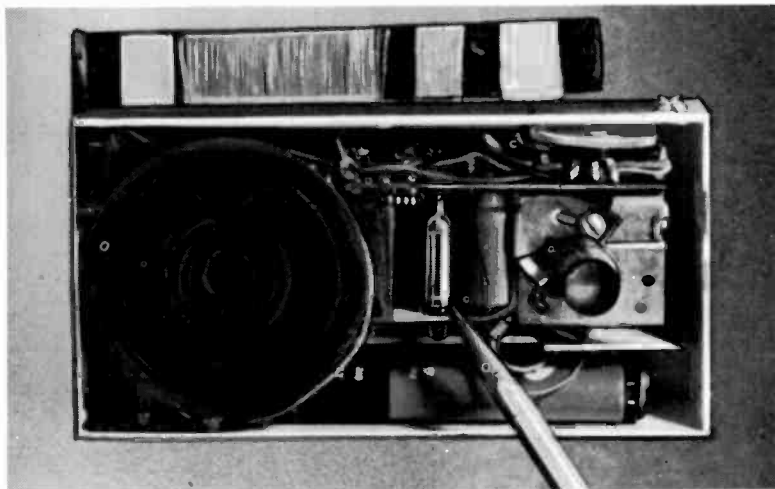


Fig. 301. The subminiature tube (one of which is indicated by the pencil) helped reduce the dimension of the radio to pocket-portable size.

Fig. 304 is the schematic for a transmitter pill. The oscillator works in the 300–400-kc band where there is no interference from high-power broadcast transmitters. One inch of pressure change (roughly the same pressure as a draft of air) will shift the transmitter frequency approximately 0.25 kc (250 cycles). The oscillator has been shielded to cut down frequency shift with changes in surrounding conditions. Powdered iron is used in the inductor to increase its “Q”. Current drain of the pill is in the order of 50 to 60 microamperes. Mercury cells power the pills from about 1 to 3 months.

Digital circuit modules

One of the big fields of application for subminiature industrial devices is in computers. To increase reliability and aid handling, these subminiature circuits are often encapsulated with just the leads exposed. A potted computer module is shown in Fig. 305.

Fig. 305 is a flip-flop unit using a medium-speed switching transistor. The unit is designed to operate from a 12-volt dc supply with 6-volt and 1.5-volt “trigger” inputs. Fig. 306 shows the schematic of this flip-flop unit. This circuit also functions as a latch, binary scaler or shift register stage.

Another modular type is the indicator driver unit (Fig. 307). This is made with three individual transistors as output drivers

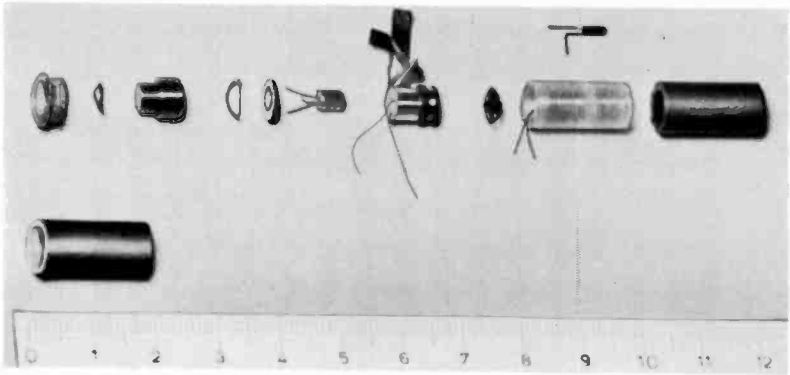


Fig. 302. Proper design makes it possible to get all these components into an object small enough to be swallowed. (Note that scale is in centimeters.) (Karolinska Institute)

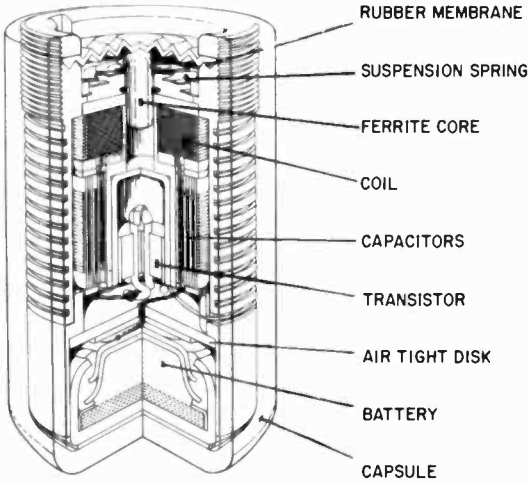
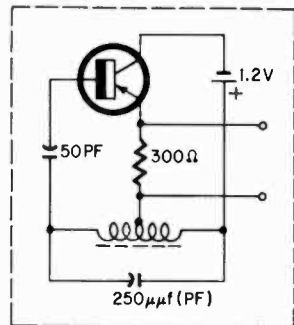


Fig. 303. Cutaway view of the endoradiosonde showing location of major components is greatly enlarged. (Dr. Bertil Jacobson, Stockholm, Sweden)

Fig. 304. Schematic for the endoradiosonde is simple — few components are used.



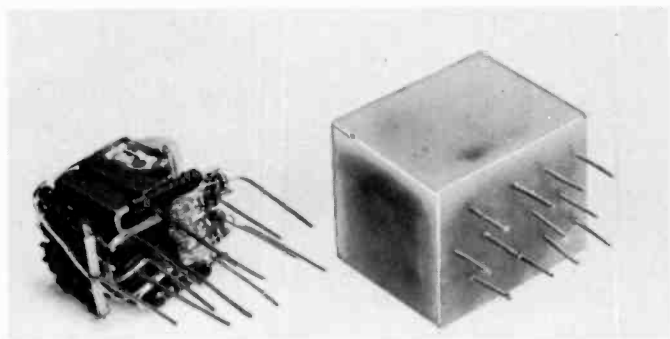


Fig. 305. This slip-stop has a high component density. Encapsulated, it is rugged and stable. It is more of a wire-in, than a plug-in device.

for incandescent lamps as shown in the schematic in Fig. 308. This device is used only for checkout and monitoring of systems.

The third unit in the series is the crystal oscillator shown in Fig. 309. This produces square waves when used in series with a crystal. Operating frequency range is about 80 to 150 kc. The schematic (and dimensions) for this oscillator is shown in Fig. 310.

Low-frequency receiver

The radio-range receiver shown in Fig. 311 was subminiaturized by the National Bureau of Standards and the US Navy. In these

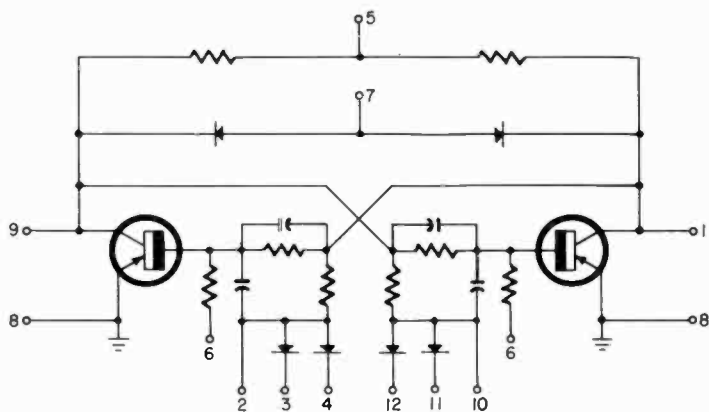


Fig. 306. Schematic of slip-stop shows the many parts included. Duplicated terminal numbers are actually paralleled connections, drawn this way to simplify schematic.

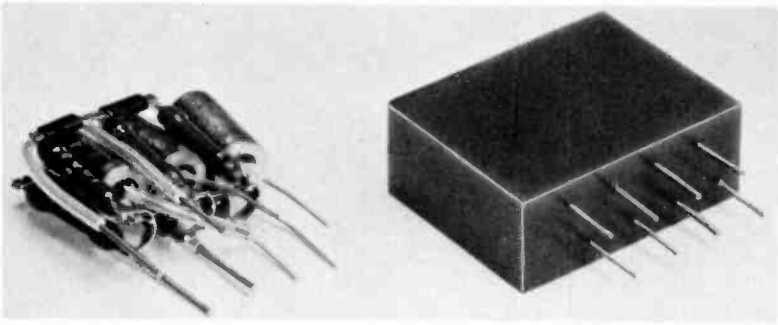


Fig. 307. The three transistors in this module are used as switches to turn pilot or indicator lamps on, or off. The lamps are not part of the module.

drawings you can see how dramatic the shrinkage process can be. The unit tunes from 190 to 550 kc and has an audio output of just under 1/10 watt. The standard receiver used the 26-volt dc aircraft-electrical system for the plate supply with the four 6-volt tube filaments connected in series.

The rf tuning assembly is made up from tuned-slug inductors, with the tuning knob attached to the oscillator-slug mechanism,

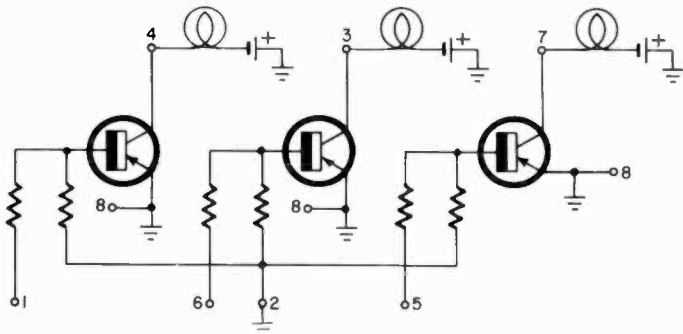


Fig. 308. The three lamps are the collector loads of the three transistors. A single battery can be used. Three are shown to simplify the schematic. A negative voltage applied across either terminals 1, 5 or 6 and terminal 2 will allow current to flow through transistor emitter-collector circuit and the indicator lamp.

and the rf slugs working off a gear train to the oscillator mechanism.

The original version of this receiver weighed 10 lbs. and occupied 300 cubic inches. It also took up a panel space 5½ by 6 inches. After "shrinking", the receiver weighed 5¼ lbs. took up

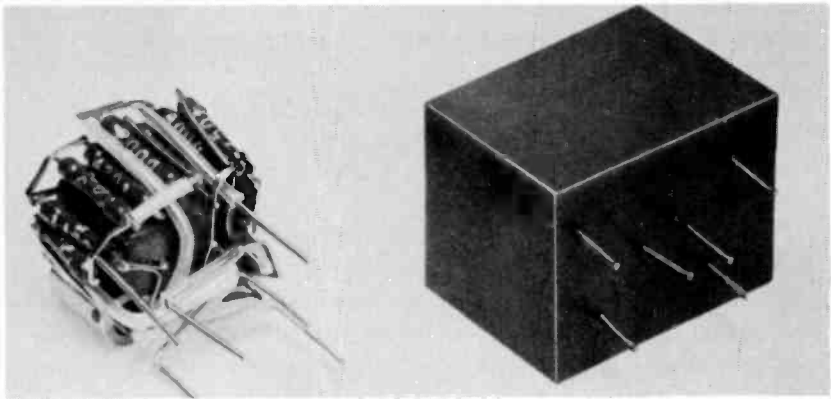


Fig. 309. This module contains the components in the schematic in Fig. 310. The crystal is external and is not encapsulated with the other module components.

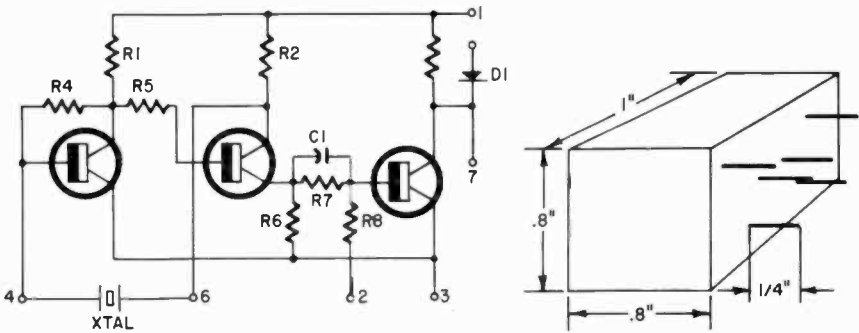


Fig. 310. Crystal-controlled square-wave generator schematic contains but one capacitor which is used to improve the high-frequency characteristics of the square wave.

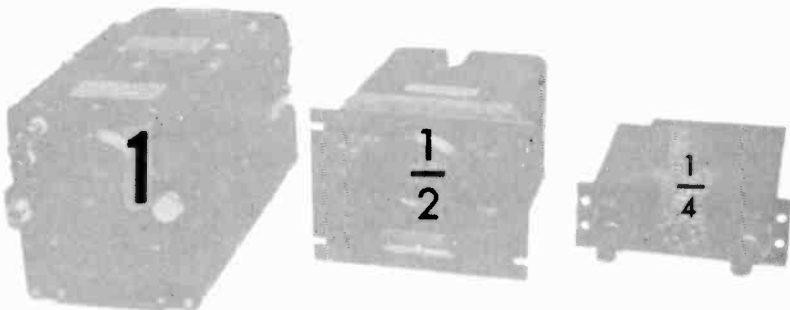


Fig. 311. Constant striving for reduction in size produces smaller and smaller units which are capable of identical or better performance. Size reduction also reduces weight. Weight and space gain can be used for additional fuel or equipment.

less than a fifth of its standard volume and required less than 2 inches of panel height and 6 inches of panel length for mounting.

Sunglass radio

One novel subminiature design, shown in Fig. 312, is a three-transistor reflex-circuit broadcast receiver built into a pair of sunglasses.

The rf section, housed in the left temple of the glasses, contains a midjet variable capacitor, rf choke, antenna coil, rf transistor and diode. The audio section in the right temple consists of two audio transistors, volume-control switch combination, hearing-aid

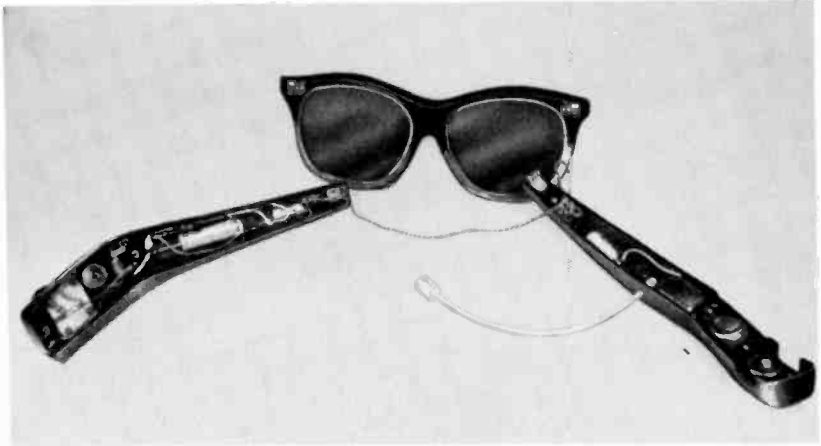


Fig. 312. Complete radio in eyeglass frame utilizes many hearing-aid principles.

type transducer and earplug. The spectacle radio is powered by a mercury cell which runs the set for about 150 hours.

The entire unit weighs about 6 ounces with the battery.

Subminiaturized oscillator wristwatch

Built around a subminiature tuning fork, the wristwatch of Fig. 313 utilizes an inductive type feedback oscillator circuit with transistor (Fig. 314). The fork is driven at 360 cycles. The drive coils are wound with approximately 8,000 turns of .0006-inch-diameter wire, and one drive coil is tapped at the 2,000th turn to pick off a phasing signal for the transistor's emitter circuit. An R-C combination provides current pulses to kick the fork. A shock, such as jarring the watch, will change the amount of movement in the fork temporarily. This temporary movement produces a voltage in one of the drive coils that is opposite to the voltage in the

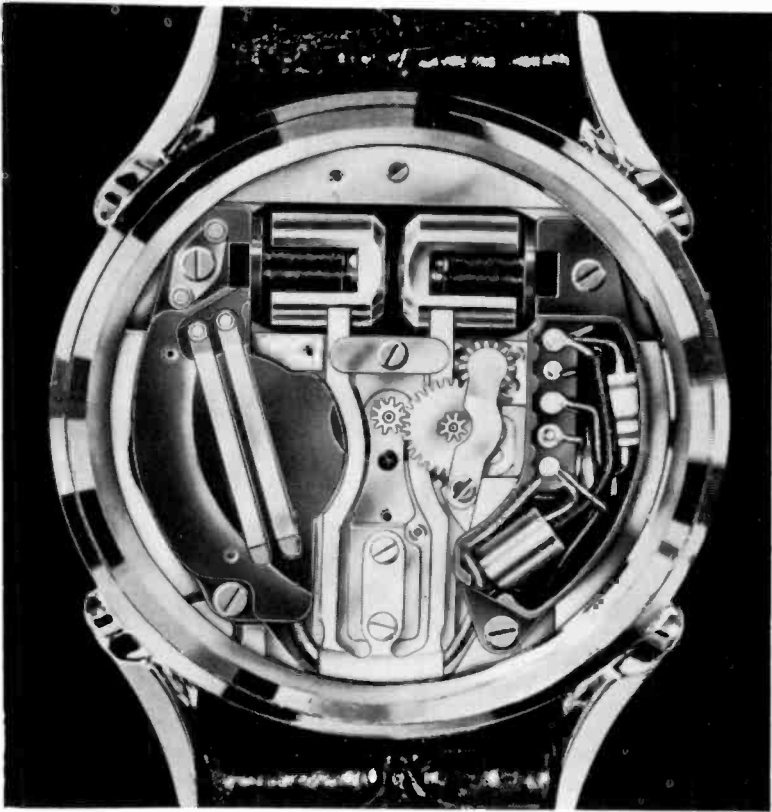


Fig. 313. This greatly enlarged view of the inside of an electronic watch shows the placement of components in the schematic of Fig. 314. (Bulova Watch Co., Inc.)

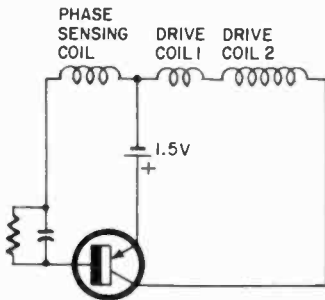
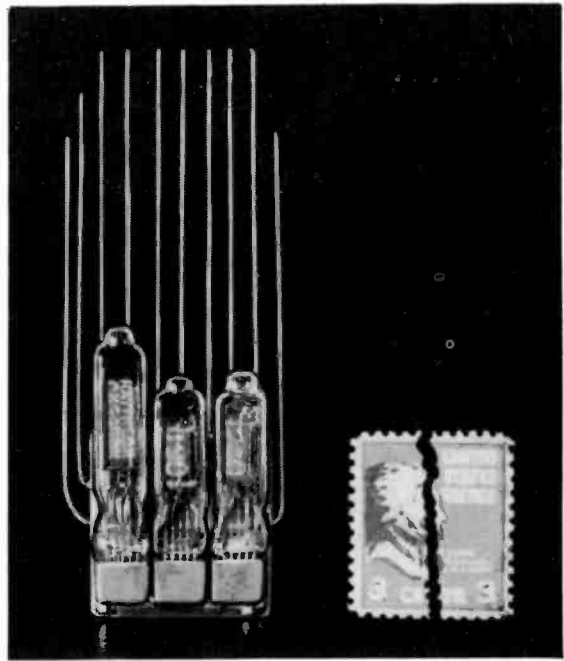


Fig. 314. Coils in this schematic are part of a tuning-fork controlled oscillator. The tuning fork is a more practical frequency controlling element at low frequencies than a crystal.

power cell (1.5-volts) and cuts down the excess movement in the fork. The fork drives an index wheel and the rest of the watch-works. Consuming under 10 microwatts, the watch will run for over a year on one battery with an accuracy of 2 seconds in a 24-hour period.

Fig. 315. Tubes are less efficient than transistors as an amplifying device. Power is wasted as heat in the filament.



Progress in a subminiaturized amplifier

Fig. 315 shows an early three-stage tube type packaged amplifier circuit. These early units measured about $1\frac{1}{8}$ by $1\frac{1}{2}$ inches with 2-inch leads, and were about $\frac{3}{8}$ inch thick overall with the tubes in place. Resistors were $\frac{1}{2}$ watt, with capacitors rated at 300 volts dc test and 150 volts dc working. The frequency response was roughly between 500 and 4,000 cycles with a 5,000 gain

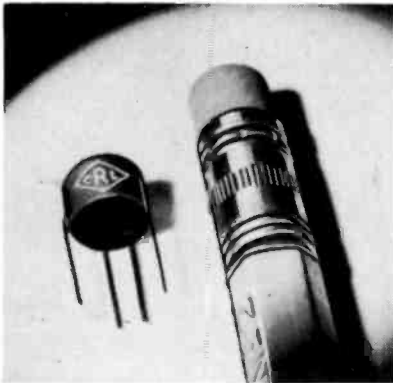


Fig. 316. Packaged unit may be either a signal amplifier or an output stage.

Fig. 317. Schematic is identical for both the signal amplifier and the output stage. Only the component values or characteristics are changed.

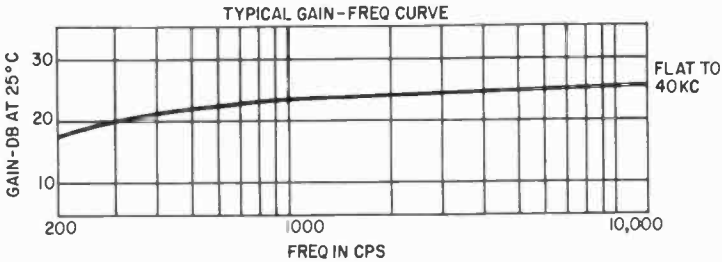
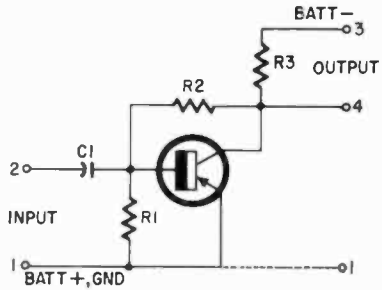


Fig. 318. Frequency response of the module is typical. Low frequency response is difficult to maintain because of increased capacitor reactance.

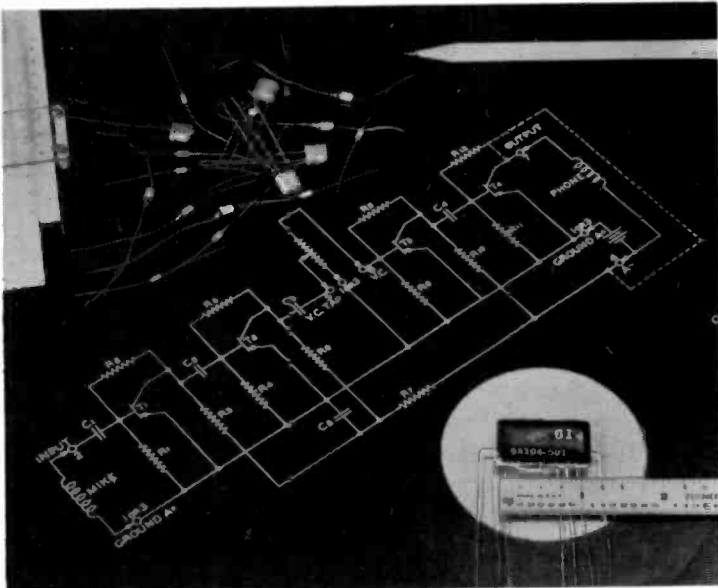


Fig. 319. This waferlike module contains four transistors as well as the resistors and capacitors required for R-C coupling. The gain control is external. It connects to three terminals on the module. (Centralab, Electronics—Div. Globe-Union)

A taped-up resist pattern can be made directly on copper laminate for "one-shot" etching. This pattern is dipped into the etchant (such as ferric chloride) and, after several minutes, is removed and rinsed in water. Then the tape is stripped off (Fig. 402) and the pattern cleaned.

Using tapes for photo set-ups

Fig. 403 shows a die-cut pattern being laid out on a piece of stiff white board, and circles and other forms put on the board in appropriate spots.

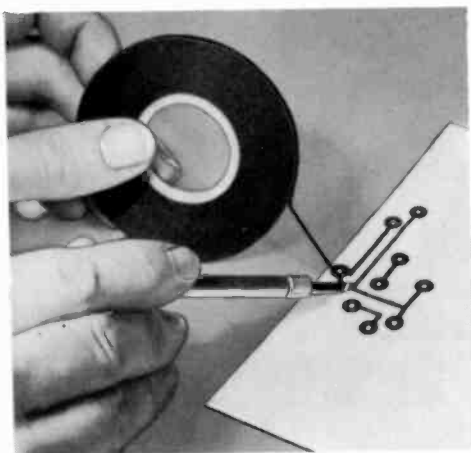
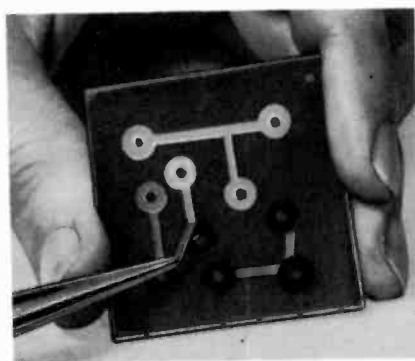


Fig. 401. Die-cut patterns make a neater looking circuit pattern than can be obtained by freehand drawing.

Fig. 402. Die-cut patterns can be used as a resist for the etching process.



Then the entire pattern is photographed using high-contrast film.

Presensitized copper-clad phenolic laminate is used for the base or chassis. A negative is laid over the presensitized plate and exposed to the sun or an arc lamp. Two minutes at 12 inches with a G-E type EBR lamp is about right. The plate is then developed and etched. The finished pattern is rinsed and dried.

across the entire unit. These earlier packaged amplifiers required both A- and B-supplies.

The next step in packaged amplifier development was the unit shown in Fig. 316. This was a single-stage transistor amplifier made in two varieties — a low-current-drain voltage amplifier or



Fig. 320. These small modules are not repaired—just replaced. Reliability in these devices is, generally, considerably higher than that of transistor radios and similar devices.

driver unit, and a higher-current-drain output unit. These measured just under $3/10$ inch in diameter and $1/2$ inch high, excluding leads. The schematic is shown in Fig. 317 and the frequency response curve in Fig. 318.

Fig. 319 shows a four-stage packaged amplifier. Current drain is 3.5 to 4.5 ma from a 1.3-volt mercury cell supply. Power output is about 1 mw across a 1,000-ohm earphone. A gain of 70 db is possible with this unit. Measuring $5/8$ inch high by $1 1/8$ long and $1/4$ thick, it weighs approximately $1/2$ ounce.

One development in four-stage packaged amplifiers is the model shown in Fig. 320. About $1/2$ inch in diameter and $1/2$ inch high with leads, this version contains four transistors, eight resistors and six capacitors, and draws a little over 2 ma on a 1.3-volt mercury cell. Power output across a 1,000-ohm phone load is about $1/2$ mw. It would take 15 of these units to weigh 1 ounce.

Chapter 4

Techniques

With the shrinking of electronic equipment, novel methods and materials have been devised to hold the newer and smaller electronic components together. Some of them involve mechanical fastening arrangements such as special notching and forming. Others involve chemical bonding or casting or embedding the circuits in a semi-rigid or rigid plastic.

New printed-circuit techniques have also been developed to produce the base patterns for subminiature circuit assemblies. These include presensitized base materials and special tape resist pattern materials.

Wherever possible, the simplest, most practical methods are shown in this chapter so that the experimenter can duplicate or simulate commercial techniques and learn the fundamental principles of packaging methods.

Printed-circuit shortcuts

One speedy method for making printed circuits is shown in Fig. 401. Here die-cut shapes of plastic tape are laid out in the required patterns. The tape can be used as an etch-resist for a "one-shot" layout or for making a photo negative.

Die-cut shapes are made in widths from $\frac{1}{32}$ to $\frac{1}{4}$ inch, and increase by $\frac{1}{32}$ inch intervals. The dots, or circles, come in various inside and outside diameters, the most common being $\frac{1}{8}$ inch outside, $\frac{1}{16}$ inch inside and $\frac{1}{4}$ inch outside, $\frac{1}{8}$ inch inside.

A taped-up resist pattern can be made directly on copper laminate for "one-shot" etching. This pattern is dipped into the etchant (such as ferric chloride) and, after several minutes, is removed and rinsed in water. Then the tape is stripped off (Fig. 402) and the pattern cleaned.

Using tapes for photo set-ups

Fig. 403 shows a die-cut pattern being laid out on a piece of stiff white board, and circles and other forms put on the board in appro-

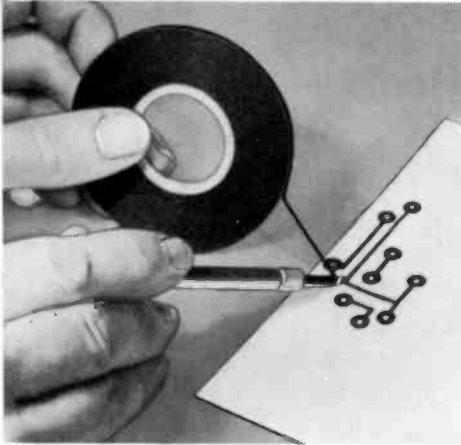
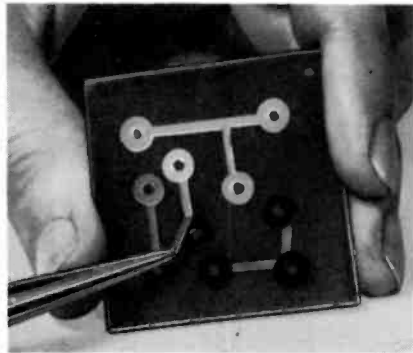


Fig. 401. *Die-cut patterns make a neater looking circuit pattern than can be obtained by freehand drawing.*

Fig. 402. *Die-cut patterns can be used as a resist for the etching process.*



priate spots. Then the entire pattern is photographed using high-contrast film.

Presensitized copper-clad phenolic laminate is used for the base or chassis. A negative is laid over the presensitized plate and exposed to the sun or an arc lamp. Two minutes at 12 inches with a G-E type EBR lamp is about right. The plate is then developed and etched. The finished pattern is rinsed and dried.

Precut "black-and-white" tape is used where a double pattern (a printed circuit on each side of the board) is needed. The tape is black on one side and white on the other. When both patterns are lined up on opposite sides of one piece of transparent plastic or translucent paper and photographed, the white tape side does not

Fig. 403. Pre-cut die patterns are laid out on stiff, white board.

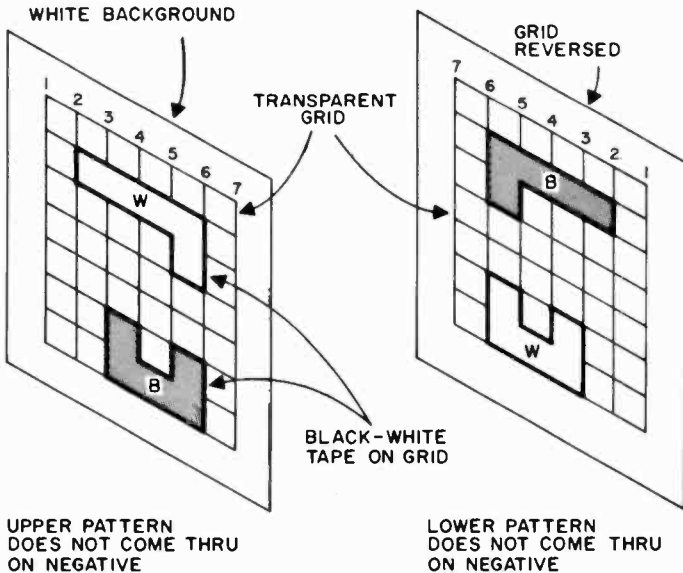
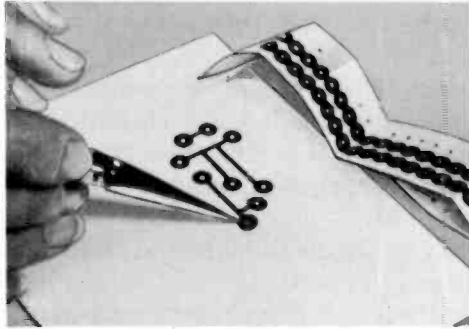


Fig. 404. Black-and-white die-cut patterns are used with a photographic process to make two-sided circuit boards.

show up against the white paper background. Turning over the pattern allows the second negative for the reverse side of the printed circuit board to be made, using one camera setup. The process is sketched in Fig. 404.

Sometimes a special shape such as a triangle or oval is not available as a stock item from the tape manufacturer. Any shape can be made from roll tape. Roll tapes comes in 1/2, 1- and 2-inch widths and black-and-white types for double-sided printed-circuit plates.

Etching with ammonium persulfate

Besides ferric chloride, ammonium persulfate is used as a copper etchant for printed circuits. The advantages claimed by its manufacturers are no sludge formations, less corrosiveness, easy rinsing and easy disposal. It will etch solder-plated circuits as well as the regular copper-clad laminates. Dilute solutions can also be used to clean the copper laminates before applying photographic emulsion type resists.

You can obtain the chemical from mail-order or drug and chemical supply houses. To make an etching solution, add 4 ounces of



Fig. 405. Etching solution is made from powder dissolved in warm (105°F to 140°F) water. When etching, solution should be between 65°F and 70°F. Solution is good for about a week, so don't make any more than you expect to use in that time. Use non-metallic containers.

the ammonium persulfate to 16 ounces of water. The water should be about 105° to 140°F. This solution will keep about a week if stored in a tightly capped bottle. Let the solution cool to room temperature — about 65°F to 70°F — before etching.

Etching can be done in a plastic or enamel tray. (Fig. 405). The average time for 1 oz. copper laminate (.002 inch thick) and sub-miniature circuit boards is about 5 minutes in a *fresh* bath. As the bath “loads up” with copper, a longer etching time is required.

Heating the bath will speed the reaction. The solution can be heated by immersing the working tray of solution in a larger tray containing hot water at about 125°F. Rinse the etched circuit three or four times in running tap water and place it in an upright position to dry.

When a board has solder plating on it, the chemical reaction with ammonium persulfate forms a film of lead sulfate on the board. This can be buffed off with a cloth and some rottenstone or pumice, or can be taken off with a motorized hand-tool buffing wheel.

Fotoceram boards

Fig. 406 shows a printed-circuit board made commercially from a glass ceramic. This board is made by starting with photosensitive

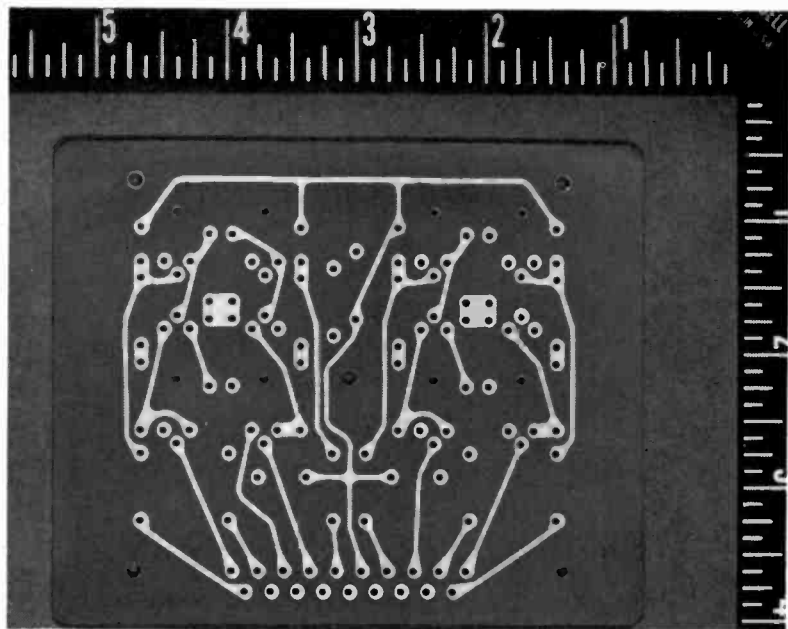


Fig. 406. A commercially prepared circuit board. Biggest problem in layout is to eliminate as many cross overs as possible.

glass which is exposed through a negative. After exposure, the image is developed by heating. It is then chemically etched to produce holes. After this, it is plated to produce the copper circuit paths.

You can get a home-use Fotoceram board from electronic parts distributors. The material comes in three standard sizes — 3 by 5,

6 by 8, and 9 by 12 inches, and is completely copper-covered when it is purchased. In addition, .052-inch-diameter holes are drilled in the board on 0.1 inch centers. A lacquer prevents the copper from tarnishing before the pattern is laid down.

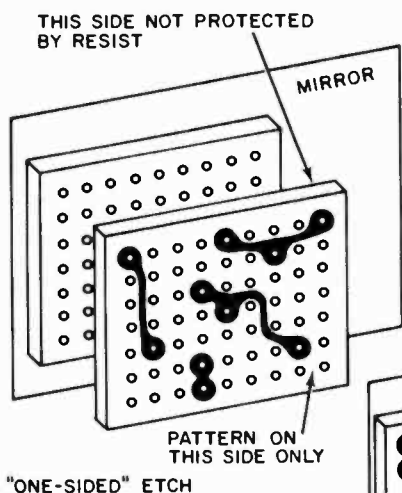


Fig. 407. Single-sided circuit board is handled just like any other. Resist patterns must travel between perforations.

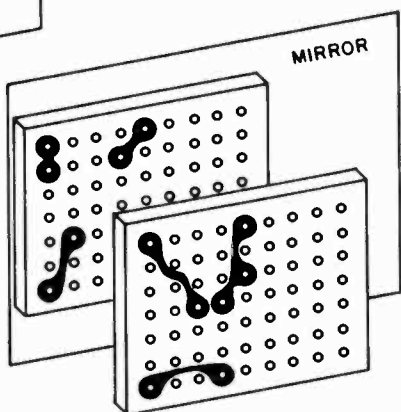


Fig. 408. Double-sided circuit board must have perforations covered or filled to prevent conductor from being removed between sides of board.

The first step in making a "home-made" circuit with this material is to remove the lacquer with a cotton swab and alcohol. Ordinary rubbing alcohol will do. Next, lay out the circuit (Fig. 407) using tape or liquid resist. If tape is used, make sure all joints are tightly sealed. If a through-hole connection is desired, mask the holes on both sides (Fig. 408). If a one-sided circuit is being made and connections must be broken, the holes should not be treated with resist and the connecting copper will etch away. The board is then put in the etchant (6 oz. of ferric chloride or 5 oz. of ammonium persulfate in a pint of water). If you use ammonium persulfate, the water should be between 105°F and 140°F when the persulfate is first dissolved. When the etching is complete, remove the board and rinse it several times in cold water.

"Potting" electronic assemblies

In building miniature projects of the type shown in this and succeeding chapters, you may want to keep them "as is" for possible change or experimentation. Or, you may conclude that, having reached your goal, no further changes are desired or necessary. In the latter case you might consider encapsulating or potting the project. This has the advantage of protecting the unit from dirt, moisture and humidity. It minimizes the effects of vibration, adding permanence to what originally might have been regarded as temporary.

Several commercial chemicals are available for "potting" or encapsulating miniature electronic devices. One of the most economical and easily obtained is Silastic RTV¹ a silicone rubber mixture.

Fig. 409 shows a miniature assembly prepared for "potting." (The same technique can be used for subminiature assemblies).

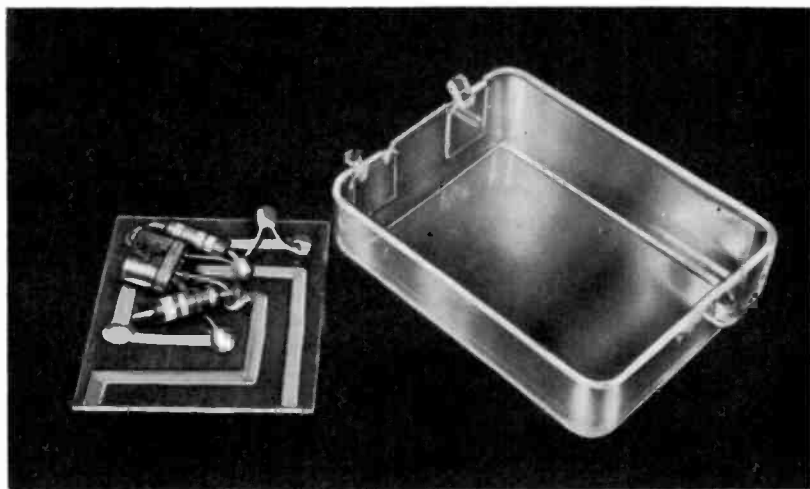


Fig. 409. Potting is the best way to insulate component leads in compact assemblies. A metal container can be used for shielding purposes. Module can be dipped, or otherwise insulated to prevent accidental shorting.

Select a plastic container and fix the assembly so that it is self-supporting in the container.

Next, pour the two parts of the silicone rubber potting compound together and mix them in a paper container. The silicone rubber is white and the catalyst is colored so that it is easy to see when they are uniformly mixed. Stir the mixture slowly to prevent air bubbles from getting trapped in it.

¹ Dow-Corning Co.

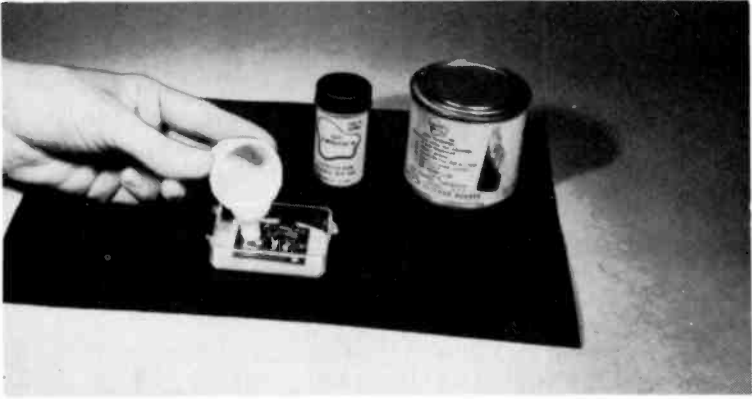


Fig. 410. Potting compound is a mixture of silicone rubber and a catalyst.

Now fill the container partially with the silicone mixture, and set the component or assembly into the mixture. Then pour the remainder of silicone mixture over the assembly as shown in Fig. 410.

After the silicone rubber has set, you can slide the encapsulated part out of the container and trim the excess material with a knife or razor blade.

Several formulations are made by the manufacturer. One will set in 24 hours at room temperature; another in 30 minutes at room temperature.

The thickness of the coating will affect the time it takes to set

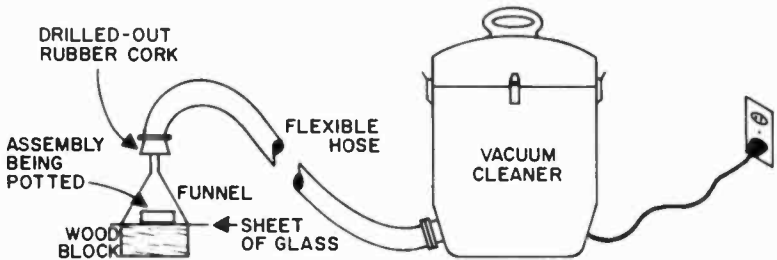


Fig. 411. Vacuum cleaner supplies suction to reduce air pressure to make trapped bubbles expand in potting mixture. The larger the bubbles are, the easier they are to detect. They often break of their own accord.

the silicone rubber. A $\frac{1}{8}$ -inch-thick coat is about the best for experimental work. If you prefer, you can apply several coats to build up thickness. Where air bubbles have been trapped in the silicone, use a vacuum cleaner (Fig. 411) to help remove them.

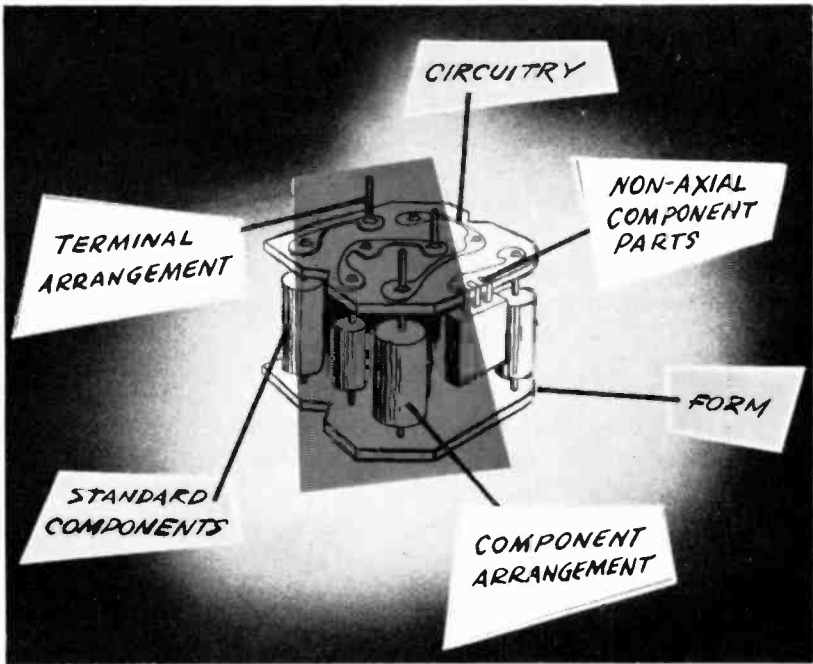


Fig. 412. This paraplate module uses standard axial lead components between two circuit boards. (Eastman Kodak Co.)

Potting with transparent dielectric "gel"

There is still another silicone material² useful for embedding subminiature assemblies. It is unique because it remains in jelly-like form around the components, and still allows testing the circuit after it has been potted. This compound does not shrink and is moisture-resistant. Temperatures from -100°F to 400°F have little effect on its properties.

The gel also comes in two parts: the first is a viscous, jellylike material, and the other is a thinner liquid which is the catalyst. Mix 10 parts of the liquid with 100 parts of the sticky, jelly substance. Make sure they are combined thoroughly. Pour the mixture over the assembly to be "potted" and allow to cure for 24 hours. The transparent quality of the gel allows visual checking. When the probe is removed, the gel will heal itself and close the hole left by the test probe.

² Sylgard 51 Dielectric Gel, Dow-Corning Corp.

The "module" idea

To take full advantage of miniature and subminiature components and provide other features such as physical strength, the concept of "modules" or packages was born. Again, we have a term that is broad in meaning. Modules can range from "flat-plate" types to cubic or rectangular units. In short, a module can be thought of as any package of electronic components complete in itself for circuit purposes, such as an amplifier, oscillator, R-C network, bridge-modulator, etc. One of the biggest reasons for "modular" subminiatures is fast and easy replacement of the entire module.

Paraplate module

This miniature module (Fig. 412) uses axial lead components such as resistors and capacitors set between two printed-circuit

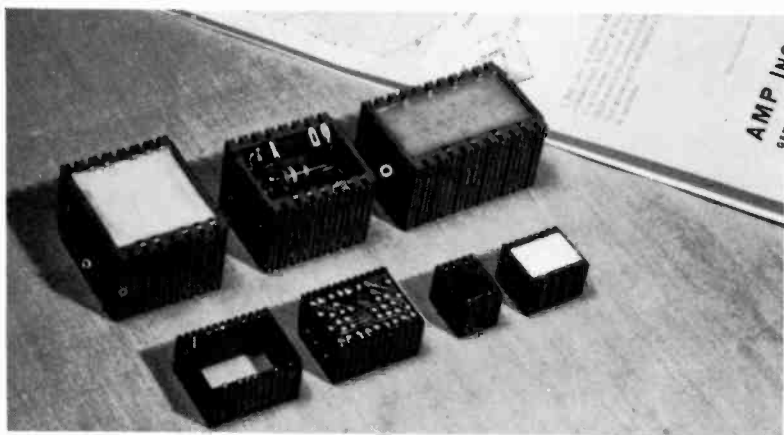


Fig. 413. Plug-in modules are very practical for large devices. Troubleshooting is made much easier when suspected stages can be replaced or transposed with an identical unit. (AMP, Inc.)

boards and soldered as a modular assembly. The boards can be slotted or shaped to take nonaxial components. The advantages of such a module include strength, a minimum of hardware and relative ease in assembly. Another advantage is the possibility of adapting such a module to automatic production.

Plus module

The key to the design of this module is the use of the diagonals in rectangular mounting spaces. A flip-flop circuit of two tran-

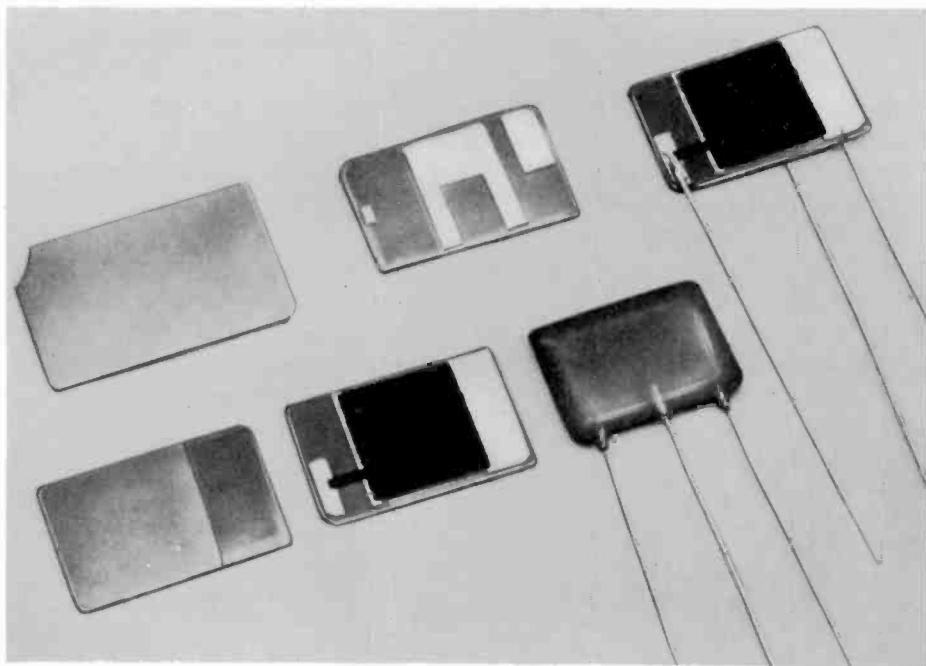


Fig. 414. These ceramic circuit elements contain many components and are generally used as coupling devices between active elements such as tubes and transistors. (Centralab, Electronics Div., Globe-Union)

sistors, eight resistors, four diodes and four capacitors can be packaged in less than $\frac{1}{4}$ cubic inch. The printed-circuit lines are .020 inch in width. The cross-rectangular assembly provides strength against shock and vibration.

MECA module

The big features of this module are the ability of the unit to become smaller as the number of components in the circuit becomes less, the use of the module's housing (or cell) for a form (or case) when the components are potted, and a unique contact arrangement that has two sets of springs and makes connection at four points. Further spacers and rib contacts make up the module. See Fig. 413.

Ceramic-base circuit plates

A technique adapted to miniature electronics is the ceramic plate circuit, a sample of which is shown in Fig. 414.

In this technique, resistors and capacitors are printed on a ceramic base which also acts as a dielectric for the capacitors and as an overall mechanical support. An average-size plate is about $\frac{1}{2}$ to $\frac{3}{4}$ inch wide by 1 inch long and $\frac{1}{8}$ inch thick. Before the individual resistors and capacitors are sealed, leads are attached to the entire plate assembly. The plate is then coated or dipped in wax and plastic for moisture protection and electrical insulation. The number of components usually varies from 4 to 10.

Titanium compounds and different clay mixtures are used to vary the dielectric constant (K) of the ceramic-base plates. K's of 50 to 10,000 are produced. When a section of ceramic is "sandwiched" between parallel silvered areas, a capacitor is formed.

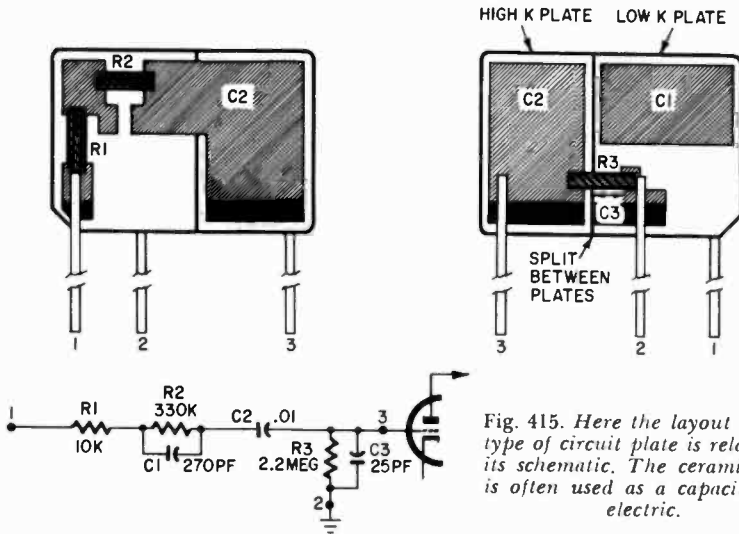


Fig. 415. Here the layout of one type of circuit plate is related to its schematic. The ceramic base is often used as a capacitor dielectric.

Sometimes different K's are combined in split plates to produce capacitors in widely separated capacitance ranges (Fig. 415). Where a very high capacitance value is desired, a rolled plastic-metal-foil capacitor is incorporated in the plate design and soldered to other components on the plate.

Some of the factors going into ceramic plate module design are worth mentioning. For one thing, only a certain number of resistors can be *printed* or *taped* on a given size of plate because of heat-dissipation requirements. The $\frac{1}{2}$ - to $\frac{1}{10}$ -watt range limits the resistors to about four or five per plate.

Lead arrangement is another touchy item. The more leads there are, the more trouble usually appears. As a general rule of thumb, the number of leads is never more than the longest dimension of

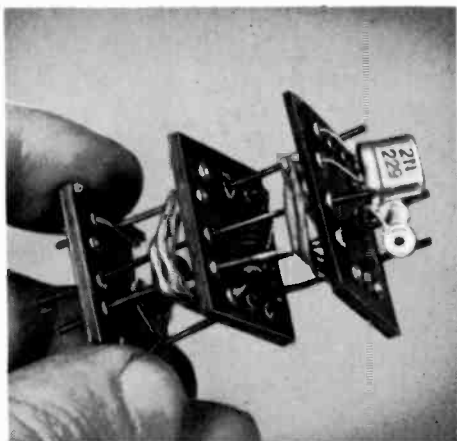
the plate divided by the distance between leads. Plugging the ceramic circuit plate designer is also the "bugaboo" of stray capacitance, hence low-K materials are often used to cut down the coupling between components. Ceramic materials must be juggled to obtain reasonable working voltages from the capacitors.

Manufactured plates include networks for an automatic-frequency control (afc) filter, diode filter, FM discriminator, triode and pentode coupling networks and a sound i.f. network for TV.

Tinkertoy modules

One of the earliest approaches to modular miniature electronic systems was the Tinkertoy unit. This consisted of 4 to 10 notched plates, each having 3 notches to a side, and measuring $\frac{7}{8}$ inch square

Fig. 416. This homemade Tinkertoy module is held together with rubber bands to make the final assembly easier. When two or more riser wires are soldered in place the rubber bands can be removed.



by $\frac{1}{16}$ inch thick. The wafers were made of talc, clay and various barium, calcium and strontium compounds. These materials were mixed and pressed out in squares. The notches were made, and the wafers fired in a kiln at about 2,200°F.

Capacitors, made from compounds of titanium, strontium and calcium, were approximately $\frac{1}{2}$ inch square and a few hundredths of an inch thick. Values ranged from 5 μf to .01 μf .

Resistors were the tape type, and were made by spraying carbon black, graphite and resin mixtures on an asbestos paper tape backing. The tape resistors ranged from 10 ohms to about 10 megohms and were rated at $\frac{1}{4}$ watt.

Small toroids in the range of 0.5 to 100 μh were wound and fastened to other ceramic discs as inductive elements for the final module. Conductive paths were applied to the various wafers by silver spraying, painting and silk-screening.

The entire system was adapted for automatic production, and several wafers were stacked together with riser wires to make these small modules.

Homemade Tinkertoy modules

The Tinkertoy technique lends itself very nicely to the construction of miniature assemblies. Components can be mounted easily in several planes — horizontally and vertically — at the same

Fig. 417. Threaded rod and hex nuts can be used for module assembly. For a permanent assembly the rods can be removed one at a time and replaced by wires which are soldered into place.

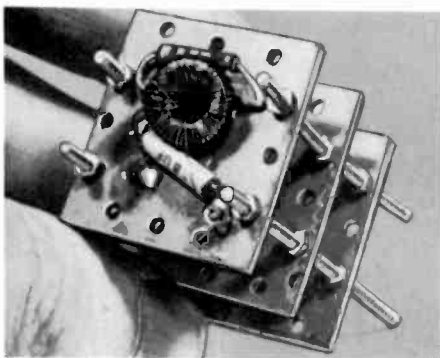


Fig. 418. Conductive epoxy cements can also be used to secure component leads and riser wires for a permanent assembly.

time using the smallest amount of lead length. The problem of mounting parts is nicely solved and the completed unit, for its size, is quite rigid and strong.

To make a Tinkertoy type module, cut phenolic sheet stock into 1-inch by 1-inch wafers and put the eyelets in. Lay out the parts for minimum space.

Fig. 416 shows three assembled wafers with vertical connecting wires temporarily held in place with rubber bands. After the wafers are lined up properly, fix them in place by soldering or

Fig. 419. Circular wafers can also be assembled into a module. Stock waste is greater than with square wafers but shape is adaptable to encapsulating in tubing.



cementing. You can build a versatile riser-deck combination (Fig. 417) using threaded studs and nuts. This has the advantage of allowing decks to be raised and lowered temporarily until final deck heights are determined. The riser studs are made of 2-56, 1-72 or 0-80 threaded rod.

Another method for assembling the individual wafer decks is

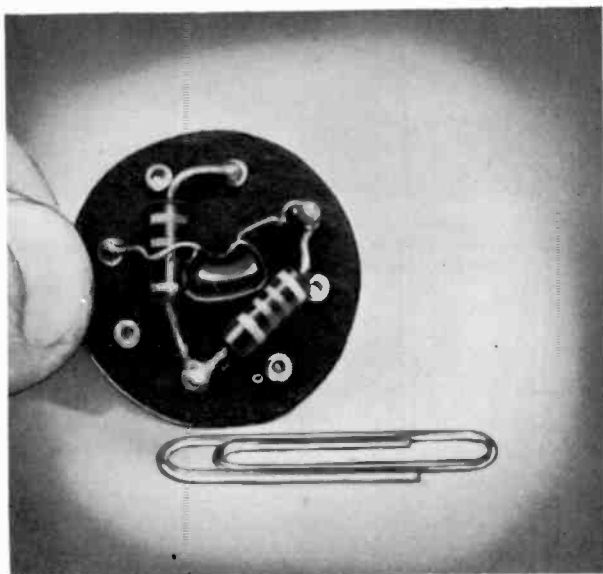


Fig. 420. Several components can be mounted on each wafer or disc. Vertical wires make interconnections and hold the wafers together.

shown in Fig. 418. Here, a conductive epoxy cement is used. The cement comes in two parts which are mixed together, just prior to use, and cured at room temperature in 8 hours.

Circular Tinkertoy type modules

Fig. 419 is a home-made wafer for a circular Tinkertoy type module. Cut a piece of phenolic $\frac{1}{16}$ inch thick to a $1\frac{1}{3}$ inch circle, and drill eight holes around the circumference. Insert eyelets. Next, drill additional holes to accommodate components on each deck.

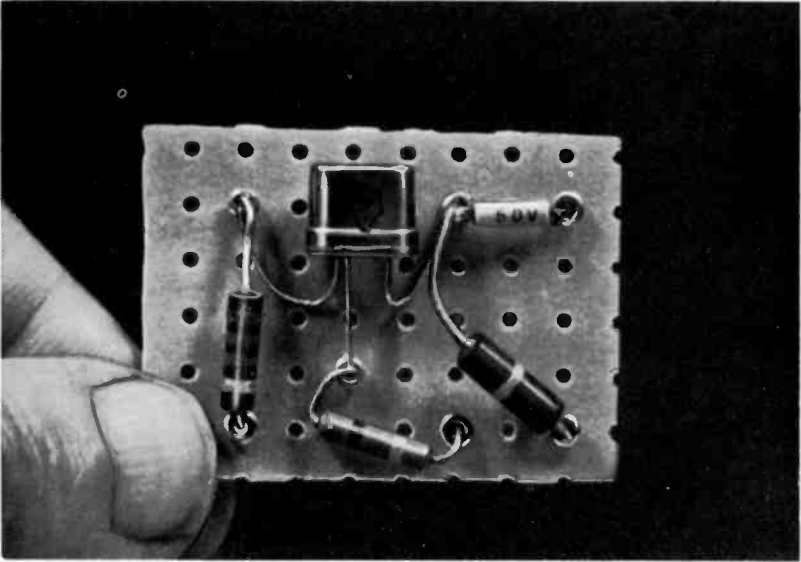


Fig. 421. A few eyelets make a neat looking layout. Pigtail leads can also be threaded through adjacent holes and soldered together on back of board without using eyelets.

These holes also receive eyelets so that the component leads can be soldered in. Add components as shown in Fig. 420, to make up the final wafer assembly. String these in place by dropping vertical wires through the empty holes. Finally, solder the vertical wires to make a permanent bundle.

Miniature wiring arrangements

Several schemes are practical for laying out a miniature chassis. The main idea is to use as little board space as possible and still get sufficient mechanical support for components. The board or the components themselves can provide this support. In a way, long leads and lead dress even on rf work are not a headache, since the size of the units makes long leads virtually impossible.

The first arrangement (Fig. 421) uses eyelets spaced around the board at convenient intervals. About 6 to 8 eyelets will usually be enough for the average miniature circuit layout. Be sure that any unused eyelets are insulated from the wiring or metallic component covers to prevent shorts.

Another layout, shown in Fig. 422, uses subminiature machine screws and nuts as binding posts at several points on the base board. The size of the screws will depend on the number of components

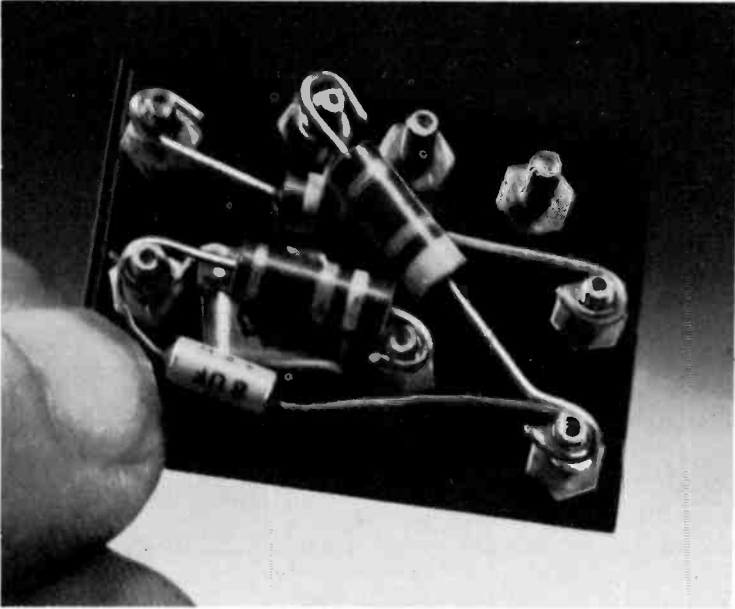


Fig. 422. For temporary circuitry small (2-56 or 1-72) machine screws and hex nuts can be used as binding posts.

and how crowded they are. Size 2-56 and 1-72 machine screws are suitable for most layouts. Bend the component leads around the screws, and, after the circuit is finally laid out, solder the leads.

Perforated boards and specialized component clips and terminals offer a very flexible layout system. Various clips are available. Boards having a 0.2 inch center-to-center for $\frac{1}{16}$ inch holes are the most practical for miniature work. For larger components that might have to be mounted near the edge of the board, angle clips can be used to support another piece of perforated board at right angles to the main board.

A homemade parallel plate assembly is shown in Fig. 423. This

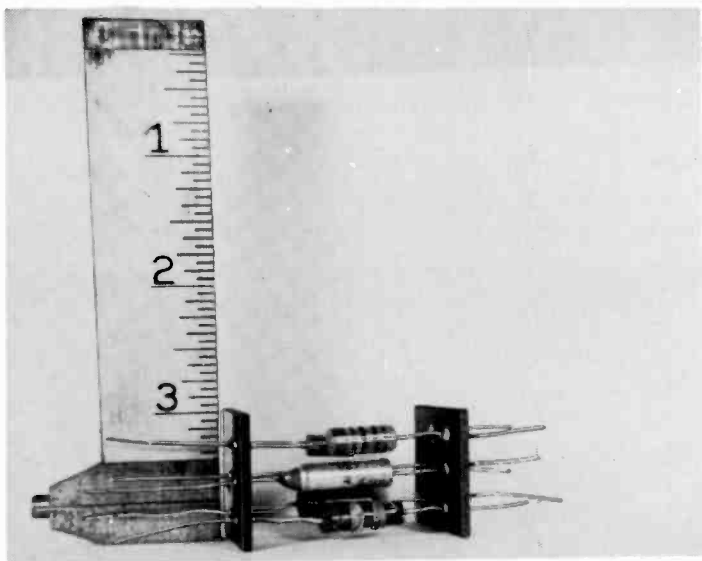


Fig. 423. A parallel plate assembly can be homemade too. Components can be difficult to replace if the lead length is kept very short.

is best adapted to circuits having a large number of axial components such as resistors and capacitors.

And, of course, printed-circuit decks can be used together with any of these schemes.

Micromodule system

A "do-it-yourself" type kit for making "micromodule" circuits is available. The kit includes holding fixtures, an oven, a special abrading tool, various solders, fluxes and chemical cleaners, and individual micromodule elements such as capacitors, resistors, diodes, transistors and inductors.

The micromodule is built around the basic wafer (Fig. 424). This wafer, of glass or ceramic, is notched to a standard pattern of three notches per side, or a total of 12 notches. One edge is *keyed* or *indexed* for proper lineup or orientation of the wafers when they are assembled. Resistors, capacitors, inductors, transistors, diodes and crystals are all available as microelements.

Microresistor wafers are made with metallic films which are about 1 to 2 millionths of an inch thick. The metallic film is depos-

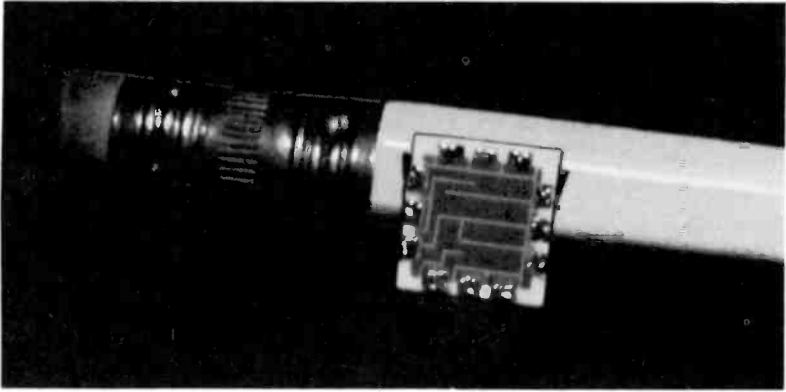


Fig. 424. *Micromodules can be built with wafers having components mounted.*

ited in a vacuum, and the films can be scribed in many ways to change resistance values or make several resistors on one wafer.

The microelement diode is a low-frequency unit available in types electrically equivalent to the 1N270, 1N277 and 1N695. One

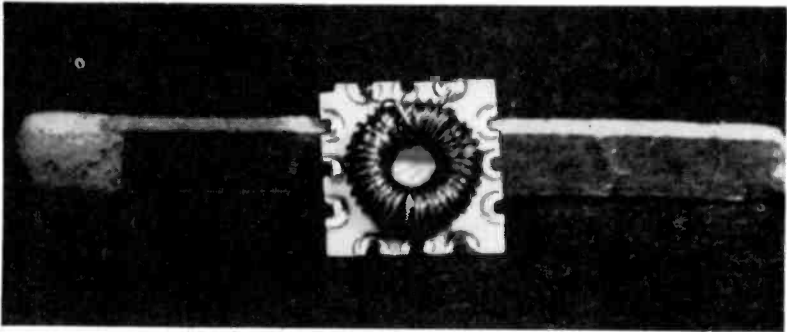


Fig. 425. *Toroid is cemented to ceramic wafer after leads are connected to appropriate notches.*

unit is a micro-element transistor and is made in types equivalent to the 2N357, 2N384, 2N404, 2N140, 2N581, 2N702 and others.

The micro element diode is a low-frequency unit available in square slug of tantalum in a hole in the center of the wafer. Leads from the specially processed tantalum slug go to notches on the edges of the wafer.

An inductor for micromodule work is wound on a ferrite toroid, or doughnut-shaped, core. The toroid inductor (Fig. 425) is held to the wafer with epoxy cement.

Converting to micromodules

Study the circuit to be *microminaturized* for its physical and electrical design. Before jumping into micromodule work, for instance, what is the signal source? Where does it go? Where is the voltage source? Where are voltages needed in the circuit? What components must be kept at a distance from others — such as input and output components in a high-gain audio amplifier?

Count the total number of components. About 10 microcomponents or eight wafers is a good limit for one micromodule. Other

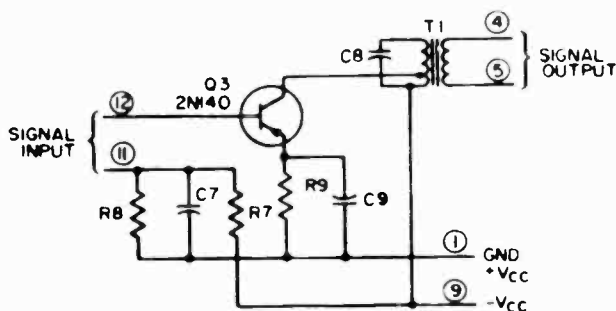


Fig. 426. Schematic for an i.f. amplifier module. Input terminals would connect to another transformer secondary.

precautions crop up in rf modules where capacitor wafers often have to be used as shields (changes in capacitance occur when the module is potted). When more than one inductor is used in a module, separate the inductors as much as possible.

Heat is another problem, and transistor and diode wafers must be mounted away from such heat-producing wafers as resistor elements. If a module contains a wafer with an element that must be adjusted after complete assembly, the adjustable wafer has to be mounted near one end of the module for easy access. An end wafer with a hole allows the adjusting tool access to the wafer being adjusted.

Leads and wafer positions

Fig. 426 is a schematic for an i.f. amplifier stage in a subminiaturized broadcast receiver. There are eight components — three resistors, three capacitors, an if transformer and a transistor — in the circuit. Fig. 427 is the worksheet at the point in which ground, output, A-minus and input leads have been assigned. Thus, riser

1 will carry the ground connections from the wafer, risers 4 and 5 will carry the output, riser 9 will carry the minus lead, and risers 11 and 12 the input.

The choice of mechanical and electrical connection points should limit mechanical connections (soldering for support only) to one point on each wafer. Using more than one supporting point in-

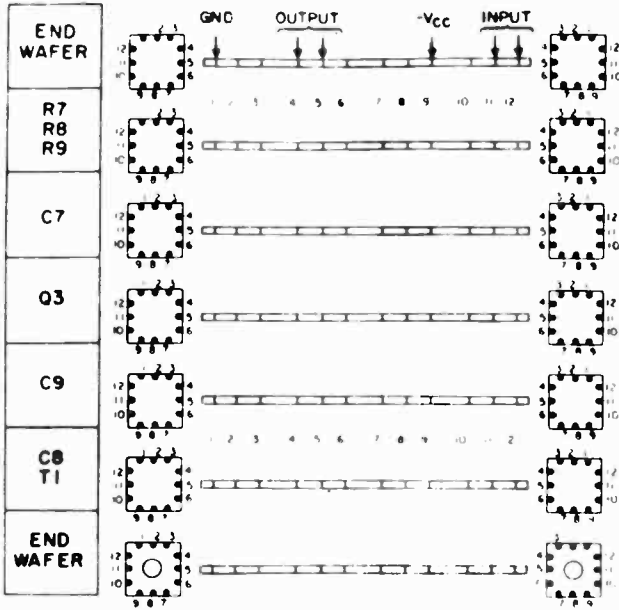


Fig. 427. Worksheet layout for i.f. amplifier stage. While a schematic is sufficient for wiring in normal circuitry, here you must plan which wafer notches will be used for connections.

creases the chance of making a “false” capacitor from the risers and wafers, and putting undesired capacitance in the circuit. Put mechanical connections on the side of the wafer opposite electrical connections to equalize stresses in the risers and give the best support. The end wafers are the only ones where all risers — mechanical and electrical — are soldered. In the case of this i.f. amplifier stage micromodule, no electrical connections, except external ones, are used on the end wafers.

Fig. 428 shows the wafers and risers in such a module. Completed modules can be plugged into individual sockets or soldered into printed-circuit boards.

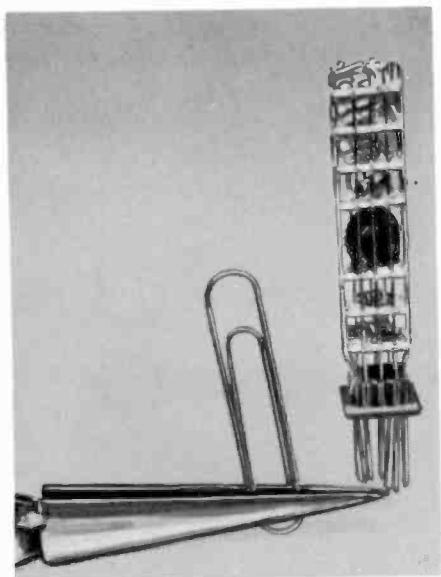
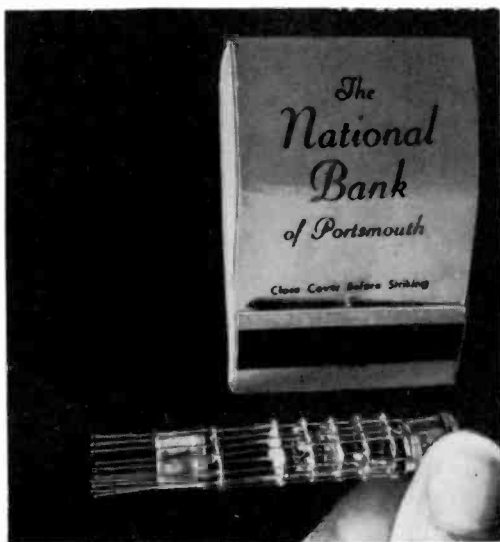


Fig. 428. Completed module is approximately actual size.

Homemade "micromodules"

Here are examples of how the experimenter can go even one step further than subminiature assemblies. The subminiature assembly contains approximately three to five components per cubic inch. The "homemade" micromodules in this section contain about 30 to 50 components per cubic inch. They are made with components that are available from electronic mail-order or supply houses.

Fig. 429. Multivibrator module flashes light bulb.



Resistors: R1—6,800 ohms; R2—2,700 ohms;
 R3—330 ohms (all $\frac{1}{10}$ watt, Ohmite)
 Capacitors: C1—.5 μ f, 20 volt (Ohmite R5520
 tantalum); C2—56 μ f, 6 volt tantalum (Mal-
 lory TAM)
 Transistors: Q1, Q2—2N35 or equivalent
 Lamp: L—Mite-T-Lite (Sylvania)
 Micromodule wafers (Coors Co.; Corning Glass
 Works, Electronic Components Div.)
 Cement: Epoxy-silver (Emerson & Cummings)

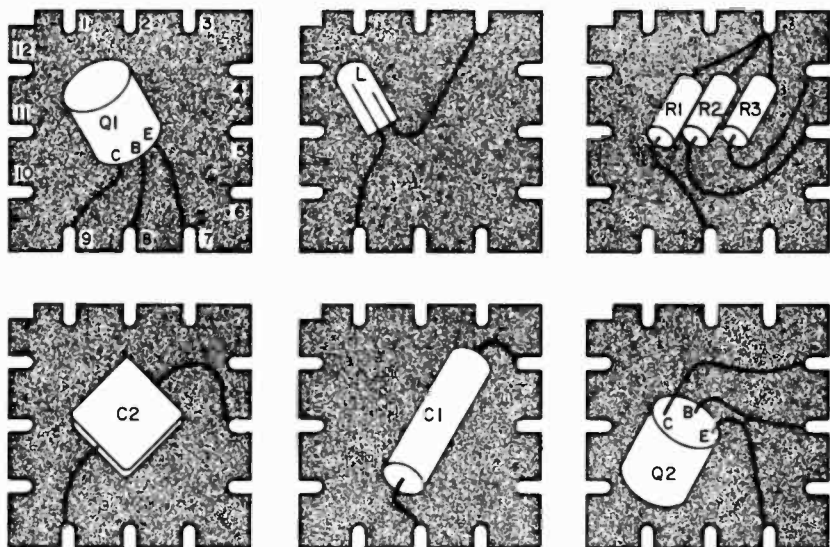
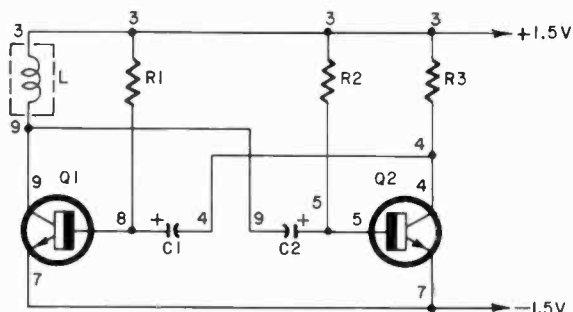
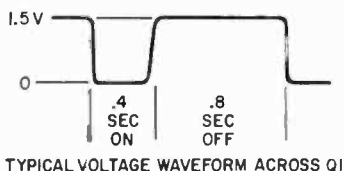


Fig. 430. A typical voltage waveform (top) found across (emitter to collector) Q1 indicates the on-off cycle generated by the circuit in the schematic (center). Component layout is shown at the bottom. All wafers should assemble easily. Any force needed to insert risers can easily snap wafer. Whether using solder or conductive cement it is necessary to watch for shorts.

Subminiature multivibrator flasher

The assembly shown in Fig. 429 is a multivibrator flasher. It consists of a six-deck module as shown in the photo, and is made following the schematic and assembly shown in Fig. 430.

Use epoxy-silver cement to assemble the micromodule. This comes in two parts, which are mixed by equal volumes or weights. Toluene, obtainable from any drugstore, drycleaner or chemical supply house, is used to thin the cement mixture to the desired consistency.

Cut the wires to lengths of about $2\frac{1}{2}$ to 3 inches and straighten them between your fingers by holding one end of the wire in one hand, and running the thumb and index finger (of the other hand) over the wire.

The assembly with three wires on one side is allowed to dry, and then turned 90° to cement on the next three wires. After three sides are cemented and dried, gently and carefully remove the assembled module from the holder, turn it over, and cement the fourth side wires into place.

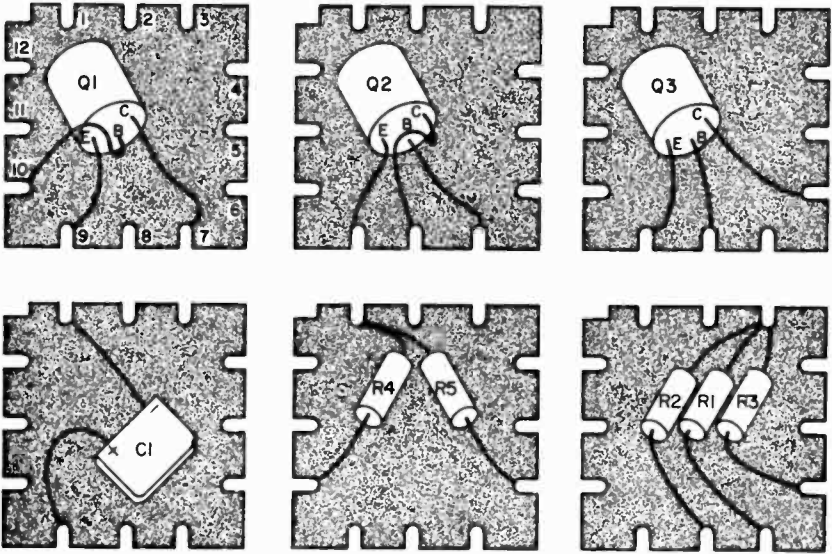
One special feature of the flasher is the $56\text{-}\mu\text{f}$ 6-volt tantalum electrolytic used for C2. This unit normally comes from the factory with a flexible rubberlike coating. Strip this coating away carefully to remove the tantalum "gut." Cement the "gut" on the appropriate wafer.

Micromodule three-stage amplifier


You can build a three-stage micromodule amplifier in a manner similar to the flasher. The exploded pictorial of the wafers and the circuit diagram are shown in Fig. 431. The tiny volume control is varied by carefully inserting a needle tool between the risers and slowly turning the knurled handle.

Additional micromodule techniques

The epoxy-silver cement normally sets overnight. If you want a fast "cure," you can speed the setting time with a heat lamp or household blower hair dryer. A handy technique is to set the cemented wafers on top of a lamp having a metal reflector. The amount of heat can be varied by changing the voltage of the bulb, or by moving the wafer around on the reflector. Check the temperature ratings of the components against the temperature on the surface of the reflector (measured with a cooking thermometer and some tin foil for a conductor between thermometer and the reflector's surface).



ALTERNATE CONSTRUCTION
USING VARIABLE POT FOR R5

Q1, Q2, Q3
 RED DOT
 2N207 BASING

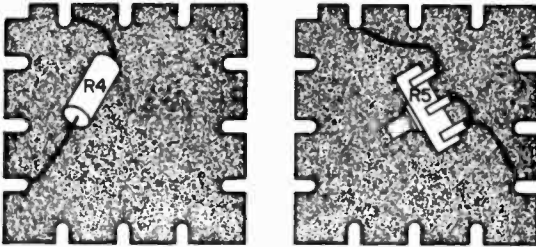
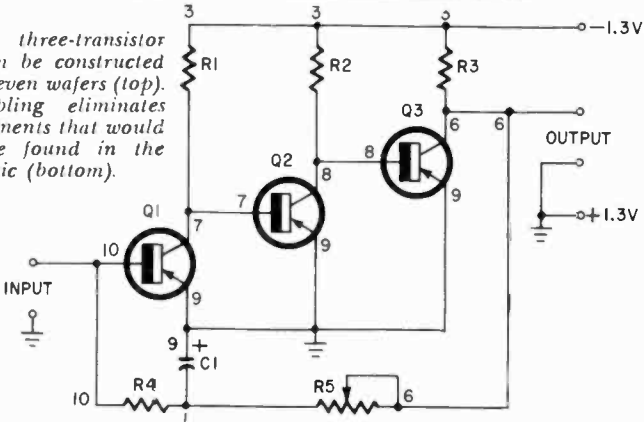


Fig. 431. A three-transistor amplifier can be constructed with six or seven wafers (top). Direct coupling eliminates many components that would otherwise be found in the schematic (bottom).



Resistors: R1—3,300 ohms; R2—2,700 ohms; R3—1,100 ohms; R4—5,600 ohms; (all $\frac{1}{10}$ watt)
 R5—25,000- to 50,000-ohm potentiometer (Centralab model 8)
 Transistors: Q1, Q2, Q3—2N207 or equivalent
 Micromodule wafers: (Coors Co.; Corning Glass Works, Electronic Components Div.)
 Cement: Epoxy-silver (Emerson & Cummings)

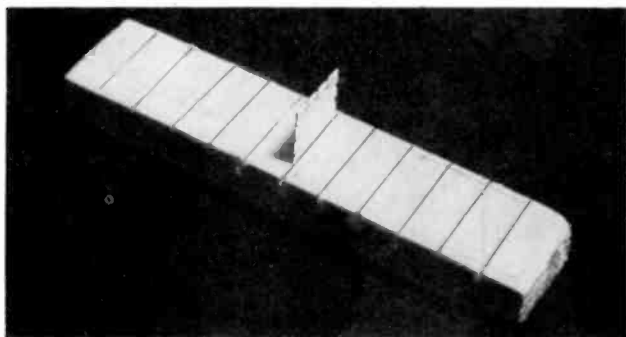


Fig. 432. Wafers are inserted in slots to prepare them for the riser wires.

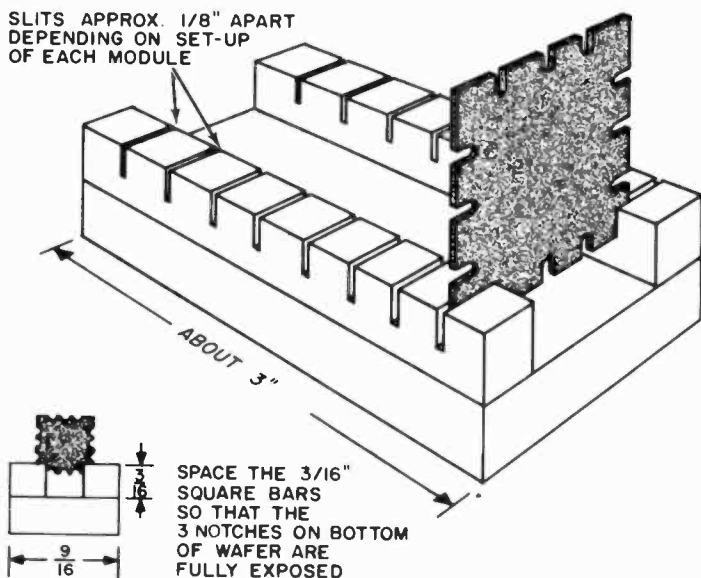


Fig. 433. A more complex jig allows wafers to be held in any position (any edge up) since inserted wires do not interfere with notches.

Another technique needed is for removal of excess cement. Do this with a hand motor tool and several assorted miniature jeweler's abrasive stone bits.

"Homemade" micromodule accessories

Fig. 432 shows a small stand useful for holding bare wafers. This is made from 1/4-inch-thick wood lattice strip. A razor saw will pro-

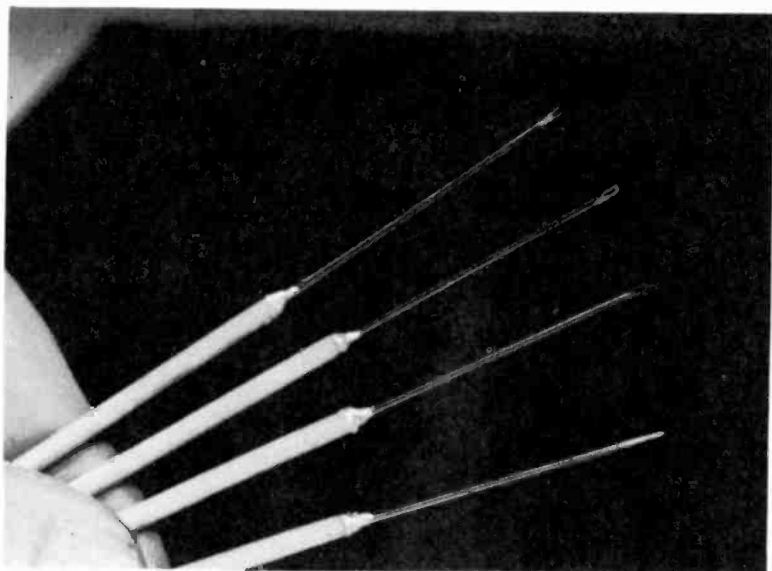


Fig. 434. Special tools used for working with fine wires are patterned after normal-sized soldering aids. Needles, mounted in matchsticks or those used for cotton swabs, are an inexpensive source of high-quality steel.

duce slits in the wood of the right width to hold the wafers gently. You can also build a wafer assembly jig as shown in Fig. 433. Make this from two $\frac{3}{16}$ -inch-square strips mounted on a base, the strips being notched and spaced, so that a wafer can be held in a pair of opposing spaces, and expose the notches in the wafer.

Fig. 434 shows a set of microminiature handling tools, made from common household needles. Seat the needles in wooden sticks, such as cotton swab sticks with the cotton removed. The four shapes made were a complete loop or regular needle eye, an open-ended loop, a chisel and a straight needle. The end of the needle is inserted into the stick after a #58 to #60 hole is drilled in the stick. Use cement to hold the needle in the stick. Use a tool grinder or knife sharpening wheel to grind off the needles for the chisel and open-ended loop type tools.

Another useful accessory is the binocular or "stereo" microscope. Available from several electronic mail-order houses, the microscope enlarges the wafer's image to 15 to 30 power, and allows closeup inspection of the cementing operations and component terminals.

Chapter 5

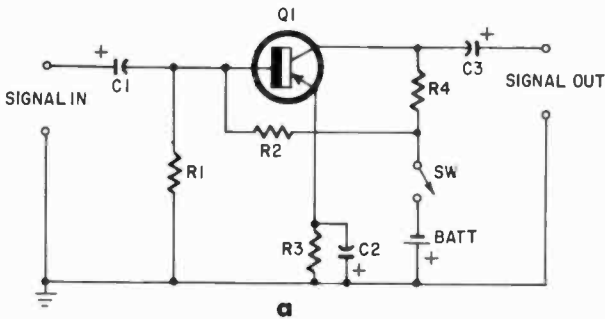
Practical Miniature Projects

The previous chapter laid the ground work for practical circuit-building of devices. In this chapter we are going to continue along the same lines. You will get directions for constructing simple oscillators, amplifiers and relatively easy-to-build miniaturized electronic assemblies. The sizes of the construction projects indicate what can be done. You *can* make them smaller, depending in part on your own ingenuity and skill.

Single-stage amplifiers

The grounded- or common-emitter circuit (Fig. 501-a) offers both power and voltage gain, and also has the characteristic of reversing the phasing 180° between input and output signals. Normally, series resistors R1 and R2 would determine the forward bias current in the base of the transistor, with R4 as the collector load. However, a bypass capacitor, C2, and a resistor, R3, have been inserted between the emitter and ground. R1 and R2 act as a voltage divider to "stabilize" transistor operation at a steady dc value. The net result of R1, R2, R3 and C2 is to keep the bias current constant.

The unit is packaged as shown in Fig. 501-b. Tantalum capacitors have been used for the sake of miniaturization. Four mercury cells make the battery which is fastened to the module with brass clips and machine screws.



Resistors: R1—27,000 ohms; R2, R3—3,300 ohms ($\frac{1}{4}$ watt or larger); R4—12,000 ohms.
 Capacitors: C1, C2, C3—10- μ f, 25-volt tantalum (Mallory TAM or equal)

Transistor: Q1—2N207, 2N220, 2N280 or equivalent
 Battery: 4 Mallory RM400 cells in series
 Misc: Spst switch; chassis; terminals; mounting hardware

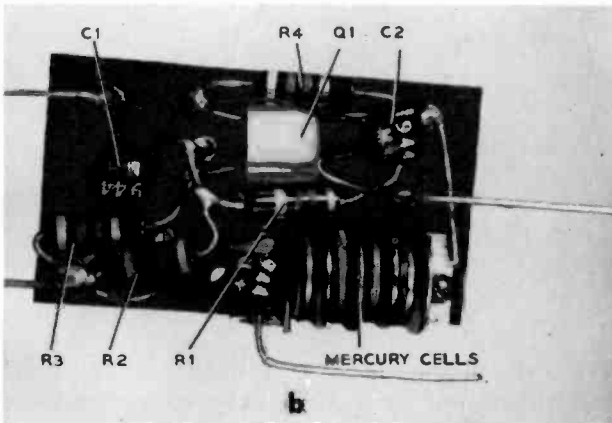
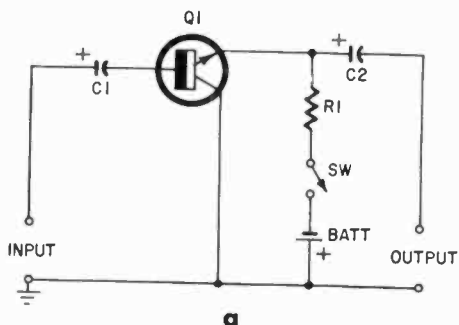


Fig. 501. Simple, single-stage amplifier uses components that do not need much room. For some applications a switch is unnecessary since current drain is so low that continuous operation approaches the shelf life of the cells.

Frequency response

The frequency response of the amplifier is flat between 150 and 2,500 cycles. The input impedance in this range is roughly 1,000 ohms and output impedance around 8,500 ohms. The voltage gain will vary with the load impedance and manufacturing differences in the individual transistors.



Resistor: R1—27,000 ohms, 1/4 watt
 Capacitors: C1, C2—2- μ f, 6 volts (Lafayette CF-100)

Transistor: Q1—2N169A or equivalent
 Battery: Burgess NE (1 1/2 volts) cell
 Misc: Spst switch; terminals; plastic vial

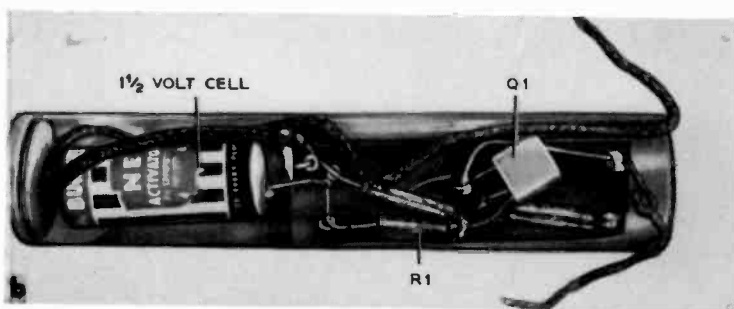


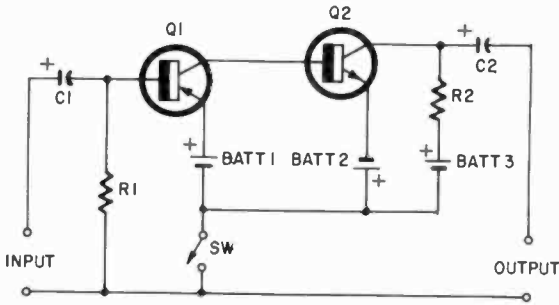
Fig. 502. This simple amplifier has little current drain from the single cell through the lone transistor. Switch is indicated in the schematic even though it can be omitted.

Fig. 502-a is the schematic for a grounded- or common-collector amplifier. Built around an n-p-n transistor, this circuit configuration is the counterpart to the vacuum-tube cathode follower. The input impedance is in the order of 20,000 to 100,000 ohms, and the output impedance 100 to 1,000 ohms. This circuit does not reverse the input-output signal phasing.

The parts layout is shown in Fig. 502-b. A shortened plastic vial is used as a container. Miniature electrolytics and a 1/4- or 1/10-watt resistor complete the parts package.

Direct-coupled n-p-n/p-n-p amplifier

The "opposite" actions of p-n-p and n-p-n transistors are utilized in the circuit shown in Fig. 503-a. Increased base current to Q1 causes decreased collector current out of Q1 into the base



a

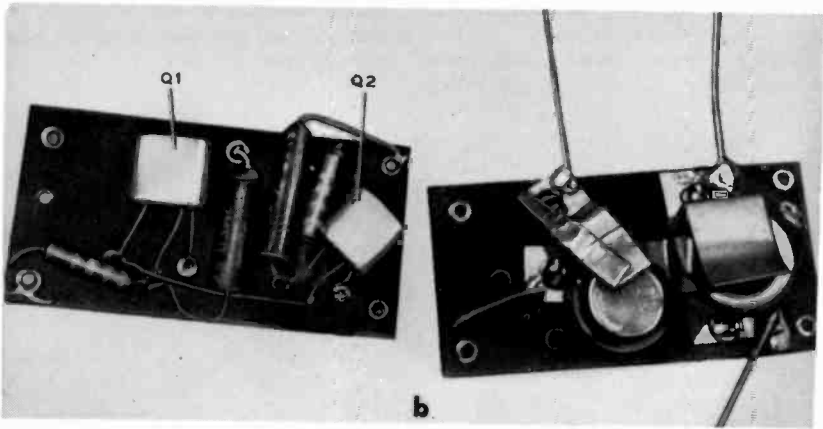
Resistors: R1—1.2 megohms; R2—39 ohms ($\frac{1}{4}$ watt)

Capacitors: C1, C2—2 μ f, 6 volts (Lafayette CF-100)

Transistors: Q1—2N207, 2N220, 2N280 or equivalent; Q2—2N169A or equivalent

Battery: Batt -1, -2, -3—Mallory RM-400R

Misc: Spst switch; phenolic sheet; terminals; mounting hardware



b

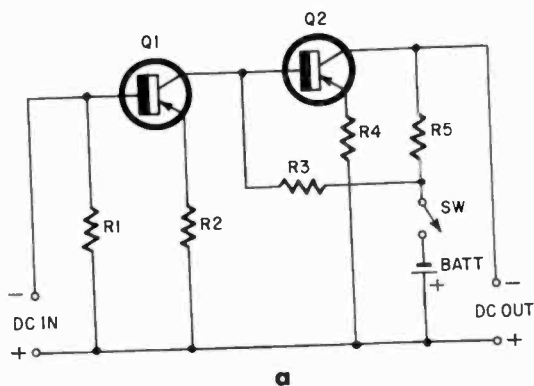
Fig. 503. Three cells make transistor biasing easier, reduce wiring complications and do away with three resistors.

of Q2. The overall result is an increase in output current for an increase in input current, and no phase reversal.

Fig. 503-b shows the physical layout. A two-tiered module was chosen, with batteries on one tier and transistors and other components on the lower tier.

Cascade voltage amplifier

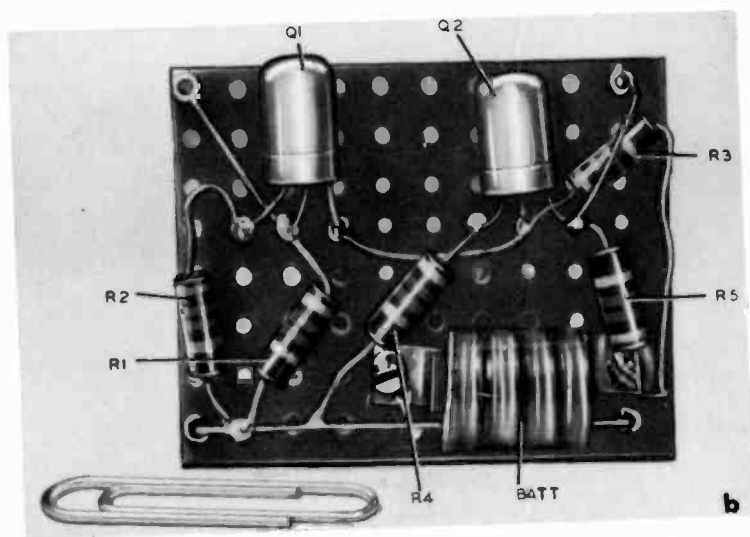
A direct-coupled voltage amplifier with a gain of about 25, is shown in Fig. 504.



a
 Fig. 504. This circuit is similar to that in Fig. 503. The cells have been reduced to one and, resistors are used for biasing. Here p-n-p transistors are used. It is possible to use n-p-n types by reversing battery polarity.

Resistors: R1, R3, R5—1,200 ohms; R2, R4—2,200 ohms ($1/10$ watt or larger)
 Transistors: Q1, Q2—2N207, 2N220, 2N280 or equivalent

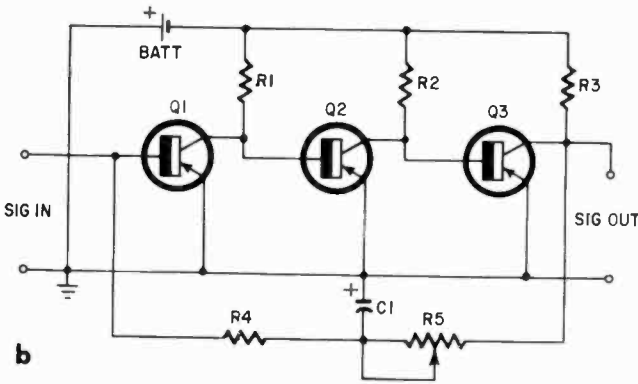
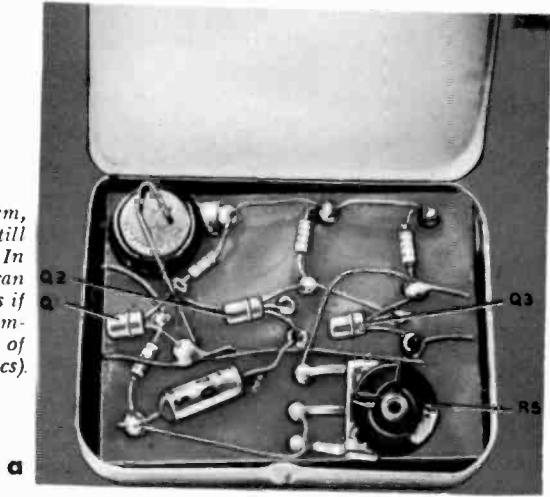
Battery: 4 Mallory RM-400R in series
 Misc: Pill box; spst switch; terminals; mounting hardware



b
 Fig. 505. The completed amplifier shown here is about $1\frac{1}{2}$ times actual size.

The entire circuit is contained on a $1\frac{1}{2} \times 2$ inch perforated board (Fig. 505) and $\frac{1}{2}$ watt resistors are suitable for it. If a little extra space must be saved, $\frac{1}{4}$ - or $\frac{1}{10}$ -watt resistors can be used,

Fig. 506. As small as it may seem, this 3-stage amplifier is still slightly larger than actual size. In most transistor circuits you can use either p-n-p or n-p-n units if the characteristics are nearly similar. Just change the polarity of the battery (and any electrolytics).



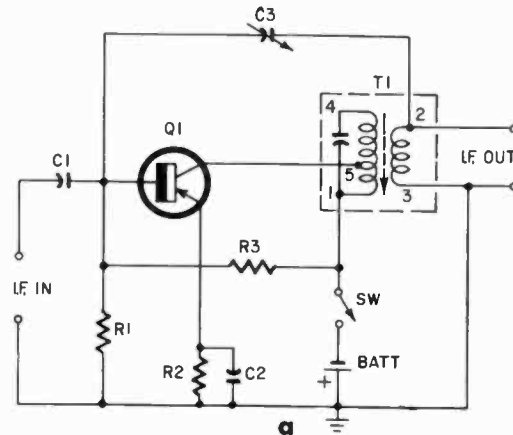
Resistors: R1—33,000 ohms; R2—2,700 ohms; R3—1,100 ohms; R4—5,600 ohms (all $\frac{1}{10}$ watt); R5—50,000-ohm potentiometer (Lafayette VC-60)
Capacitor: C1—12- μ f, 15-volt Mallory STNT tantalum

Transistors: Q1, Q2, Q3—2N207 (Philco)
Battery: Mallory RM400 cell
Misc: Metal box (aspirin box); chassis; terminals; mounting hardware

although they will operate closer to maximum dissipation. Four subminiature mercury cells are taped together to make the midget battery.

“Aspirin-box” amplifier

One of the smallest three-stage audio amplifiers ever home-built (Fig. 506-a) fits into an ordinary pill box. The chassis is $\frac{1}{16}$ -inch phenolic and eyelets are used for compactness of the entire as-



Resistors: R1—2,700 ohms; R2—1,200 ohms; R3—12,000 ohms (all $\frac{1}{2}$ watt)
 Capacitors: C1—.01- μ f, 100-volt tubular paper; C2—.1- μ f, 75-volt ceramic; C3—10—365 pf (μ mf) for test purposes (ceramic capacitor for final value) (Lafayette MS-445)

Transistor: Q1—2N136, 2N394 or equivalent
 Transformer: T1—Miller No. 2041 i.f. transformer or equivalent
 Battery: 4 Mallory RM-630 (in series)
 Misc: Chassis material; plastic box; spst switch; terminals; mounting hardware

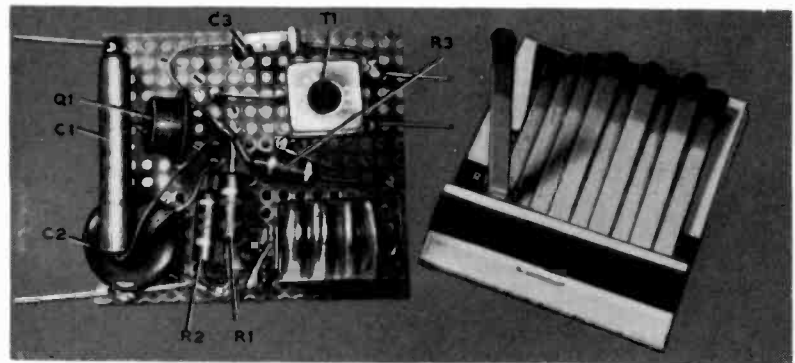


Fig. 507. It is easy to determine the size of this single i.f. stage when you see it alongside a familiar object like a book of matches

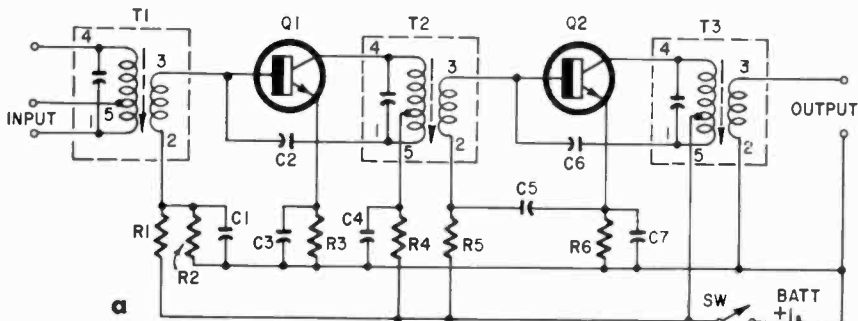
sembly. The schematic is shown in Fig. 506-b. Take special care and use a heat sink when soldering the ultra-small 2N207's.

I.f. amplifier

Using a 2N136 rf transistor and a subminiature i.f. transformer, the single tuned i.f. amplifier of Fig. 507-a is useful at 455 kc and is typical of i.f. stage practice in many pocket transistor receivers. A feedback capacitor (C3) is put across the i.f. output and

transistor base to neutralize the stage and prevent oscillation. The subminiature i.f. stage has an input and output impedance of 25,000 and 600 ohms, respectively. Terminal coding should be followed carefully. Power gain is about 22 db with an 11-kc bandwidth at the 3-db points.

Alignment is accomplished with a 400-cycle modulated rf-signal generator on the input of the i.f. amplifier and an ac vacuum-tube voltmeter (usable at 455 kc) or a dc vtvm with a demodulator



Resistors: R1—27,000 ohms; R2—5,600 ohms; R3—1,200 ohms; R4—470 ohms; R5—330,000 ohms; R6—180 ohms (all $\frac{1}{2}$ watt)
Capacitors: C1, C3, C4, C5, C7—.01- μ f, 75-volt ceramic (Lafayette C-612); C2, C6—5 pf (μ mf), 200-volt tubular ceramic

Transformers: T1, T2, T3—Miller No. 9-C1 i.f. transformer or equivalent
Transistors: Q1, Q2—2N169, 2N410, 2N634 or equivalent
Battery: 4 Mollary RM-625 (in series)
Misc: Printed circuit board; spst switch; terminals; mounting hardware

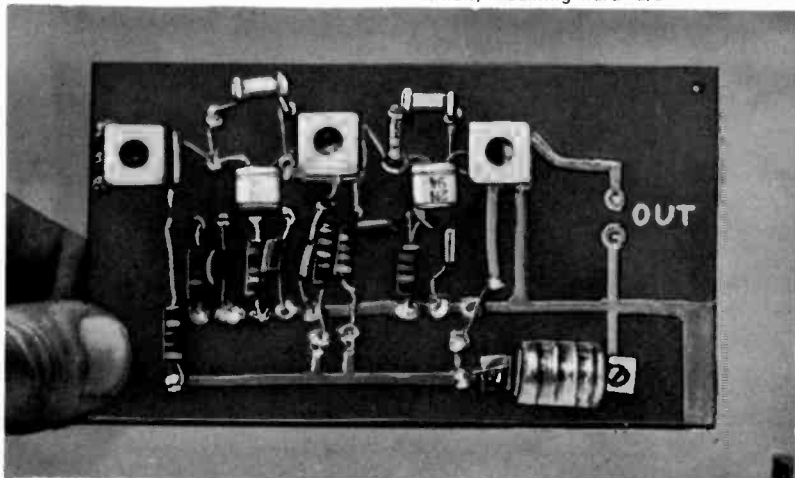


Fig. 508. Using three i.f. transformers makes the module a complete i.f. unit. Input (T1) can be connected into a mixer-oscillator and a diode or transistor detector can be connected to the output.

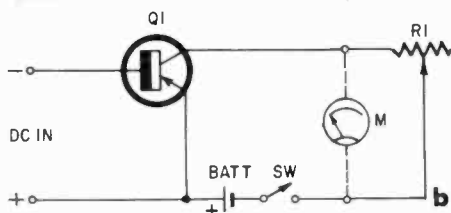
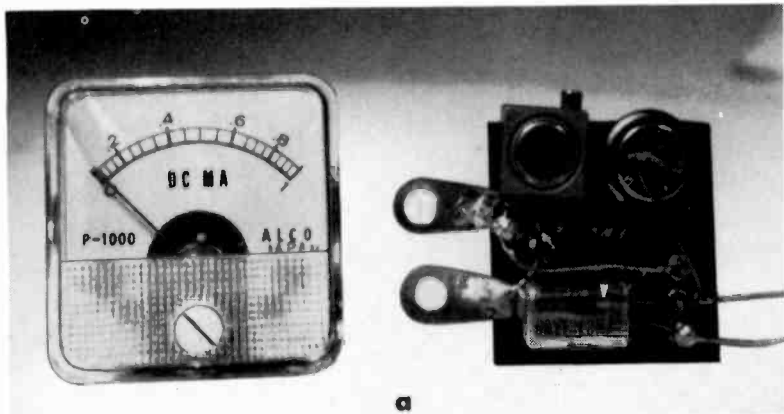


Fig. 509. This simple circuit can increase the effective sensitivity of a meter movement. The full scale current of the meter must not exceed the collector current rating of the transistor.

Resistor: R1—200-ohm, 1/2-watt, variable wire-wound potentiometer
 Transistor: Q1—2N207, 2N369 or equivalent
 Battery: Mallory RM400

Meter: M—(user's choice of 0-1 milliamper, dc)
 Misc: Spsst switch, phenolic sheet; terminals; mounting hardware

probe on the output terminals. Switch on the i.f. amplifier and set the generator to 455 kc. Then tune the i.f. slug for peak reading on the vtvm. The generator should be attenuated enough to prevent jamming or blocking.

Parts layout is shown in Fig. 507-b. The i.f. can should be mounted for easy access to the slug. A variable or trimmer capacitor is used to determine capacitance needed for neutralization, and is then replaced with a fixed unit of the required capacitance to save space. If a capacitance tester is not handy, several fixed capacitors can be substituted until oscillation ceases.

Two-stage i.f. amplifier

Fig. 508-a is the schematic for a two-stage i.f. amplifier. The i.f.'s have impedances of 25,000 ohms and output impedances of 600 ohms, and the overall gain is about 60 db. The bandwidth is 12 kc at the 3 db points.

A 5- to 10-pf ($\mu\mu\text{f}$) capacitor is used between the i.f. primary and the base of the preceding transistor to prevent oscillation.

Common-emitter setups oscillate easily in such circuits unless these feedback capacitors are included.

A printed-circuit board (Fig. 508-b) was used, mainly because of the "straight-line" nature of the wiring in the i.f. amplifier.

Be careful not to mix up the terminal coding on the i.f. cans. A spot of red paint on one corner of each can and on the board near that corner helps in restoring the right hookup should the i.f. cans ever be removed.

Align the amplifier with a 455-kc signal generator and vacuum-tube voltmeter, adjusting the 3 slugs until the signal is peaked.

Meter extender

Fig. 509-a shows a transistor amplifier used as a range extender for a basic 0-1 ma meter movement. The transistor, battery and wirewound variable resistor are all laid out on a 1-inch square of phenolic with eyelets, to solder them to, to hold them in place. Miniature machine screws and soldering lugs permit the "extender" to be soldered or fastened to the back of the 0-1 ma meter.

Fig. 509-b is the schematic for this circuit.

The potentiometer is adjusted for full-scale meter reading when 50 microamperes are fed to the input of the "extender module." There will be a small reading on the meter (10 to 30 microamperes) when the input current is taken away, due to the transistor's collector-current characteristic. This can be mechanically "zeroed-out" with the meter's zero-set screw.

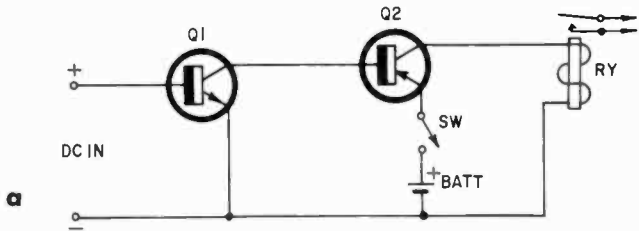
Microampere input relay

Fig. 510-a is a sensitive relay amplifier useful for detecting input currents of about 1 to 5 microamperes, dc. The input resistance is about 6,500 ohms, and input voltages vary from 6.5 to 30 millivolts. The circuit has a current gain of over 500, and the power gain averages 25 to 30 db per transistor.

Fig. 510-b shows the parts layout.

This circuit arrangement is called a complementary p-n-p/n-p-n dc amplifier. When the dc input signal goes into the base of the Q1, a large current flows in the collector of the Q1. This brings a large current to the base of the Q2 which amplifies and passes on a larger current for the load (relay coil) in the collector circuit of Q2.

Variations of this circuit include a high-resistance potentiometer (Fig. 510-c) for reduction of input voltages to levels where 1 to



Resistors: R1—500,000-ohm potentiometer (Lafayette VC-61); R2—12 megohms (1/2 watt)
 Transistors: Q1—2N35, 2N169A or equivalent; Q2—2N34, 2N207, 2N369 or equivalent

Battery: Eveready 505, 22.5 volts
 Relay: Ry—Jaidinger Gem 7,250-ohms or equivalent
 Misc: Mounting hardware; terminals; spst switch

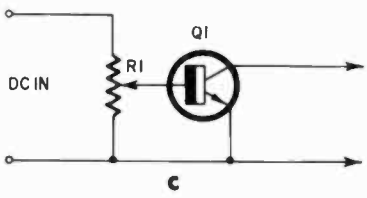
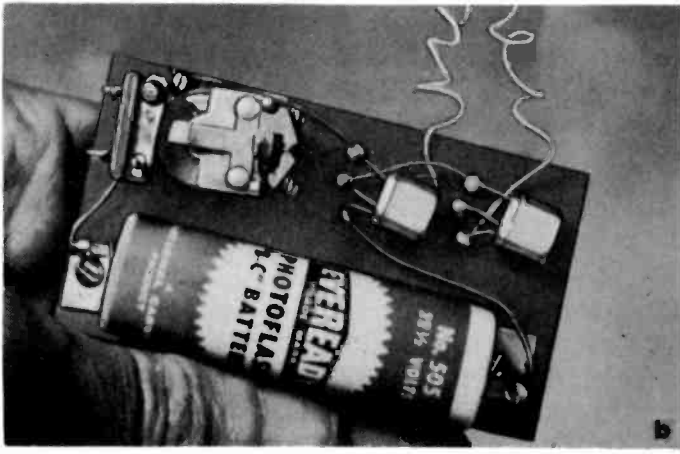
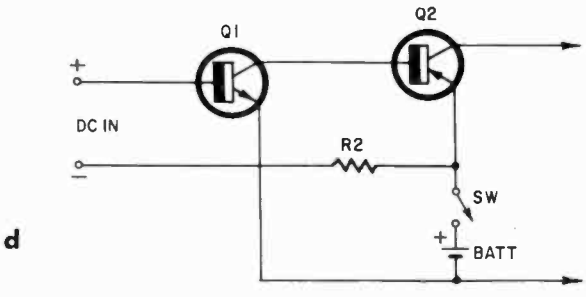
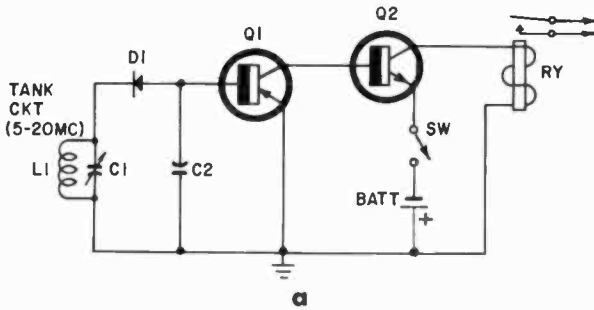


Fig. 510. Very small currents will actuate the relay when they are applied to the base of a transistor amplifier used to control the relay current.

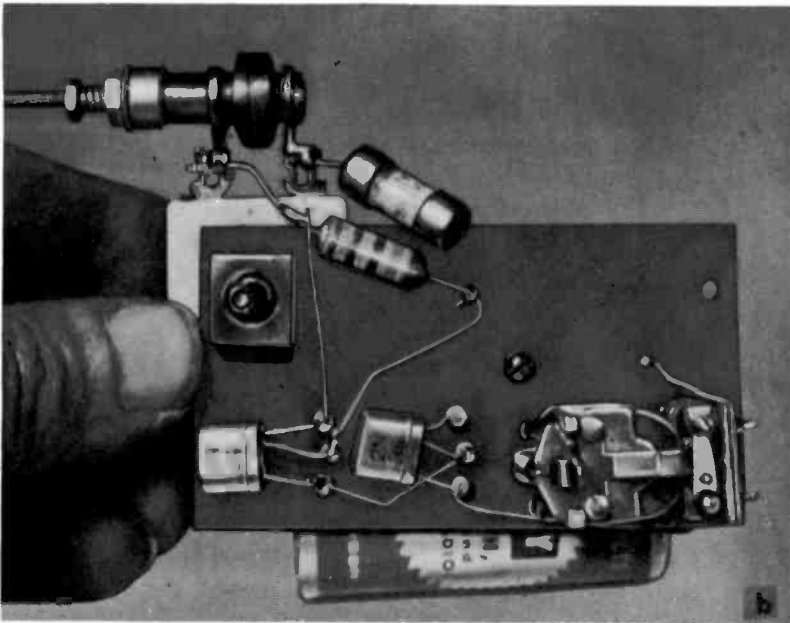




Capacitors: C1—30 to 100 pf (μmf) (see text);
C2—.002- μf , 100-volt tubular ceramic
Transistors: Q1—2N34, 2N169A or equivalent;
Q2—2N35, 2N207 2N369 or equivalent
Diode: D1—1N34, 1N105, 1N147, 1N268,
1N295 or equivalent

Coil: L1—(see text); Relay—Jaico Gem. 7,250
ohms, set for 1.5 ma pull-in
Battery: Mallory 22.5-volt mercury "B" battery,
Burgess Y-15, Eveready 505 or equivalent
Misc: mounting hardware; spst switch

Fig. 511. This circuit is very similar to that in Fig. 510-a. Transistor types have been switched around. The few microamperes needed to actuate the circuit are supplied by the detector and the tuned circuit.



5 milliamperes are passed, and a self-excited circuit (Fig. 510-d) where a few microamperes are supplied by tapping the emitter lead of Q2.

Rf relay

The combination of a p-n-p and n-p-n transistor provides a sensitive rf relay circuit (Fig. 511-a). A subminiature battery occupies approximately the same space as the other components in the circuit. A relay with a 7,250-ohm coil completes the circuit and has contacts for the control of an outside or secondary circuit. The diode (D1) rectifies the incoming rf from the tuned circuit, and the .002- μ f capacitor (C2) bypasses rf ripple to the ground supplied by the case. The lower the frequency of the rf circuit, the more efficient the diode action. Tuned circuits in the range of 5 to 20 mc are best for experimenting. Fig. 511-b is the layout of the complete assembly.

Phase splitter

Fig. 512-a shows a phase splitter using less than a dozen components in a small metal box.

The circuit in Fig. 512-b shows a p-n-p transistor that develops the split output signal voltages across both emitter (R3) and collector (R4) load resistors. The common-emitter phase shift throws the collector output voltage out of phase with the input signal voltage, while the emitter output voltage stays in phase with the input signal.

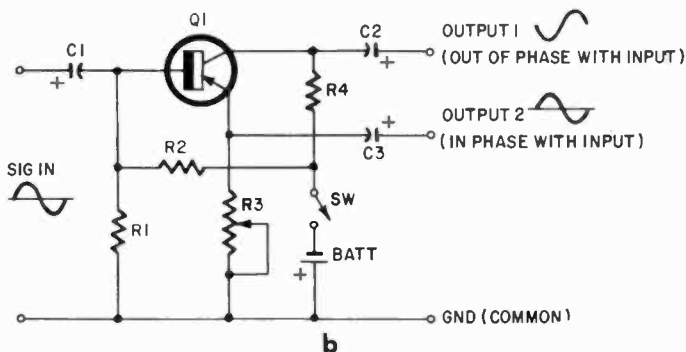
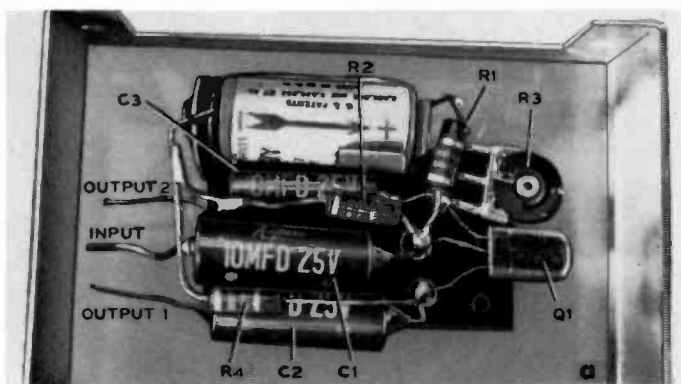
A 10-20 mv ac signal fed into the input of the inverter produces almost $\frac{3}{4}$ -volt output into loads of 10,000 to 50,000 ohms. Tiny jacks are provided for choice of output polarities. The balancing pot, R3, is adjusted to give nearly equal output voltages.

The components are mounted on a strip of phenolic with miniature solder lugs and machine screws for tie points (Fig. 512-c).

Balanced transformerless phase splitter

Two p-n-p transistors, 5 resistors and two electrolytics make up the transformerless phase splitter. The circuit, Fig. 513-a, is symmetrical with the exception of the two electrolytics and the battery branch, and is basically a balanced class-A push-pull amplifier. The absence of a transformer widens the bandpass to a range of 10 cycles to 70 kc. The collector load resistors, R4 and R5, are 5,000-ohm variables, and are set for equal collector currents under steady signal input.

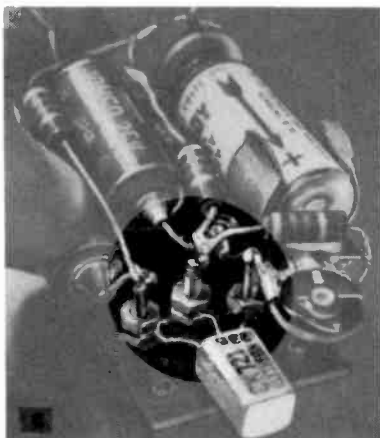
To offset the space lost in using 6 cells for a battery pack miniature electrolytics were used in the layout shown in Fig. 513-b.

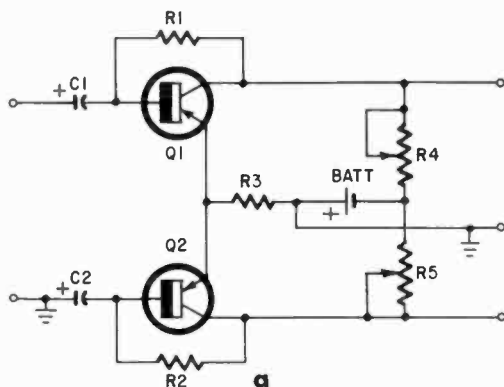


Resistors: R1—3,300 ohms; R2—22,000 ohms; R4—4,700 ohms; (all 1/2 watt); R3—5,000-ohm potentiometer (Lafayette VC-58)
 Capacitors: C1, C2, C3—10- μ f, 25-volt aluminum electrolytics (Lafayette CF-142)

Battery: Mallory TR-115R
 Transistor: Q1—2N207, 2N280, 2N369 or equivalent
 Misc: Chassis material; terminals; mounting hardware; spst switch

Fig. 512. This phase-splitter circuit is a substitute for a transformer. Here gain is sacrificed for compactness, economy or high-frequency response.





Resistors: R1, R2—47,000 ohms; R3—470 ohms (all $\frac{1}{2}$ watt); R4, R5—5,000-ohm potentiometers (Lafayette VC-58)

Capacitors: C1—10 μ f, 15 volts (Mallory TAM); C2—44 μ f, 15 volts, (2 Mallory 22- μ f TAM in parallel)

Transistors: Q1, Q2—2N1265

Battery: 6 Mallory RM-400's (in series)

Misc: Chassis; plastic box; terminals; mounting hardware

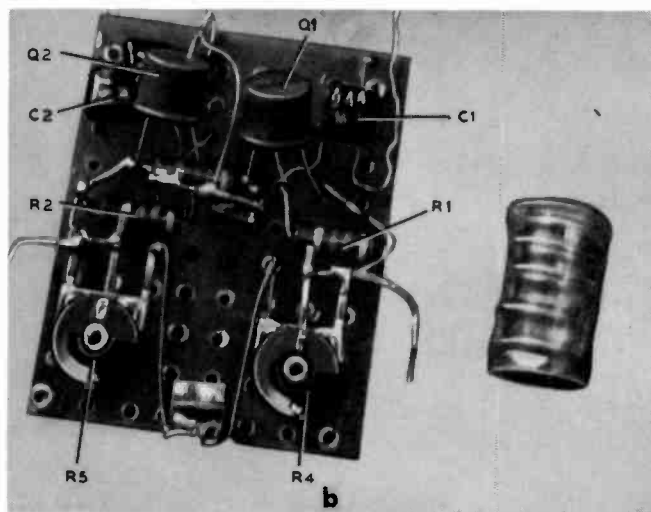
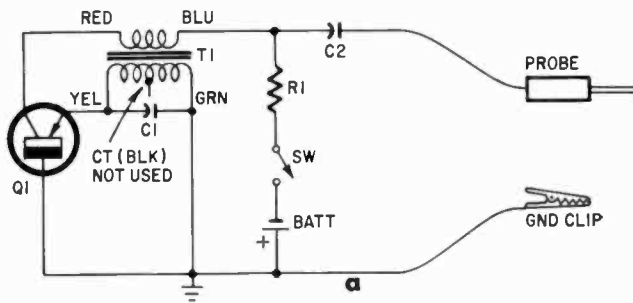


Fig. 513. Biased for pushpull operation these two transistors can give considerably more gain than a single-transistor circuit.

A 50-mv signal into this unit will produce just under 1-volt output from either collector to center, or about 1.7 to 1.8 volts as a push-pull output. The output impedance is in the order of 2,500 to 3,000 ohms.



Resistor: R1—120,000 ohms, $\frac{1}{4}$ watt
 Capacitors: C1—.05- μ f, 100-volt paper tubular; C2—.1- μ f, 50-volt disc ceramic
 Transistor: Q1—2N109, 2N188A, 2N241A, 2N363, 2N462 or equivalent

Transformer: T1—10,000- to 2,000-ohm driver (Lafayette TR-98)
 Battery: Mallory RM-400
 Misc: Spst switch; probe; ground clip; mounting hardware; chassis or metal or plastic tubing

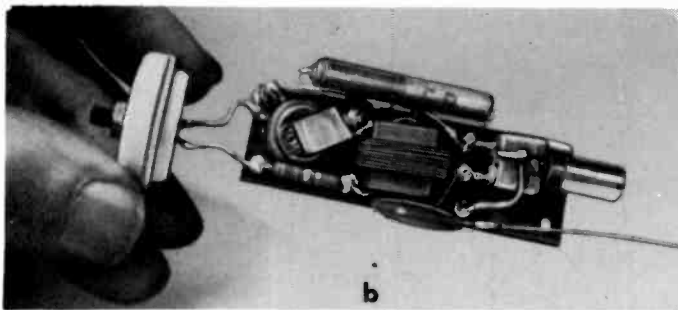
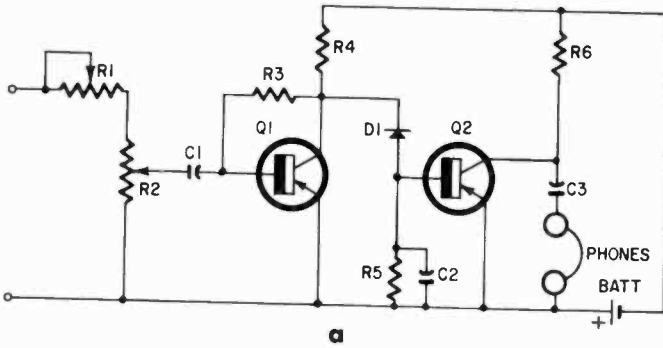


Fig. 514. A simple audio oscillator can make signal tracing (by injection) easy.

Audio signal squitter

Fig. 514-a is the schematic of a low-frequency (about 800 to 1,000 cycles) audio signal squitter, which can be built into a fountain pen or piece of plastic tubing. A 1.3-volt mercury cell, a subminiature driver transformer and a p-n-p transistor are the three major components in the circuit.

The transformer is a 10,000 to 2,000-ohm center-tapped driver, and measures only $\frac{1}{2}$ -inch square. The center tap on the secondary is not used. Connections to the transformer *must* be followed exactly for proper phasing or there will be no oscillations. The frequency can be changed by making the bypass capacitor (C1) larger or smaller. The unit is grounded externally if the plastic tube design is used. If a metal chassis or metallic tubing is used,



a

Resistors: R1—500,000-ohm potentiometer (Lafayette VC-61); R2—10,000-ohm potentiometer (Lafayette VC-59); R3—10,000 ohms; R4—5,600 ohms; R5—47,000 ohms; R6—1,200 ohms (all $\frac{1}{2}$ watt)
Capacitors: C1, C2—.01- μ f, 100-volt ceramic disc; C3—.001- μ f, 75-volt ceramic disc

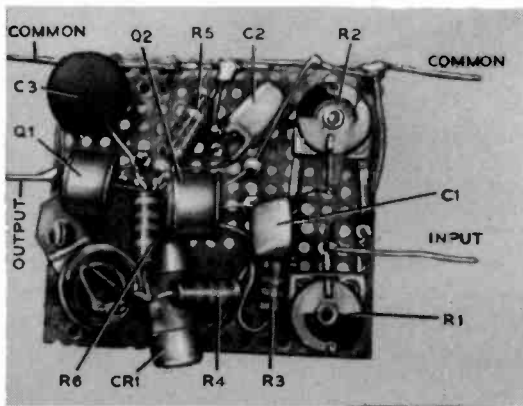
Transistors: Q1, Q2—2N1265

Diode: D1—1N60

Battery: Mallory RM-400 cell

Phones: 3,000-ohm magnetic (Lafayette AR-50)

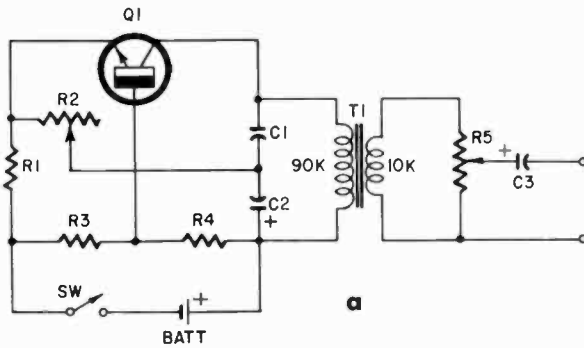
Misc: Chassis; terminals; mounting hardware



b

Fig. 515. A combination of an amplifier and a detector makes a versatile signal tracer.

the ground is made to the case of the unit. The signal magnitude, depending on the loading, runs from about 1 volt across a 40,000-ohm load to about 100 millivolts across a 2,000-ohm load. The unit shown in Fig. 514-b will run for weeks on a 1.3-volt mercury cell, the drain being about 10 ma. The coupling will depend on the gain of the audio amplifier under test, and, with very high gain circuits, the prod does not have to touch the circuit.



Resistors: R1—27,000 ohms; R3—1,200 ohms; R4—2,700 ohms; (all 1/2 watt); R2—5,000-ohm potentiometer (Lafayette VC-58); R5—50,000-ohm potentiometer (Lafayette VC-60)
 Capacitors: C1—.005- μ f, 75-volt ceramic (Lafayette C-611); C2—.25- μ f, 50-volt aluminum electrolytic (Mallory); C3—1- μ f, 12-volt electrolytic (Sprague Transi-lytic)

Transistor: Q1—2N35, 2N169A or equivalent
 Transformer: T1—90,000-ohm primary, 10,000-ohm CT secondary (United Transformer O-7 or SO-2)
 Battery: 4 Mallory RM-40 cells in series
 Misc: Spst switch; plastic box; chassis; terminals; mounting hardware; subminiature output jack

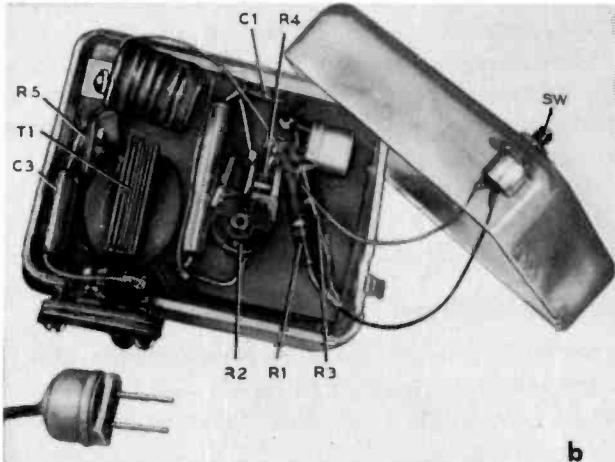


Fig. 516. This sine-wave generator can be a versatile signal source. A selector switch can be added to change values of C1, C2 and R2. This will give frequency change and wave-form adjustment together.

Audio/i.f. signal tracer

A circuit for a low-level signal tracer in audio and i.f. work is shown in Fig. 515-a. It uses two p-n-p transistors in a two-stage grounded-emitter amplifier. Q1 is a wide band amplifier and Q2 an audio amplifier. The diode demodulates the rf when modulated, and also lets through audio present in the first stage.

A pair of potentiometers provides input attenuation. The unit will trace signals from 500 cps to about 600 kc.

Physically, the unit occupies very little space. See Fig. 515-b. Part of the compact arrangement is possible because of the 1.3-volt mercury cell. Subminiature ceramics cut down the size of the coupling capacitor (C1) to Q1 and the size of the rejection network, R5-C2. A 1,500- to 3,000-ohm subminiature earphone provides the load for the second stage. The two subminiature potentiometers are mounted in such a way that they can be adjusted while the unit is in or out of any case that might be used with the tracer.

Single-frequency sine-wave generator

One transistor, a miniature transformer, two subminiature potentiometers and about a half-dozen other components make up the compact single-frequency sine-wave generator shown schematically in Fig. 516-a. A pair of capacitors (C1 and C2) eliminates separate feedback taps on the primary of the transformer. The oscillator will produce up to 100 mv on an open circuit output with the 5-volt supply, and the frequency, with the parts indicated in the schematic, is around 1,000 cycles. Changing C1 and C2 or the transformer type will alter the frequency and the waveshape which can be adjusted with R2 and a scope.

The parts layout is shown in Fig. 516-b. A plastic box, 1 by 1½ by 1 inch was used. The output of the transformer can be terminated in a subminiature jack.

Matchbox code oscillator

Fig. 517-a is the circuit for a two-frequency audio oscillator. The transformer input is shunted by C1 and C2 (.02- and .05- μ f capacitors) to give about 1,600 and 900 cycle notes, respectively. A potentiometer in the collector circuit will change the waveshape, and this adjustment can be made with a scope, if desired. This control can be omitted to make the oscillator even more compact.

The physical layout is shown in Fig. 517-b. Note the use of a subminiature pushbutton as an on-off switch. The capacitor values are selected by subminiature microswitches and a holddown arm is made from sheet brass.

Multiple-frequency audio oscillator

A multiple-step audio oscillator circuit is shown in Fig. 518-a.

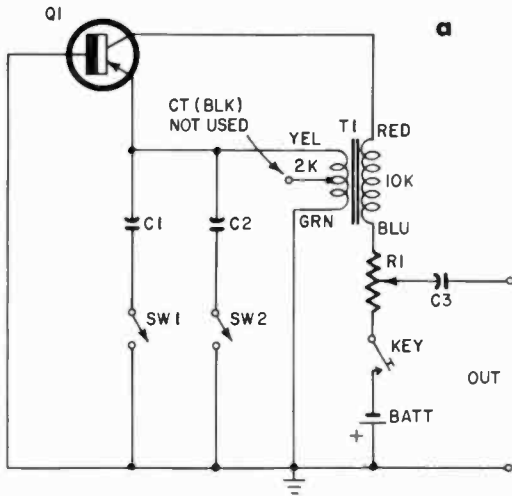


Fig. 517. This oscillator circuit will give two frequencies, controlled by C1 and C2.

Resistor: R1—1,000-ohm potentiometer (Lafayette VC-57)

Capacitors: C1—.02- μ f, disc ceramic; C2—.05- μ f disc ceramic; C3—.1- μ f ceramic (Lafayette C-615)

Transistor: Q1—2N35, 2N207, 2N265, 2N369 or equivalent

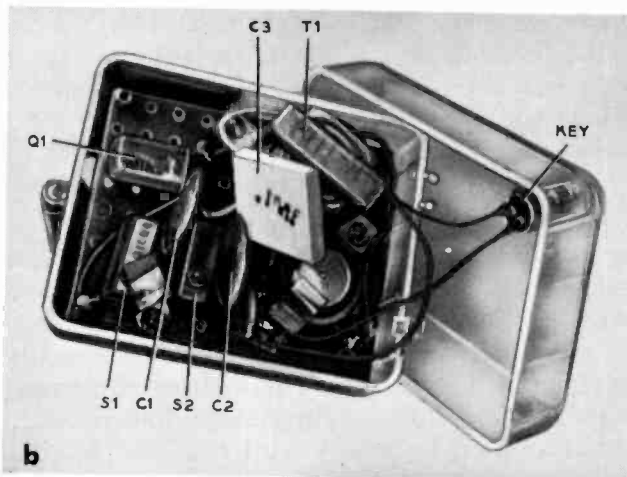
Transformer: T1—10,000-ohm primary, 2,000-ohm CT secondary (Lafayette AR-109)

Battery: Mallory RM-630

Switches: SW1, SW2—pushbutton types

Key: Pushbutton (Grayhill 39-1)

Misc: Chassis; terminals; mounting hardware



The builder has his choice of using the commercial selector switch or building his own as shown in Fig. 518-b. The home-made selector switch can be made smaller than a commercial switch, with the number of positions limited only by the skill of the builder. Another selector could be made from a gang of subminiature snap-action switches. Fig. 518-c shows the assembled unit.

Capacitors of .01, .02, .025, .03, and .05 μf will give audio tones of approximately 2,000, 1,600, 1,300, 1,100 and 900 cycles respectively, depending on the transformer's primary inductance.

Phase-shift audio oscillator

Fig. 519-a is a circuit for a phase-shift oscillator. Each combination of resistor and capacitor (C1-R1, C2-R2, C3-R3) shifts the signal phase by 60° to give the total 180° phase shift required for oscillation.

The parts layout shown in Fig. 519-b is on a rectangular phenolic base. Eyelets are used at several points for fastening components. No. 22 AWG tinned solid hookup wire is used to form 1-inch stiff leads for output takeoff. The subminiature 22.5-volt B-battery is held on the board with small brass clips. A miniature toggle switch is used to close the battery circuit, and the volume control R4 is mounted by its three terminals.

Light-powered pillbox code oscillator

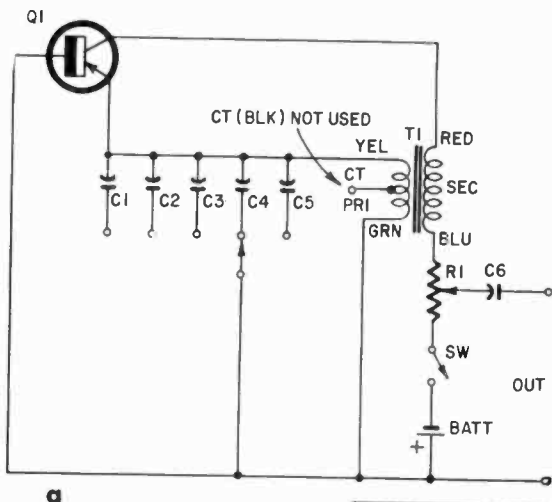
Here is a pocket-size code oscillator built into a plastic box. See Fig. 520-a. The subminiature transformer is the first component to be fastened to the bottom of the box. Next, the photocell is mounted. The transistor socket is cemented to the box, and the earphone jack fastened to the side of the box. Connections are made by direct point-to-point wiring.

Fig. 520-b shows the schematic for this compact oscillator.

Colpitts code oscillator

The transformer feedback circuit, so often used in oscillators, can be replaced with the inductance supplied by a low-impedance magnetic earset. A 1,000- to 3,000-ohm headphone is best. Fig. 521-a shows the schematic of this transistorized Colpitts oscillator.

The two capacitors (C1 and C2) are picked for an impedance match to the input and output of the transistors, and also for L-C resonance at some desired frequency with the headphones. Depending on the inductance of the headphones, a choice of C1 at



a

Resistor: R1—1,000-ohm potentiometer (Lafayette VC-57)

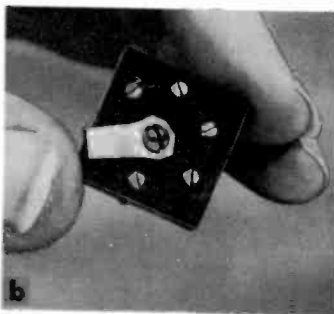
Capacitors: C1—.01 μf ; C2—.02 μf ; C3—.025 μf ; C4—.03 μf ; C5—.05 μf ; (all 50-volt ceramic) C6—.1- μf , 75-volt ceramic (Lafayette C-615)

Transistor: Q1—2N207, 2N369 or equivalent

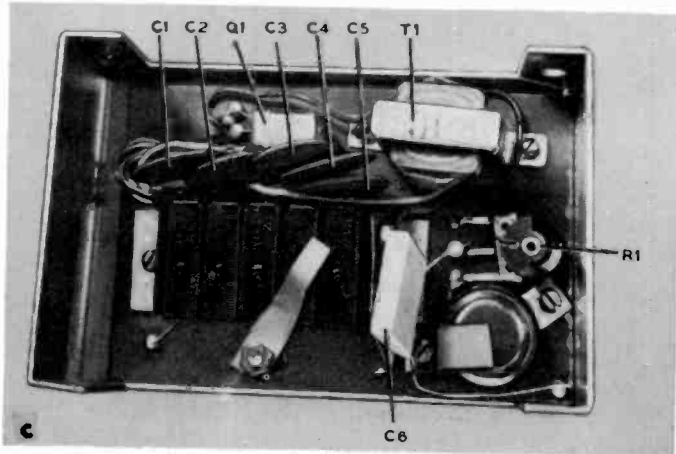
Transformer: T1—10,000-ohm primary, 2,000-ohm CT secondary (Lafayette AR-109)

Battery: Mallory RM-630 cell

Misc: Chassis; spst switch; terminals; mounting hardware

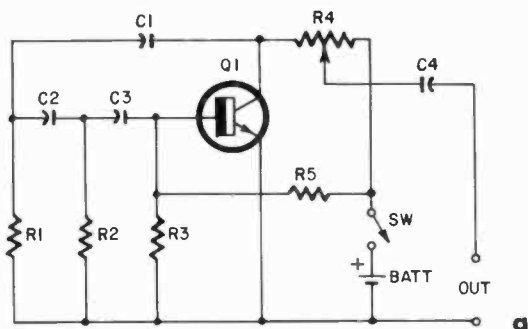


b



c

Fig. 518. Basically the same circuit as that in Fig. 517 this oscillator will give 5 frequencies with a rotary switch. If individual switches are used C1, C2, C3, C4 and C5 can be used, in many combinations for different frequencies.



Resistors: R1, R2, R3—8,200-ohms; R5—1,000 ohms; (all $\frac{1}{2}$ watt); R4—10,000-ohm potentiometer (Lafayette VC-59)
 Capacitors: C1, C2, C3—.002- μ f, 75-volt ceramics (Lafayette C-610); C4—.1 μ f, 100-volt paper tubular

Transistor: Q1—2N35, 2N169A or equivalent
 Battery: Burgess U-15 or Eveready 412
 Misc: Phenolic chassis; mounting hardware; terminals; eyelets

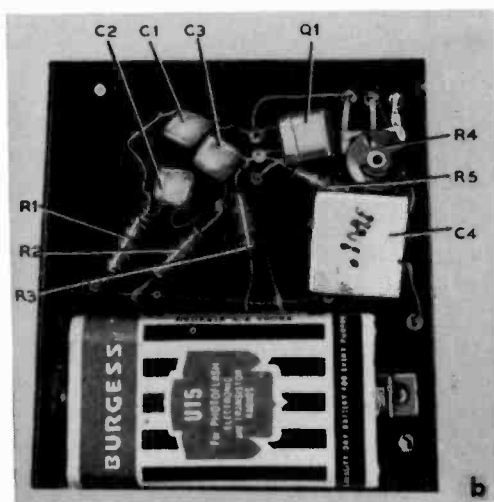


Fig. 519. In this oscillator the phase shift is accomplished by C1-R1, C2-R2, C3-R3 instead of a transformer. To change frequency all six components must be changed.

.2 μ f and C2 at .02 μ f should put the audio tone in the region of 500 to 3,000 cycles.

Parts are arranged as shown in Fig. 521-b. The "key" is a miniature pushbutton. Three mercury cells are taped together for a battery pack. The entire circuit fits into a cutdown aluminum cigar container. A subminiature jack is brought through the top of the container for the plug of the earphones.

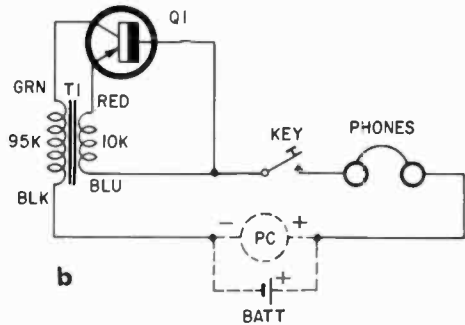
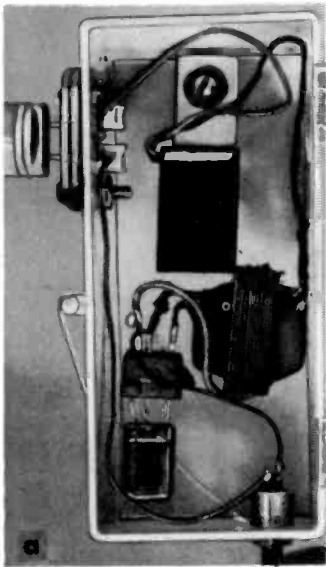


Fig. 520. This circuit is similar to those in Figs. 517-a and 518-a. The physical capacitor is replaced by the often overlooked stray capacitance within the transformer. Additional capacitance can be added to lower the tone.

Transistor: Q1—2N207, 2N369 or equivalent
 Transformer: T1—10,000-ohm primary, 95,000-ohm secondary (United Transformer SSO-2)
 Phones: 3,000-ohm magnetic (Lafayette AR-50)

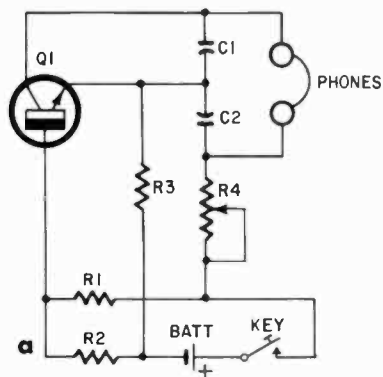
Photocell: PC-B2M or B3M (International Rectifier) cell
 Battery: Mallory RM-400 cell
 Misc: Plastic box; mounting hardware; key

Self-excited 100-kc oscillator

Two n-p-n transistors coupled emitter-to-emitter form the basis for the self-excited 100-kc oscillator circuit in Fig. 522-a. Silver micas are used in parallel with a high-grade mica trimmer and shielded rf choke for the tank circuit. Fig. 522-b is the photo of the physical layout.

To calibrate, the oscillator is tuned to beat against WWV or a laboratory-grade frequency meter. When calibrating a receiver, the rf coupling should be loose—the oscillator is brought close to the receiver under test, using radiation from the coil for receiver pickup.

The open-circuit rf output is just under 1 volt with a supply voltage of 1.5 volts, and about 1.35 volts with a 3-volt battery. The current drain is under 500 μ a in each case.



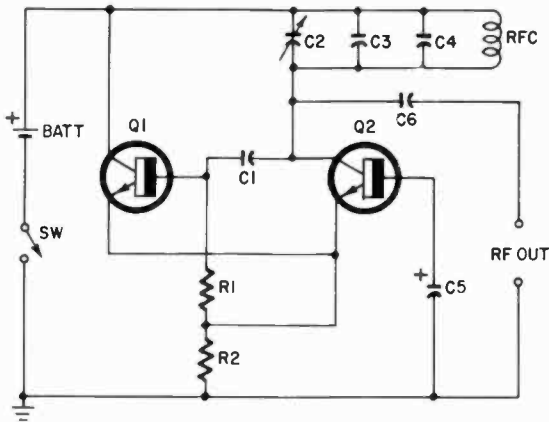
Resistors: R1—2,700 ohms; R2—1,200 ohms; R3—27,000 ohms (all $\frac{1}{2}$ watt); R4—50,000-ohm potentiometer (Lafayette VC-60)
 Capacitors: C1—.2- μ f, 100-volt ceramic; C2—.02- μ f, 75-volt ceramic (Lafayette C-616)
 Transistor: Q1—2N229
 Earphones: 2,000 ohms (Telex HMY-01)
 Battery: 3 Mallory RM-630 cells in series
 Key: Subminiature pushbutton switch (Grayhill 39-1)
 Misc: Aluminum cigar container; phone jack; mounting hardware



Fig. 521. Here the phones replace the transformer (T_1) used in the circuit (Fig. 516-a) as an inductance. This allows considerable size reduction in the completed module.

100-kc oscillator

A subminiature 100-kc crystal oscillator unit is shown in Fig. 523-a. Here a midget type variable capacitor (C_2) has been used in an L-C circuit with an 8.2 millihenry iron-core rf coil (RFC2). This package will put out 100 mv across a 2,000-ohm load. The big feature is low current drain (15 to 20 μ a) eliminating the need for any switch. The battery is simply removed when the oscillator has to be turned off, but even if the battery were left in, it could run continuously for months. A plastic box (Fig. 523-b) was chosen to house the circuit, which is laid out on a perforated board.



a

Resistors: R1—270,000-ohms; R2—2,200 ohms (1/2 watt)

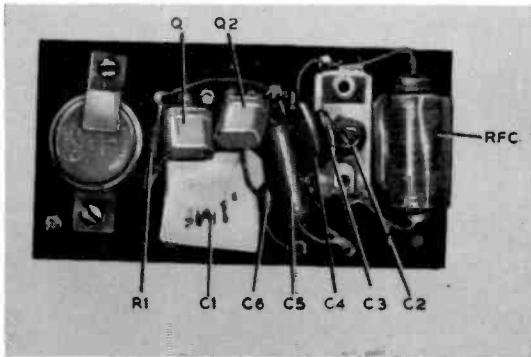
Capacitors: C1—1- μ f, 75-volt ceramic; C2—100-pf (μ μ f) mica trimmer (Arco 425); C3—50-pf, 100-volt, ceramic (Elmenca DM-10); C4—820-pf, 100-volt disc ceramic; C5—1- μ f, 6-volt electrolytic; C6—500-pf, 100-volt disc ceramic

Transistors: Q1, Q2—2N35, 2N169A or equivalent

RFC: 2.5-mh rf choke (Miller 6302)

Battery: Mollory RM-625 cell

Misc: Chassis material; spst switch; terminals; mounting hardware

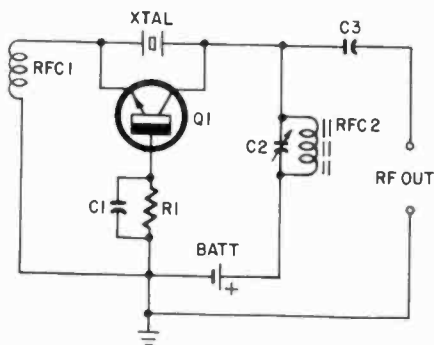


b

Fig. 522. This multivibrator circuit is frequency stabilized by C2, C3 and C4 in parallel with RFC. This tuned circuit makes a sine wave out of the multivibrator square wave.

20-kc crystal oscillator

The circuit (Fig. 524-a) will produce 0.4-volt output, between collector and base, into a 330-ohm impedance. Wide-range stability of the operating point is established by biasing resistors R1 and R2. The combination of C2, C3 and L1 provides a high



a

Resistor: R1—27,000-ohms, ½ watt

Capacitors: C1—.01- μ f, 75-volt ceramic; C2—90-400-pf trimmer (Arco 429); C3—30-pf, 100-volt tubular ceramic

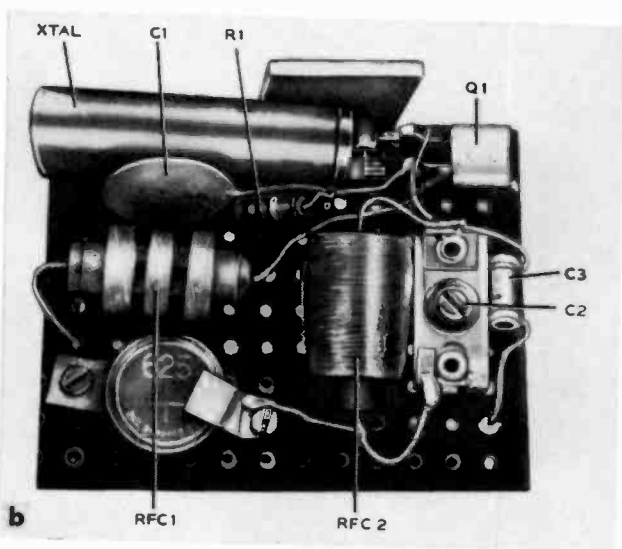
Transistor: Q1—2N35, 2N169A

Chokes: RFC1—2.2 mh (Miller 70F223A1);

RFC2—8.2 mh (Miller 70F823A1)

Battery: Mallory RM-625 cell; Xt1—100 kc (J. K. Knight H-17)

Misc: Phenolic chassis; plastic box; terminals; mounting hardware

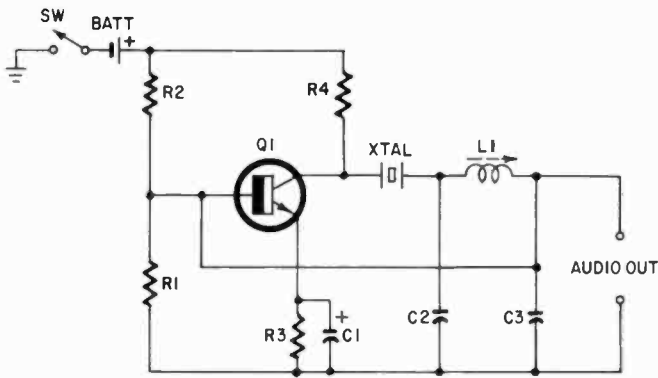


b

Fig. 523. For greater frequency stabilization a crystal is used in this circuit. The L-C circuit (C2-RFC2) must be tuned to the frequency (or a harmonic) of the crystal.

(approximately 100,000 ohms) to low (1,000 ohms) impedance transformation network.

In the layout (Fig. 524-b) note that the crystal is mounted edgewise on the board.



Resistors: R1, R3—5,100 ohms; R2—30,000 ohms; R4—10,000 ohms (all $\frac{1}{2}$ watt)
 Capacitors: C1—1- μ f, 100-volt (Mallory) C2— $.005$ - μ f, disc ceramic; C3—.05- μ f disc ceramic
 Transistor: Q1—2N333
 Coil: L1—2.5 to 17 mh adjustable choke (Miller 6314)

Xtal: 20 kc (J. K. Knight H17 or McCoy type M-22)
 Battery: Burgess U-15
 Misc: Mounting hardware; spst switch; terminals; phenolic chassis; plastic box

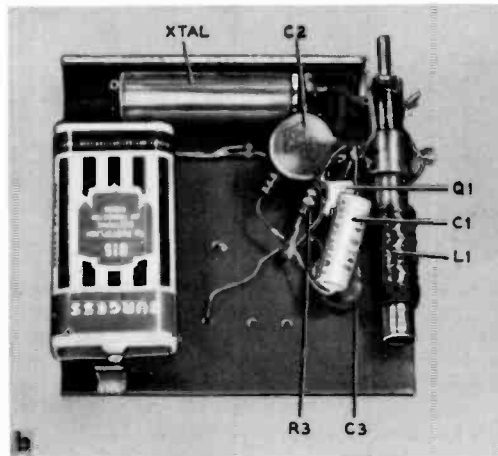
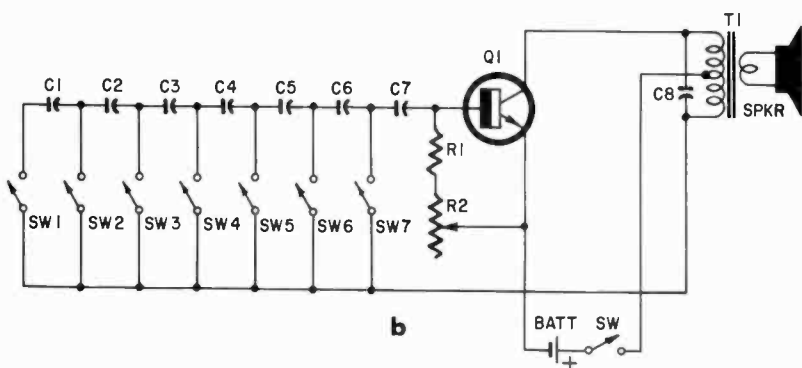
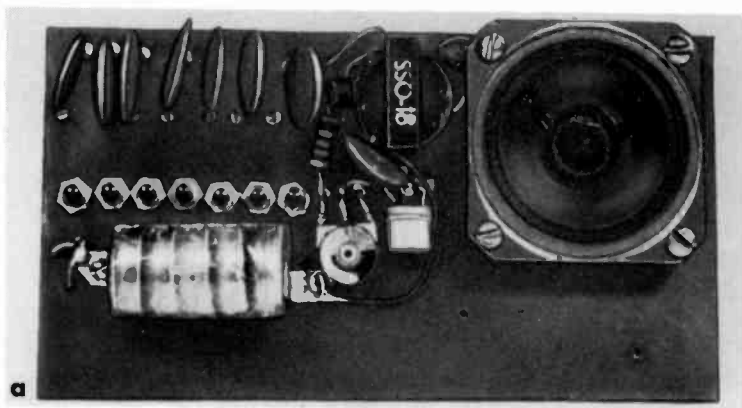


Fig. 524. The parallel tuned L-C circuit in this module is formed by L1 and C2-C3. The inductance must be tuned for maximum output.

If a different layout is wanted make sure the unshielded coil is kept away from the metal cases of the battery and the crystal. Changes in the values of C2 and C3 can affect the waveform since they are a voltage divider controlling the amount of feedback. A low-impedance output can be had by winding a few turns of wire around the bottom end of L1.

Transistor organ

Fig. 525-a shows a miniature electronic organ built around one 2N229 transistor and several subminiature switches. A miniature



Resistors: R1—510 ohms, $\frac{1}{2}$ watt; R2—500,000-ohm potentiometer (Lafayette VC-61)
 Capacitors: C1 to C8—.02- μ f disc ceramic, 50 to 100 volts
 Transistor: Q1—2N229 (Sylvania)
 Transformer: T1—7,500/9,400 ohms CT primary, 3.2/4 ohms secondary (UTC SSO-18)

Speaker: 3.2 ohms (Lafayette SK-61)
 Battery: 5 Mallory RM625 cells in series
 Switches: SW1 to SW7 subminiature push-button (Grayhill 39)
 Misc: Chassis materials; mounting hardware; spst switch

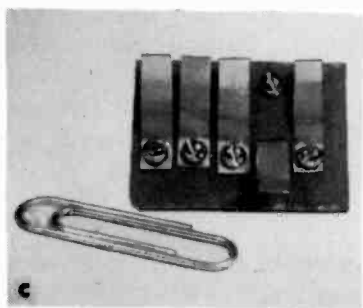
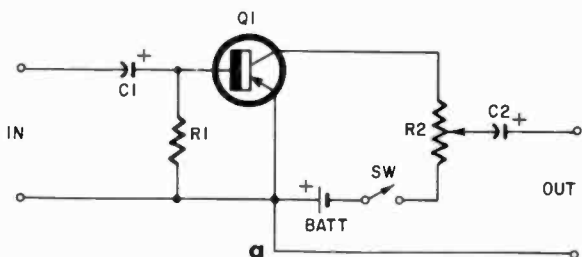


Fig. 525. Similar to the circuit in Fig. 518 this hookup makes it impossible to connect more than one capacitor into the circuit at a time. The lowest frequency is determined by C7—the other capacitors, being in series, are effectively lower capacitances and produce a higher frequency.



Resistors: R1—24,000 ohms, $\frac{1}{2}$ watt; R2—10,000-ohm potentiometer (Lafayette VC-59)
 Capacitors: C1, C2—1 μ f, 15 volts (Lafayette CF-128)

Transistor: Q1—2N107
 Battery: 4 Mallory RM-400
 Misc: Chassis material; spst switch; terminals, mounting hardware

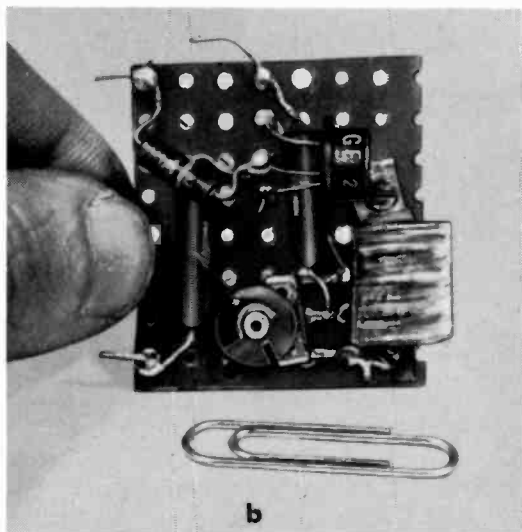
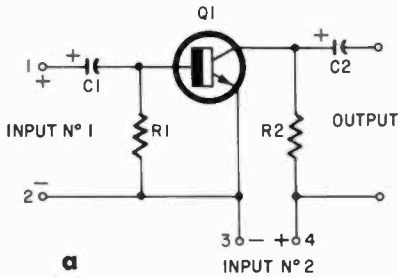


Fig. 526. This module can be added to one of the previous oscillator circuits to give a square-wave output.

transformer and midget case complete the organ. When more than one switch is pressed simultaneously, the note emitted is the one corresponding to the switch electrically nearest C7.

The overall tone range of the organ can be raised by cutting the capacitance of C8 to .01 or .005 μ f. Resistor R1 varies the bias voltage to the base of the transistor. Five mercury cells supply voltage for the pocket-size organ.

The schematic is shown in Fig. 525-b. Instead of the commercially available subminiature switches, a home-made keybank can be constructed (Fig. 525-c).



Resistors: R1—1,100 ohms; R2—110,000 ohms (all 1/4 watt)
 Capacitors: C1, C2—1 μ f, 20 volts (Astran TES)
 Transistor: Q1—2N35, 2N207, 2N369 or equivalent
 Misc: Chassis material; terminals; mounting hardware

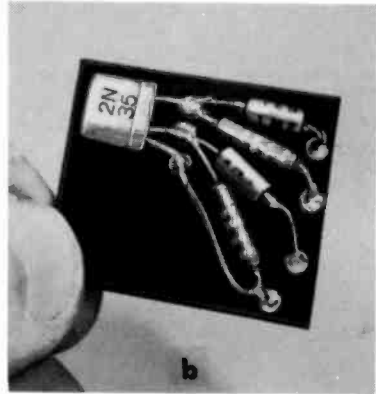
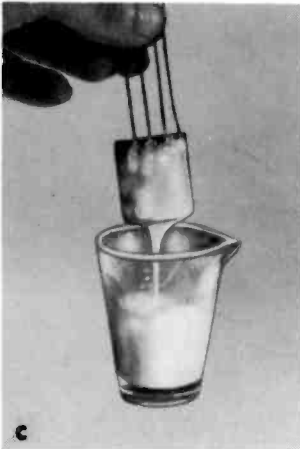


Fig. 527. A computer-like and circuit can be put to use in model radio control systems. It can be adapted to electronic sequence switching.

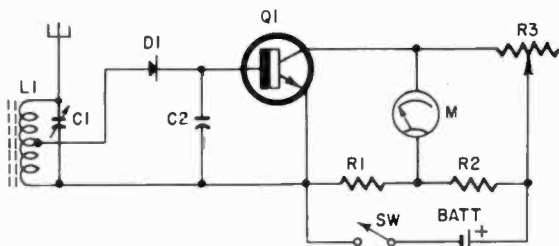
Sine-wave clipper

A p-n-p transistor is the foundation of the sine-wave clipper circuit in Fig. 526-a. When a low-voltage sine wave (0 to 5 volts) is fed into the clipper, the output resembles a square wave. Changing the setting on the output potentiometer changes the output waveshape.

The parts layout of the unit is shown in Fig. 526-b. The input and output blocking capacitors have high dc voltage ratings for extra protection.

Coincidence pulse circuit

If a square pulse of 6 volts dc is fed into terminals 1 and 2 of the circuit shown in Fig. 527-a, and another similar pulse (in



a

Resistors: R1, R2—470-ohms, ½ watt; R3—10,000-ohm variable (Lafayette VC-59)

Capacitors: C1—1.8 to 13 pf (μmf) (E. F. Johnson type U); C2—.001- μf ceramic

Coil: L1—chosen for proper frequency to resonate with C1 (wind on CTC type LSM or Miller 4300 coil form)

Transistor: Q1—2N170, or equivalent

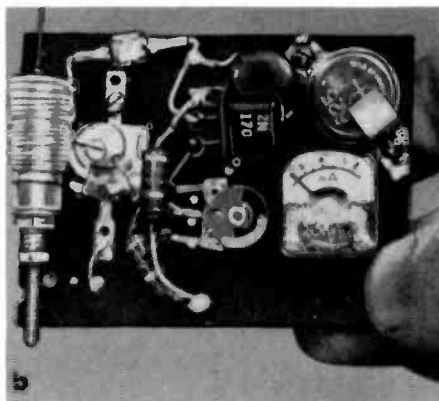
Diode: D1—1N34, 1N48, 1N267, 1N295 or equivalent

Meter: Alco ½ inch 0-1 ma dc

Battery: Mallory RM625 cell

Misc: Chassis material; spst switch; mounting hardware

Fig. 528. By using a pair of ear-phones in the circuit in place of the meter and R2, discarding R1 and R3, you have a simple receiver tuned by L1-C1. A shorting type jack can be used to open the collector circuit and connect directly to the battery.

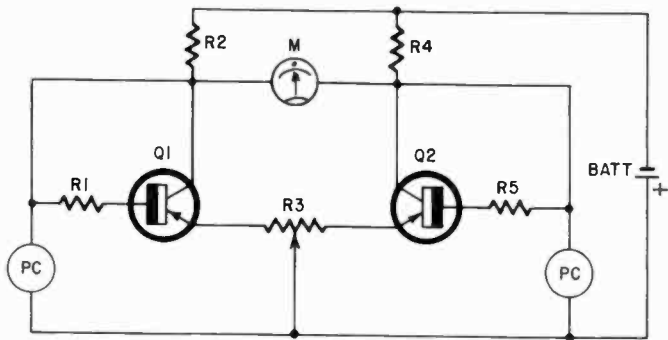


phase) is fed simultaneously into terminals 3 and 4, a pulse will be produced at the output terminals. However, pulses at terminals 3 and 4 close the circuit for amplification of pulses from input terminals 1 and 2 if these pulses (at 1 and 2) are out of phase (with 3 and 4).

The subminiature circuit package is shown in Fig. 527-b. A module has been made up using a phenolic wafer. The wafer is dipped in silicone rubber (Fig. 527-c) to protect it against moisture and physical damage. Leads are attached to the circuit before "potting" in the silicone.

Field-strength meter

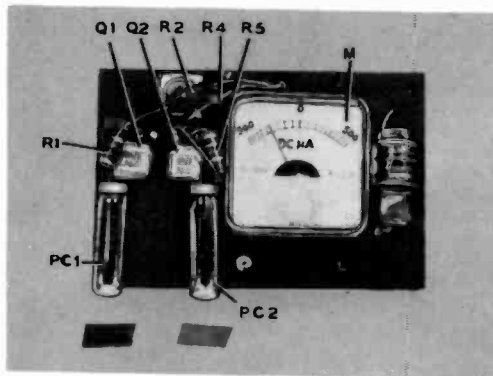
A diode, transistor, and subminiature ½-inch dc milliammeter are the three basic components in a vest-pocket field-strength



Resistors: R1, R5—150,000 ohms; R2, R4—680,000 ohms (all $\frac{1}{2}$ watt); R3—10,000-ohm potentiometer (Lafayette VC-59)
Transistors: Q1, Q2—2N1266

a

Photocells: PC—D1767 (Sylvania) or CL404 (Clairex)
Meter: 1-0-1 ma (Alco 1 inch)
Battery: 3 Mallory RM625 cells
Misc: Chassis material; mounting hardware



b

Fig. 529. Photocells are only one possible input for this balance-indicating circuit. Any type of variable voltage, current or resistance device can be used to unbalance the meter through the transistors.

meter circuit (Fig. 528-a). The tuned circuit is ferrite-core coil (L1) and subminiature precision variable capacitor (C1). The rectified rf from the diode is fed into the base-emitter transistor input, and the n-p-n gives a dc power gain of 12 to 14. Two fixed resistors (R1) and (R2) and a subminiature variable (R3) make up a zeroing type bridge for the meter. A mercury cell provides power.

Fig. 528-b shows the physical layout of the unit. The zero control, inductor slug and capacitor shaft are all located for ease

in adjustment. The antenna (about 8 inches long) is made from No. 24 or No. 26 AWG brass wire.

Comparison photocell detector

Sometimes it is convenient to compensate for ambient light in a photocell circuit. The schematic (Fig. 529-a) shows how this can be accomplished. Two photocells are used as variable collector-bias resistors. The photocells change resistance from several hundred ohms in the light, to over a megohm in the dark. Collector currents are set by R1 and R5, and balanced out with R3. Both cells see the same ambient light, so that only slight differences will unbalance the meter.

Since the circuit operates by comparison, colors can be matched as shown in Fig. 529-b. The samples to be matched should be at the same distance from each cell, and should be evenly illuminated.

A zero-center meter should be used in the circuit but can be replaced by a single-stage transistor relay amplifier circuit.

Chapter 6

Practical Subminiature Devices

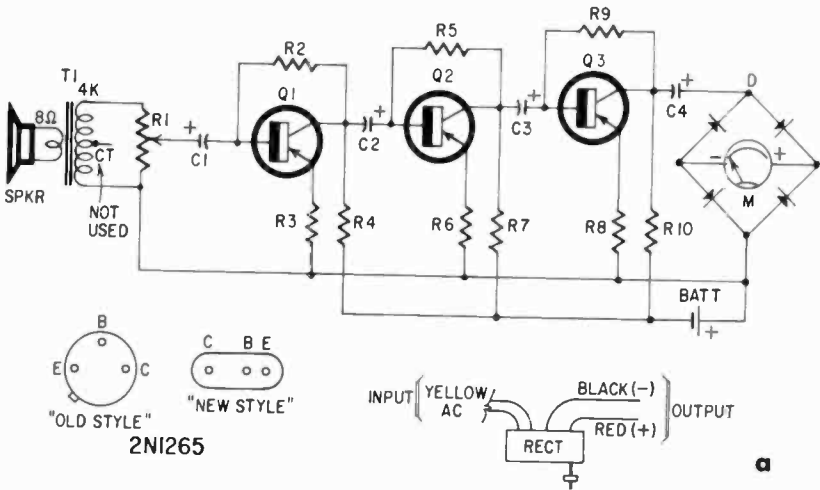
The assemblies in this chapter are, in general, a bit more advanced, than those in Chapter 5. In many cases, such as the vest pocket receivers, they serve to illustrate the combination of several basic circuits or demonstrate unusual ideas such as the reflex circuit.

Sound-level meter

Fig. 601-a shows the circuit of a pocket-sized sound-level meter built around a 1-inch diameter 0-1 dc milliammeter and three p-n-p transistors. The circuit is basically a three-stage audio amplifier with capacitive coupling ahead of a full-wave bridge rectifier and the output meter.

The physical layout is shown in Fig 601-b. The instrument is built on a piece of phenolic, about 3 by 5 inches. The PM speaker picks up the audio signal—driving the input transformer, T1. The three transistors are hooked up as common-emitter amplifiers. The amplified audio is capacitively coupled to the bridge rectifier, and read as dc on the 0-1 ma dc output meter.

Low-level audio voltages can be read on the meter by bypassing the input transformer and feeding the input signal to the input attenuator (R1), and the emitter "ground" line. The secondary of T1 should be disconnected to prevent false readings. To measure sound level or intensity, just point the speaker in the direction of the source of the sound.



Resistors: R1—5,000-ohm potentiometer (Lafayette VC-58); R2, R5, R9—180,000 ohms, $\frac{1}{2}$ watt; R3, R6, R8—100 ohms, $\frac{1}{2}$ watt; R4, R7, R10—2,200 ohms, $\frac{1}{2}$ watt
 Transistors: Q1, Q2, Q3—2N1265
 Capacitors: C1, C2, C3, C4—10- μ f, 25-volt electrolytics (Lafayette CF-142 or MEC type E)
 Meter rectifier: D—bridge rectifier (Conant 160B)

Transformer: T1—8 ohms to 4,000 ohms (Argonne AR-134)
 Speaker: Spkr—1- $\frac{1}{2}$ inch (Lafayette SK-61 or Calrad)
 Meter: M—0-1 ma dc (Alco P-1000)
 Battery: Batt—6.75 volts (5 Mallory RM630 cells in series)
 Misc: Perforated board; mounting hardware

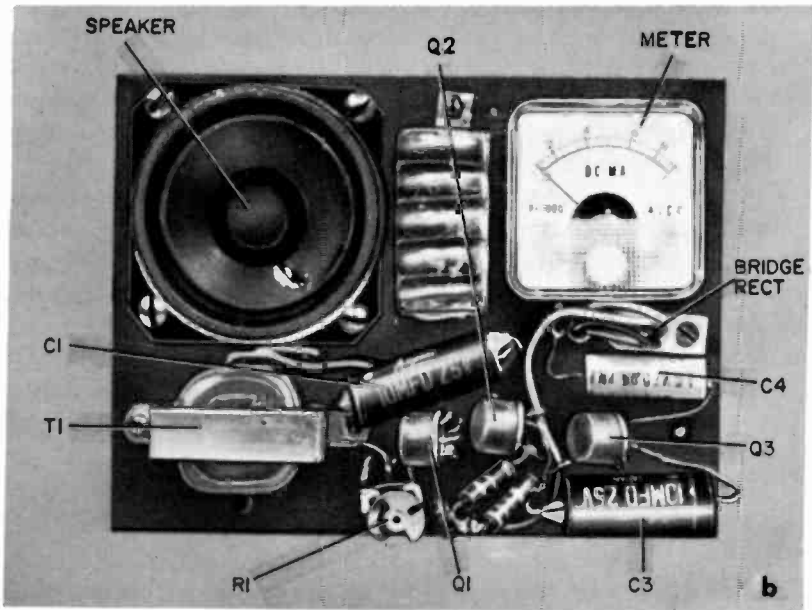


Fig. 601. Compact unit for making sound-level measurements.

Subminiature tone generator

The circuit of Fig. 602-a uses two audio transistors Q1 and Q2 in a multivibrator arrangement to produce a 400- to 600-cycle tone. The unit, designed by Phillip Kraft, is available in kit form. The output can be taken from the base of the second transistor, Q2, and coupled by a capacitor to the grid of a power amplifier tube in a radio-control transmitter for tone modulation. With a .02- μ f for C1, this particular unit gives an audio tone of about 490 cycles.

A printed-circuit board layout is shown in Fig. 602-b and the physical packaging is pictured in Fig. 602-c.

Two-transistor pocket radio

Fig. 603-a is the schematic for a two-transistor reflex receiver about $3\frac{3}{4}$ inches square by $1\frac{1}{4}$ inches deep. This was built first as a miniature radio, and then modified for smaller size.

Signals tuned by L1 and C2 are amplified by input transistor Q1 as rf and detected by the diode, D1. The audio is coupled back to the base of Q1 which amplifies it again—this time as af. The amplified audio passes through L2 and C6 to the second-stage transistor, Q2, a power amplifier, where it is amplified for the output. The use of the first-stage transistor for both af and rf amplification is a characteristic of reflex circuits.

Fig. 603-b shows the printed-circuit board with most components mounted. The board can be purchased already etched, or made using the printed-circuit techniques described in Chapter 4. Be sure to check polarities on the electrolytics before making the final soldered connections.

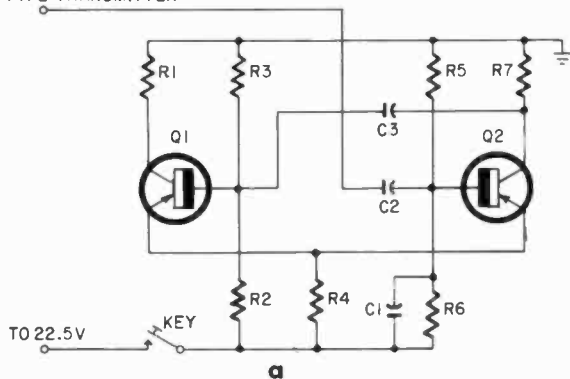
The same circuit has been used for a subminiature version. Here, the major size reduction would be in the use of the smaller variable capacitor and potentiometer (pot) and substitution of tantalum for aluminum electrolytics. Point-to-point wiring was used, after the subminiature variable and potentiometer were mounted on the phenolic chassis.

The beginner should wire the larger receiver first and experiment with the circuit and placement of parts to get the "feel" for reducing the receiver's size.

High-impedance input preamp

Fig. 604-a shows a three-transistor amplifier circuit (with an input impedance in the order of 100,000 to 200,000 ohms) suitable for probe "sensitizers" (extending low ranges of ac meters)

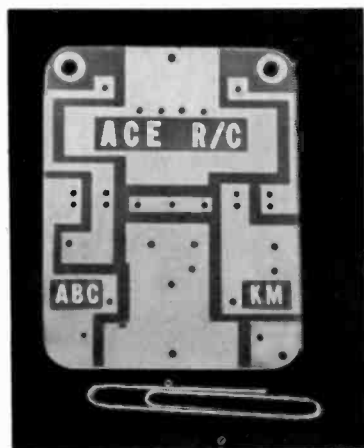
TO AMPL IN MOPA (MASTER OSC PWR AMPL)
TYPE TRANSMITTER



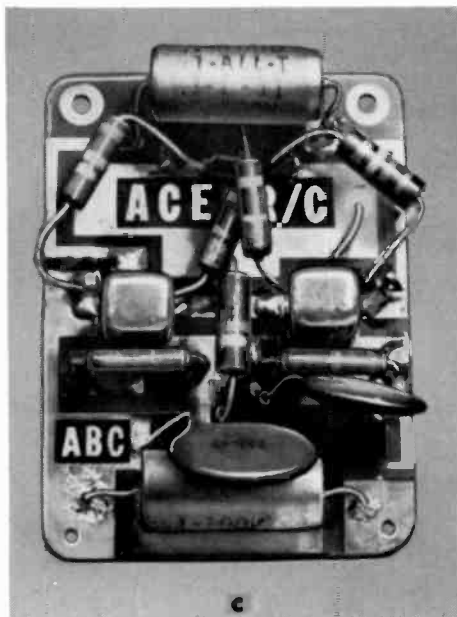
Resistors: R1—82,000 ohms; R2, R6—10,000 ohms; R3, R5—470,000 ohms; R4—1,000 ohms; R7—330,000 ohms (all $\frac{1}{2}$ watt)
Capacitors: C1—.01- μ f to .05- μ f (see text); ceramic disc; C2—.01- μ f, ceramic disc; C3, —.1 μ f.

Transistors: Q1, Q2—2N224, CK722 or equivalent

Misc: Mounting hardware; key; printed circuit board (available in kit form from Ace Radio Control)

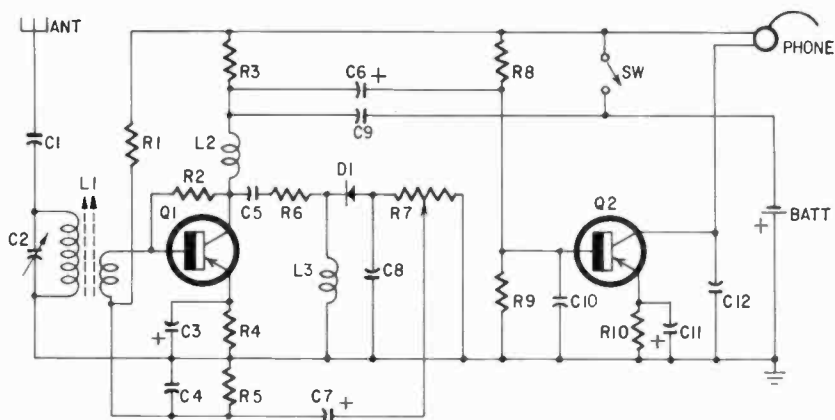


b



c

Fig. 602. Printed-circuit chassis makes the construction of the tone generator simpler. The circuit is a multivibrator.



Resistors: R1—47,000 ohms; R2, R8—82,000 ohms; R3—2,200 ohms; R4, R5—1,100 ohms; R6—82 ohms; R9—5,600 ohms; R10—390 ohms (all ½ watt); R7—10,000-ohm potentiometer
Capacitors: C1—10- μ f (pf) ceramic disc; C2—365- μ f (pf) air variable; C3, C11—90 μ f, 3 volt electrolytic; C4, C8, C10, C12—.005- μ f, ceramic disc; C5—.001 μ f ceramic disc; C6, C7—5 μ f, 6-volt electrolytic; C9—.01- μ f ceramic disc

Transistors: Q1—2N136 or 2N140; Q2—2N-188A or 2N109
Coils: L1—ferrite antenna coil (Miller 6313); L2—.5 mh choke
Diode: D1—1N295
Battery: Batt—9 volts (Mallory TR-177 or equivalent)
Misc: Earphone, phone plug and jack; spst switch; mounting hardware; printed-circuit board (Available in kit form from Allied Radio Corp.)

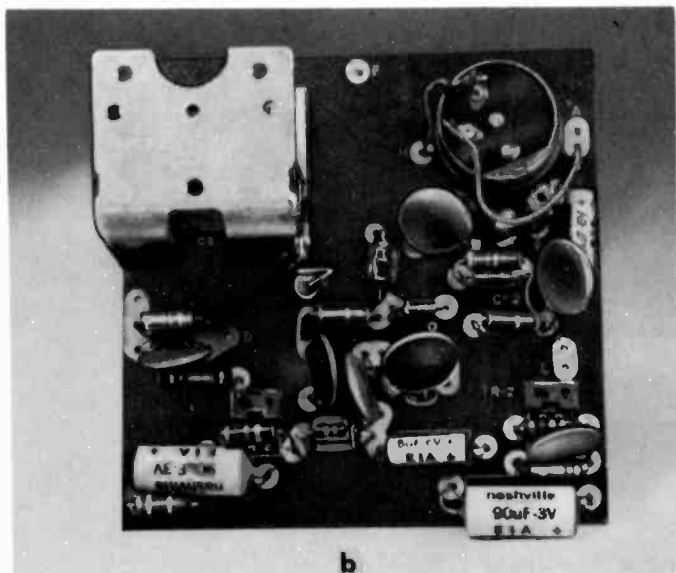
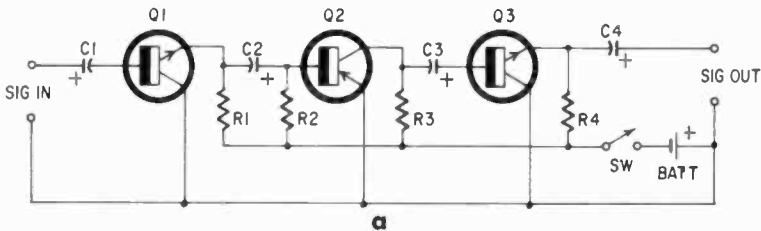


Fig. 603. Reflex receiver uses two-winding antenna coil. Tapped ferrite antenna can be used by omitting ground connection to the L1-C2 combination and using the connections to C1, R2 and R1-C4 only.



Resistors: R1—18,000 ohms; R2—120,000 ohms; R3—15,000 ohms; R4—560 ohms (all ½ watt)

Capacitors: C1, C2, C3, C4—1- μ f, 15-volt electrolytics (Lafayette CF-128)

Transistors: Q1, Q3—2N35; Q2—2N34 or equivalent

Battery: Batt—5.4 volts (4 Mallory RM-265 cells in series)

Misc: Perforated-board chassis; spst switch; terminals; plastic case; mounting hardware

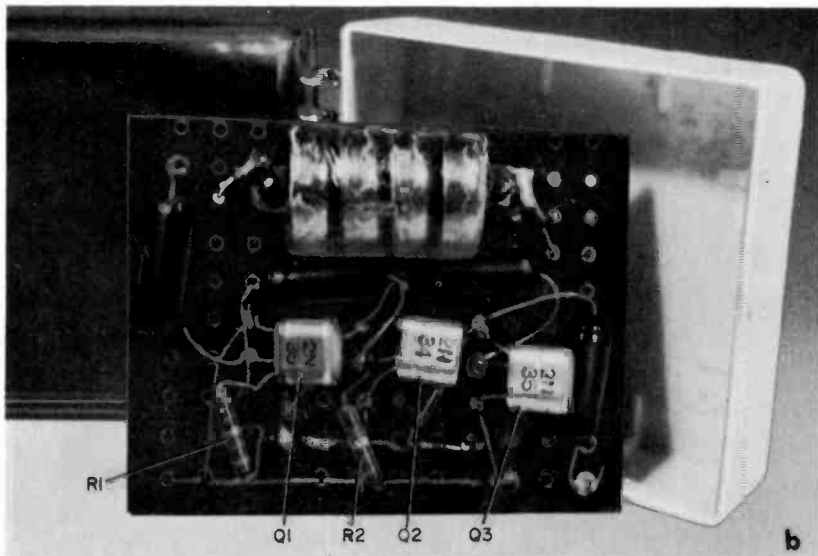
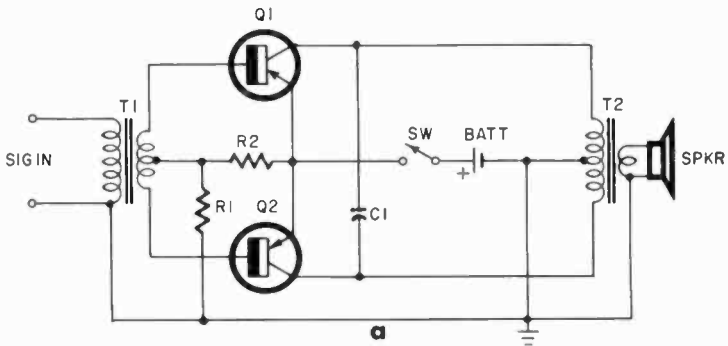


Fig. 604. In this three-transistor amplifier R3 can be a potentiometer if space permits. Increasing the output (by changing R3) reduces battery life.

and crystal-microphone input circuits such as “detectaphones.” The preamp takes an ac signal input up to 3 or 4 mv before the output is affected by clipping. Output is about 25 to 150 mv depending on the setting of R3. The current drain on the four series-connected mercury cells is approximately 500 μ a.

The physical layout is shown in Fig 604-b. Using perforated board and terminal pins, the entire circuit (with battery and volume control) fits into a plastic case about ¼-inch thick.



Resistors: R1—3,000 ohms; R2—270 ohms (both $\frac{1}{2}$ watt)

Capacitor: C1—.05- μ f, 50-volt ceramic disc

Transistors: Q1, Q2—2N109 or equivalent

Transformers: T1—input, 50,000 ohms to 1,500 ohms CT (Argonne AR-128); T2—output, 400 ohms, CT to 8 or 3.2 ohms (Argonne AR-167)

Speaker: Spkr—1- $\frac{1}{2}$ -inch PM speaker (Lafayette SK-61 or Calrad)

Battery: Batt—5.4 volts (4 Mallory RM-625 cells in series in Keystone 113 battery holder)

Misc: Phenolic chassis; 2-56 machine screws and hex nuts; metal box; subminiature transistor sockets (Cinch 46T24231 or Elco 799-BC), spst switch; mounting hardware

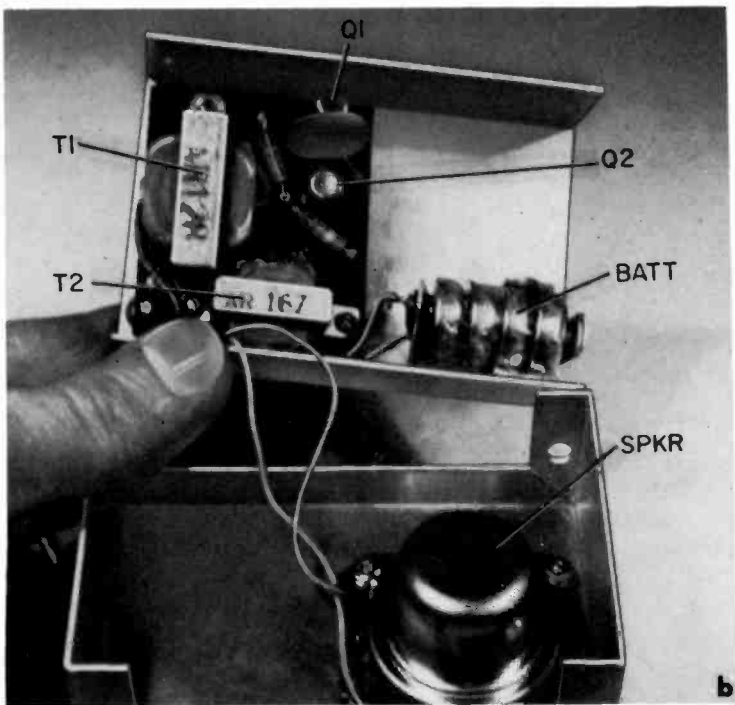
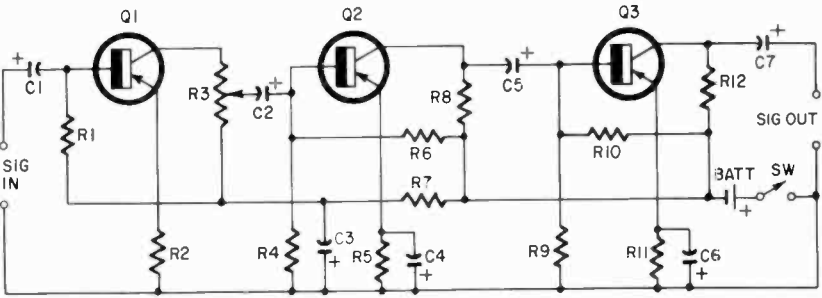
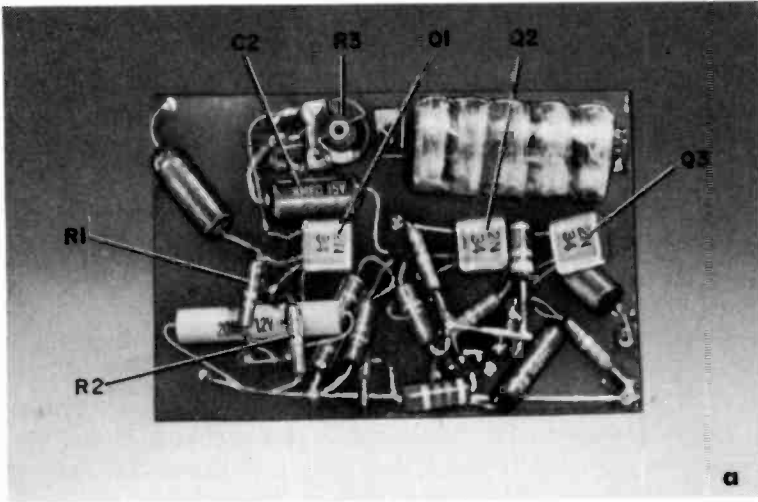


Fig. 605. This push-pull amplifier operates Class-B. It can be driven by the amplifier in Fig. 606.



Resistors: R1—1.1 megohms; R2, R5, R11—1,000 ohms; R4, R9—3,900 ohms; R6, R10—10,000 ohms; R7—18,000 ohms; R8, R12—8,200 ohms; (all 1/2 watt); R3—10,000-ohm potentiometer (Lafayette VC-59)
Capacitors: C1, C2, C5, C7—1 μ f, 15 volt electrolytics (Lafayette CF-128); C3—20 μ f

12 volt electrolytic (Mallory); C4, C6—2- μ f, 6 volt electrolytics (Lafayette CF-100)
Transistors: Q1, Q2, Q3—2N34, 2N207, 2N369 or equivalent
Battery: Batt—6.75 volts (5 Mallory RM625 cells in series)
Misc: Phenolic chassis; spst switch; mounting hardware

Fig. 606. This amplifier can drive a power amplifier. Better efficiency can be obtained if R12-C7 is replaced by the primary of a driver transformer.

Class B push-pull amplifier

Fig. 605-a is the schematic of a Class-B push-pull transistor amplifier. Class-B operation has very high transistor collector-circuit

efficiency, as maximum current flows when there is a signal. In the absence of signal, the current drops to a very low value, approximately 10% of maximum. Peaks of audio give maximum current flow. Fig. 605-b is a photo of the completed project.

The subminiature circuit package is laid out in a small metal box about 1 inch x 1½ inches x ⅞ inch deep. The two transformers, a 50,000-ohm to 1,500-ohm center-tapped input (T1) and 400-ohm center-tapped to 3.2 ohm output (T2), are mounted with 2-56 screws to the phenolic chassis. Subminiature in-line sockets are used, since the transistors have very short leads. Connections to the socket bases are protected from shorting by a layer of tape over them.

The input impedance of this unit is about 50,000 ohms and the output matches a miniature 3.2-ohm speaker. Power output is about 50 mw. With no signal, the unit draws 3.5 ma, which jumps to about 30 ma on a maximum signal.

Three-stage R-C coupled amplifier

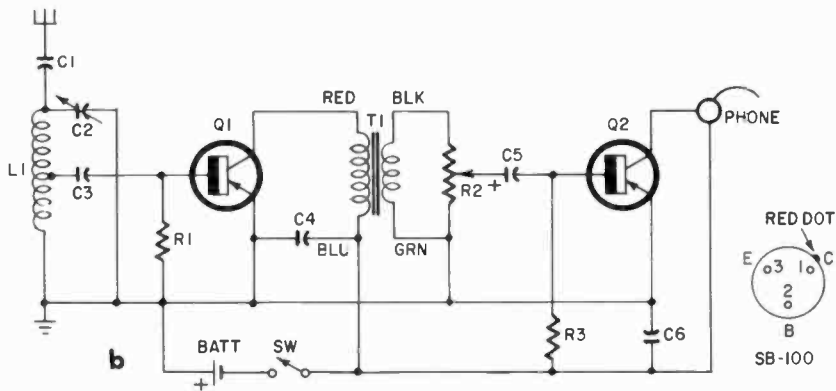
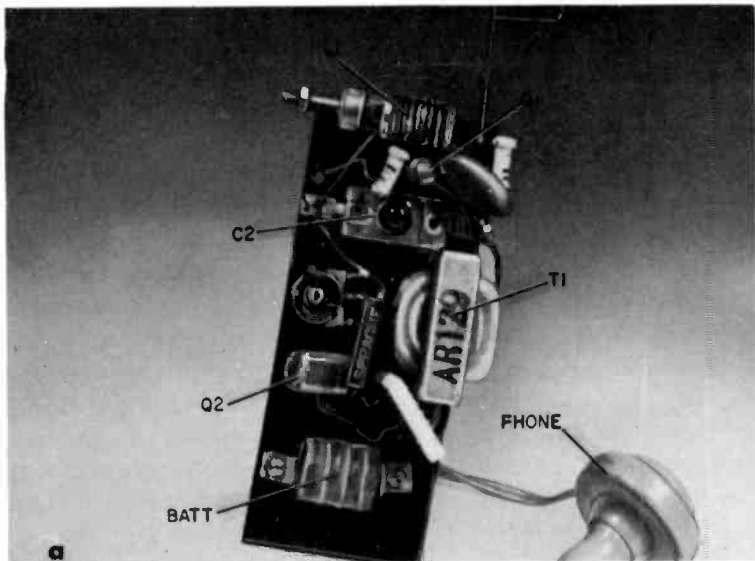
Fig. 606-a is the photo of a three-stage R-C-coupled amplifier constructed on a perforated board and using p-n-p junction transistors. The subminiature gain control is ⅜-inch in diameter. The voltage gain through the three stages is about 2,500. The input voltage should be limited to 0.1 mv for an output signal of about 0.8 to 1 volt.

The bases of the transistors are biased by resistor voltage dividers consisting of 3,900 and 10,000-ohm combinations, such as R4 and R6 for Q2 and R9 and R10 for Q3. The 1,000-ohm resistors (R5 and R11) in the emitter leads of the second and third stages are bypassed with 2-μf aluminum electrolytics (C4 and C6). The 1,000-ohm resistor (R2) in the emitter of the first stage is not bypassed so as to give some degeneration. See Fig. 606-b.

To conserve space, ½ watt resistors were used, and wiring was done using several eyelets as a "holding" pattern with other components wired and soldered to each other mechanically.

High-frequency receiver

Sometimes a high-frequency pocket receiver is needed for transmitter checks or for short-range communication. The unit shown in the photo in Fig. 607-a was originally designed for cuing actors and it is small enough to be worn under a coat lapel or put in a pocket of the person who is to receive the signal.



Resistors: R1—120,000 ohms; R3—270,000 ohms (all $\frac{1}{2}$ watt); R2—50,000-ohm potentiometer (Lafayette VC-60)

Capacitors: C1—20 μmf (pf) ceramic tubular; C2—4 to 80 μmf mica trimmer; C3—50 μmf ceramic tubular; C4—.01 μf ceramic; C5—2 μf , 12-volt electrolytic; C6—.1 μf ceramic.

Transistors: Q1—SB-100, 2N248, 2N310; Q2—2N207, 2N369, CK721 or equivalent

Transformer: T1—input, 1,000 ohms to 50,000

ohms (Argonne AR129 or UTC SSO-7)

Coil: L1—8 turns No. 20 enameled on CTC type LSM form topped at 4th turn from common (Batt+) end

Battery: Batt—5.4 volts (4 Mallory RM-400 cells in series)

Phone—2,000-3,000 ohms (Telex HMY-01 or Lafayette AR-50)

Misc: Antenna—10-inch length bare copper wire; phenolic chassis; spst switch; mounting hardware

Fig. 607. Transformer coupling in this receiver makes up for the lack of a reflex circuit. Here the transformer substitutes for R3, R8 and C6 in Fig. 603.

The heart of the receiver (See Fig. 607-b) is a surface-barrier transistor (Q1) which is capable of operating up to 30 or 40 mc. Here it is used in a regenerative circuit consisting of L1, C1, C2 and C3. A tapped coil is used for feedback. The p-n-p af amplifier is fed the detected audio signal through a subminiature input transformer (T1), control R2 and coupling capacitor C5. A low-impedance (2,000-3,000 ohm) magnetic earpiece is used for audio output. A stack of four mercury cells (connected in series) provide approximately 5 volts for the unit which should run about 30 to 50 hours before requiring replacement batteries.

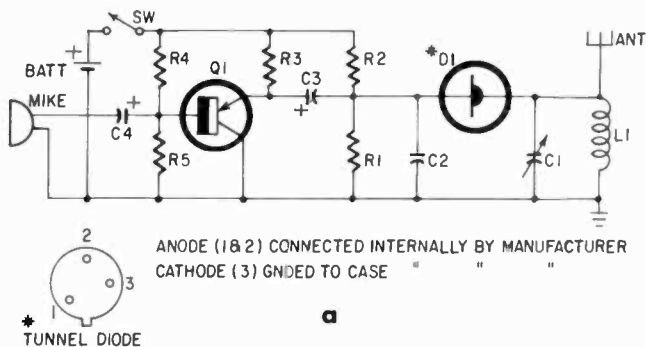
As usual, component leads in the high-frequency section should be kept short—not too difficult a job in view of the overall size of the unit. Volume control R2 is located in such a position that it will be easy to adjust (with a midget screwdriver) as the battery voltage gradually decreases with use. The variable capacitor (C2) is also located for ease in tuning and can be fitted with a knob, if desired. It may be necessary to experiment with antenna length to obtain best results for a given frequency. An 8 to 12-inch antenna worked best for 27-mc reception.

FM tunnel-diode transmitter

Fig. 608-a is the schematic for a pocket-size FM transmitter that can be used for remote locations such as lectures, demonstrations, and sales talks by clipping the transmitter to the clothing or coat lapel, and picking the "broadcast" up on a standard FM receiver.

Built around a tunnel diode (D1), the first stage oscillator tank (L1) is made from six turns of silver-plated No. 16 copper wire wound to a $\frac{3}{8}$ -inch diameter wired in parallel with a subminiature air-dielectric variable capacitor (C1). The audio stage is built around a p-n-p audio amplifier in an emitter-follower circuit. The reluctance microphone produces FM by having the audio signal modulate the voltage or bias on the anode of the tunnel diode. The range of the FM transmitter used in conjunction with an average FM receiver is 50 to 100 feet. The frequency will be in the FM band—88-108 mc.

The transmitter layout is shown in Fig. 608-b with the rf section and antenna at one end, and the mike and audio section at the other. A piece of $\frac{1}{16}$ -inch phenolic is used as a base for the unit, which can be encased in a metal box, if desired. The subminiature variable capacitor is mounted to permit tuning the tank circuit after the unit is boxed, and the antenna is run through a polystyrene bushing to prevent accidental grounding to the case. An



Resistors: R1—22 ohms; R2—270 ohms; R3—470 ohms; R4, R5—11,000 ohms (all $\frac{1}{2}$ watt)
Capacitors: C1—1.5 to 8 μf (pf), air variable, (Johnson type U); C2—.001- μf disc ceramic; C3—50 μf , 6-volt electrolytic; C4—4 μf , 12-volt electrolytic
Tunnel diode: D1—1N2939
Transistor: Q1—2N188A

Battery: Batt—1- $\frac{1}{2}$ volts (Eveready E340E, 904, E90, E401 or equivalent)
Coil: L1—6 turns No. 16 silver-plated copper wire on $\frac{3}{8}$ -inch diameter coil form
Microphone: Mike—controlled magnetic (Shure MC-11 or MC-20)
Misc: antenna—5-inches No. 12 bare copper wire; phenolic chassis; terminals; mercury switch; mounting hardware

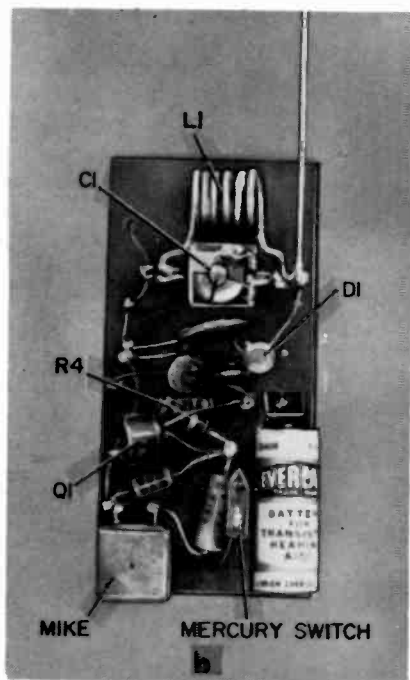


Fig. 608. Simple circuit makes a low-power transmitter. Changing values for L1-C1 will change frequency. Use of transmitter is governed by FCC rules.

alkaline-manganese cell is used for the power source, and a mercury switch turns the transmitter *on* and *off* depending on the position of the antenna—that is, whether the antenna is held vertically or not.

Delayed action photoelectric relay

Fig. 609-a is the schematic for a light-operated relay with an adjustable delay in the outside circuit being controlled. A p-n-p and an n-p-n transistor (Q1 and Q2) are used as amplifier and relay driver, respectively. Light falling on the photocell (PC) generates a voltage across the 10,000-ohm potentiometer R1, which changes the base-emitter bias on Q1. The 1,000- μ f electrolytic capacitor C1 is discharged through the combined network consisting of R2, R3 and R4. A switch, SW1, is provided to remove the R2, R3, R4—C1 time constant and permit rapid relay action.

R1 can be adjusted as follows: Advance R1 until the relay closes when the photocell is subjected to the desired increase in light. Continue turning the light on and off until the relay opens and closes as a result of this action. Now close SW1 to put the time delay capacitor C1 back into the circuit. With R1 set at a minimum, a delay of 2 to 5 seconds is normal. Increasing the amount of resistance by varying R3 will increase the delay to between 2 and 10 minutes, depending on the setting of R3 and R1.

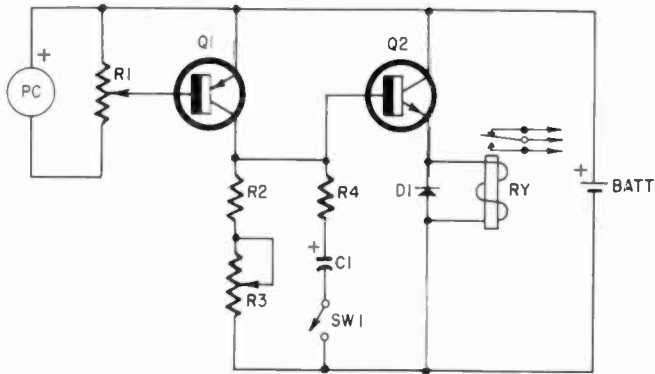
A *photoconductive* cell and a 1- $\frac{1}{2}$ volt battery can be substituted for the *photovoltaic* cell. It may be necessary to experiment with R1 again to get the proper relay action.

An auxiliary power relay should be used if more than a 1-amp load is drawn through the relay shown. A lens system and light-shielding hood are additional refinements needed if the photocell unit has to operate in a high ambient light.

Fig. 609-b shows the layout of the photocell unit. The adjustable resistors are mounted for easy access. The 1,000 μ f electrolytic is $\frac{7}{8}$ inch in diameter and 2 inches long, actually lower in height than the relay. A diode (D1) is connected in parallel with the relay coil (RY) to smooth out any sudden voltage changes due to inductive voltages generated when the relay coil is de-energized. The delayed action photoelectric relay can be used as part of an alarm system or just to turn lights on and off automatically.

Thermistor thermometer

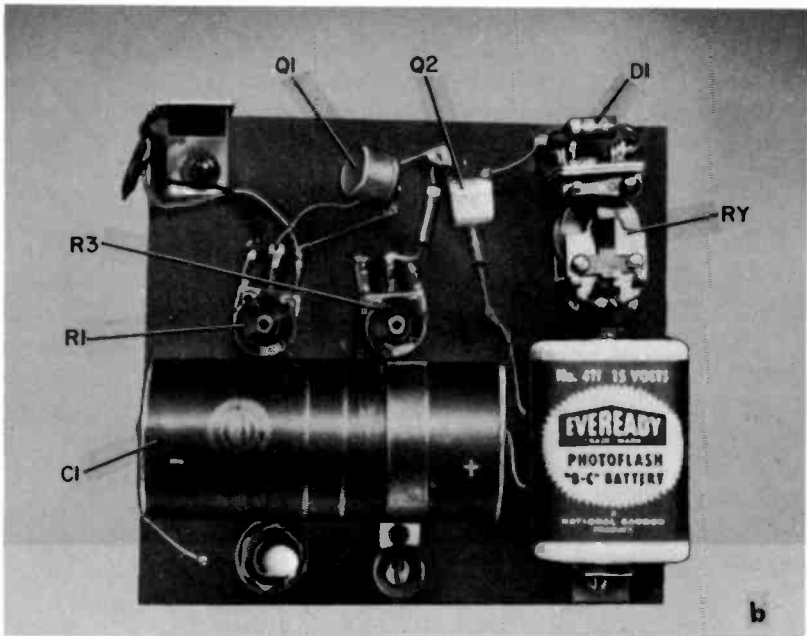
Fig. 610-a is the circuit diagram for a thermistor thermometer. A thermistor is a resistor with a very high negative temperature



a

Resistors: R2—51,000 ohms; R4—1,200 ohms (both ½ watt); R1—10,000-ohm potentiometer (Lafayette VC-59); R3—500,000 ohm potentiometer (Lafayette VC-61)
 Capacitor: C1—1,000 μ f, 15-volt electrolytic (Cornell-Dubilier BR)
 Transistors: Q1—2N1265; Q2—2N229

Diode: D1—1N295
 Relay: Ry—1,000-ohm coil (Sigma 11F-1000G)
 Battery: Batt—15 volts (Eveready 411)
 Photocell: PC—International Rectifier B-2M
 Misc: Phenolic chassis; terminals; spst switch; mounting hardware



b

Fig. 609. Photoelectric relay actuation is delayed by the charge-discharge of C1. With SW1 open relay responds normally.

coefficient. Its resistance varies inversely with temperature. At low temperatures, the resistance of a thermistor is highest, and at high temperatures the resistance decreases. In Fig. 610-a, one resistor of a regular four-resistor Wheatstone bridge has been replaced with a thermistor (TH). When the voltage drop across R1 plus R2 equals the voltage drop across R3 plus R4, there is no *difference* in potential between points A and B, and the bridge is said to be balanced. A galvanometer, or sensitive microammeter (M), connected between A and B will not deflect since no current flows through it.

If any one of the four resistors is changed in value—in this case, the thermistor—the bridge becomes unbalanced and the meter deflects since current now flows from A to B, or from B to A, depending on the voltage relationship between these two points.

A glass probe-type thermistor has been used in the layout of Fig. 610-b and is wired into the bridge with 12-inch insulated flexible leads. These can be made of stranded hookup wire or phonograph pickup cable. The rest of the circuit consists of three subminiature controls, R1, R3 and R5.

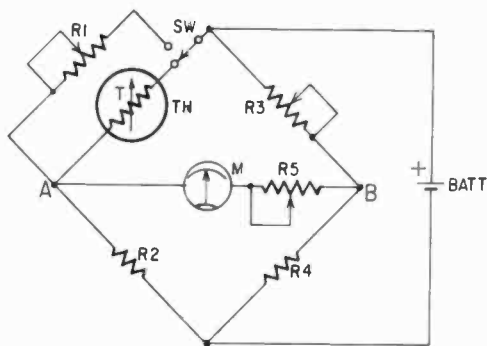
R3 permits adjusting that leg of the bridge to match the resistance of the thermistor at a selected reference temperature, say 72°F. R5 limits the series current through the galvanometer and acts as a “zeroing” potentiometer. R1 allows recalibration of the circuit as the battery voltage decreases with use.

The face of the meter can be changed so as to read directly in degrees Fahrenheit.

Transistor “vtvm’s”

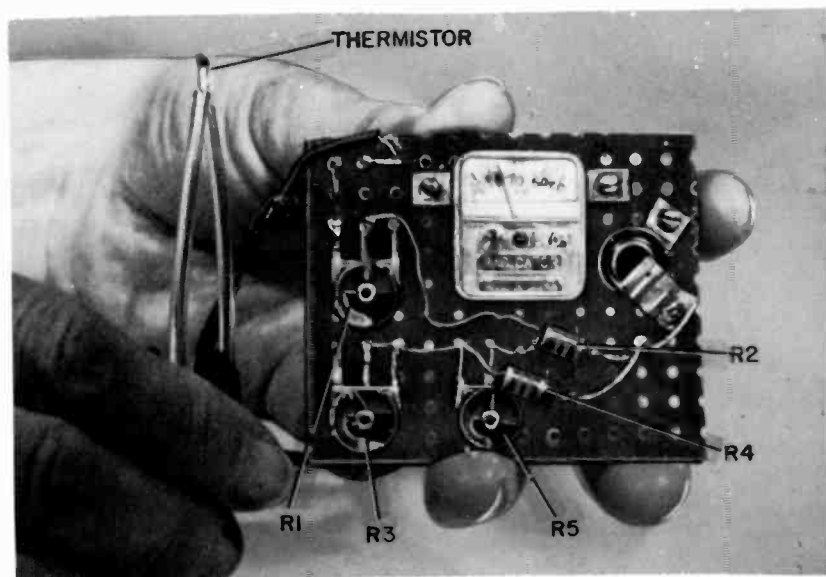
A subminiaturized transistor “vtvm” can be built around a 1-inch 0-100 (full scale) dc microammeter as shown in Fig. 611-a. The space occupied by the 7 resistors (including the 2 potentiometers) a capacitor, and transistor is about equal to that of the meter alone. Technically, we should not apply the term vacuum-tube voltmeter (vtvm) to these test instruments, since they use transistors. However, they perform the same function as a vtvm. They could be called high-impedance test units, but the abbreviation vtvm, however incorrect, seems (through accepted usage) to convey much more information.

Using an n-p-n transistor Q1 (see Fig. 611-b), this unit has an input current sensitivity of 10 μ a dc for full-scale deflection of the one-inch meter. The scale arc is about 1¼ inches. The key components are the 1% precision resistors, which can be either



a

Resistors: R1, R3, R5—5,000-ohm potentiometers (Lafayette VC-58); R2, R4—2,700 ohms, $\frac{1}{2}$ watt
 Meter: zero center reading $300 \mu\text{a}$
 Thermistor: TH—(Victory Engineering type 32A1)
 Battery: Batt 1.7 volts (2 Mallory RM 400 cells in series)
 Misc: Phenolic chassis; terminals; spdt switch; mounting hardware



b

Fig. 610. A thermistor plus a simple bridge circuit is a useful remote-reading thermometer.

wirewound or carbon film types. The 10-megohm resistor (R1) is made up of two 5-megohm units in series. The practical limit for such high-megohm resistors is about 25 megohms but, because of space, the resistor string was limited to 100,000 ohms, 1 megohm and 10 megohms. Either a miniature rotary selector switch (SW1) or a shorting bar type switch can be used. The calibration and controls for zero setting (R6 and R7) are subminiature potentiometers, physically arranged for easy access. The voltmeter sensitivity is 100,000 ohms-per-volt.

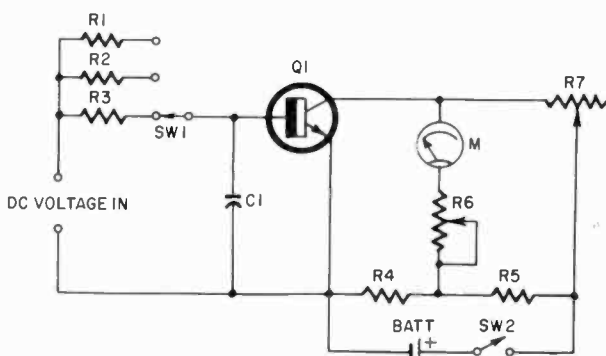
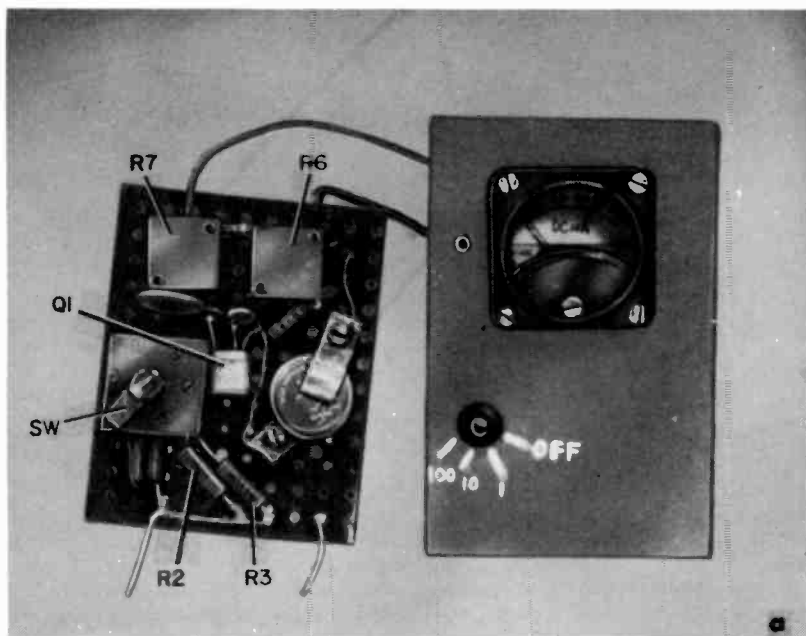
The instrument can be calibrated as follows: The switch (SW2) is turned on and, with the dc voltage input open, the zero control (R7) is adjusted for zero on the meter. With 10 volts dc applied to the input (this 10 volts can be taken from a battery box, using a potentiometer and a calibrated meter) the calibration potentiometer (R6) is adjusted for full-scale deflection of the 0-100 μ a meter. After the calibration pot is adjusted, the 10-volt source is removed, and the zero potentiometer readjusted until the meter pointer is at zero. The 10-volt dc potential is applied and removed several times while the calibration and zero potentiometers are adjusted to each other. When the application of the 10 volts drives the 1-inch meter full scale, and the removal of this voltage lets the meter needle drop back to zero, the transistor vtm is ready to go.

The 10-megohm resistor limits the voltage reading to 100 volts, more than enough for most transistor circuits.

In another circuit using two p-n-p transistors and a one-half-inch 0-1 milliammeter (meter reads 1 ma, full-scale deflection), the vtm of Fig. 612-a goes to 50 volts dc. One transistor (Q2) is used in a stage of direct-coupled amplification with a higher current gain p-n-p in the output bridge circuit. The negative input lead is a short length of shielded wire. The range switch (SW1) operates contacts in both the base circuit of the input transistor (Q1) and the emitter circuit of the output transistor.

The vtm is set at zero by turning the range switch to 1 volt, and feeding in a 1 volt dc signal. The calibration and zero-set controls (R6 and R4, respectively) are adjusted for full scale and zero with signal and no-signal. Because the potentiometers are carbon types, it may be necessary to readjust them for each position of the range switch. Wirewounds can be substituted for more stability, using a little more space but having a higher building cost.

The photo in Fig. 612-b shows the placement of parts. Note

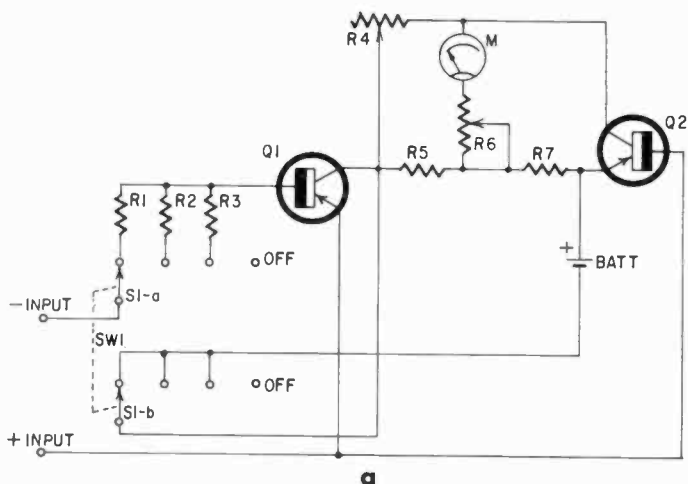


Resistors: R1—10 megohms (2–5 megohm in series); R2—1 megohm; R3—100,000 ohms; (all IRC MDA, $\frac{1}{8}$ watt wirewound); R4, R5—1,800 ohms, $\frac{1}{2}$ watt; R6—1,000-ohm potentiometer; R7—10,000-ohm potentiometer
Capacitor: C1—.002- μ f ceramic
Transistor: Q1—2N35 or equivalent

b

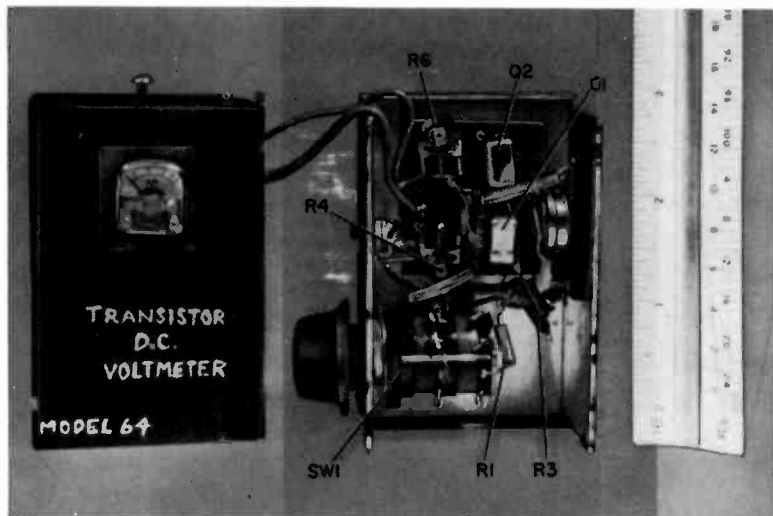
Switch: SW1—Single pole, 3 position; SW2—spst
Meter: M—0 to 100 μ a dc (Alca 1 inch)
Battery: Batt—1.35 volts (Mallory RM-625)
Misc: Phenolic chassis; terminals; mounting hardware

Fig. 611. This bridge circuit uses a transistor as the active element. Changes in base current cause an unbalance in the bridge circuit and meter indicates change. Bridge circuit is used to balance out emitter-base leakage current.



Resistors: R1—100,000 ohms; R2—1 megohm; (both IRC MDA $\frac{1}{8}$ -watt wirewound); R3—10 megohms, 1 watt (2–5 megohm in series) (Cont. Carbon NR25); R4—10,000-ohm potentiometer; R5, R7—470 ohms $\frac{1}{2}$ watt; R6—5 000-ohm potentiometer
Transistors: Q1—CK722, 2N265, 2N369, etc;

Q2—CK721, 2N197, 2N280, etc.
Switch: SW1—2-pole, 4 position (Grayhill or Daven type G)
Meter: M—0 to 1 ma (Alco $\frac{1}{2}$ inch)
Battery: Batt—1.35 volts (Mallory RM625 cell)
Misc: Phenolic chassis; terminals; shielded wire; mounting hardware



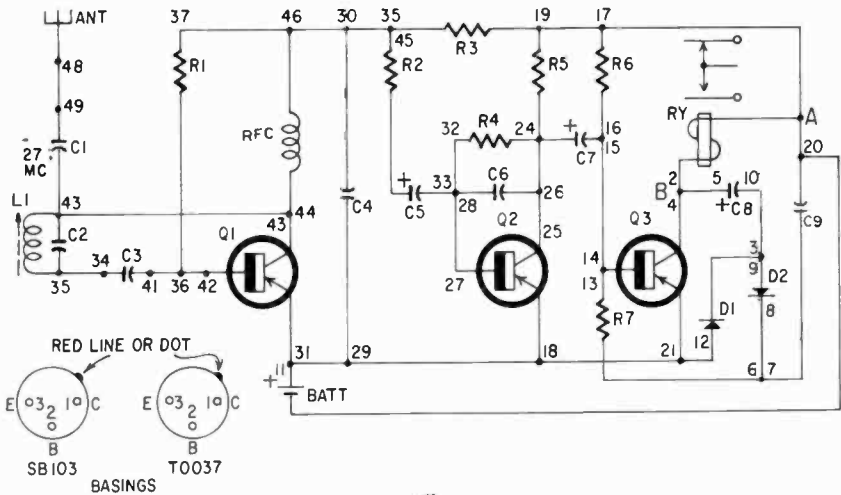
b

Fig. 612. The bridge circuit used here takes advantage of the push-pull action of the two transistors to increase meter deflection.

that the meter is connected to the circuit by a pair of flexible leads, long enough so that the cover can be removed easily.

Subminiaturized 3-transistor radio-control receiver

The radio-control receiver circuit shown in Fig. 613-a is unique in several respects. First, it uses a surface-barrier transistor (Q1) in the rf "front end" and, second, the circuit will produce a change of over 12 to 15 ma in the relay circuit when it receives



a

Resistors: R1—100,000 ohms; R2—30,000 ohms; R3—6,800 ohms; R4—1 megohm; R5, R7—10,000 ohms; R6—47,000 ohms (all ½ watt)

Capacitors: C1—5 μf; C2—47 μf; C3—470 μf; C4—.01 μf; C6—.001 μf (all disc ceramic) C5, C7, C8, C9—.25 μf, 15-volt electrolytics (Barca PT-50-25)

Transistors: Q1—SB103; Q2, Q3—T0037 or equivalent

Coil: L1—8 turns No. 26 enameled on CTC type LSM form

Choke: RFC—22 μh (Jeffers Electric)

Diodes: D1, D2—1N295

Relay: RY—350-ohm coil (Jaidinger Co. GEM)

Battery: Batt—6 volts

Misc: Printed-circuit board; terminals; mounting hardware; {2,000-ohm phones and 0-1 ma meter for tests}

Fig. 613-a. The many numbers and small black dots refer to locations on the printed-circuit furnished with the kit.

an unmodulated carrier. The dimensions of the complete receiver, less battery, are 2- x 3- x 1-inch and total weight is just one ounce!

The printed-circuit board is shown in Fig. 613-b and a pictorial of the wiring in Fig. 613-c. Coil L1 and the relay (RY) are mounted first, and then the 47-μf disc capacitor (C2). The 5-μf (C1) and 470-μf (C3) disc capacitors are put in place next. The



Fig. 613-b. This printed-circuit board is shown somewhat less than actual size. Compare it to the parts layout in Fig. 613-c.

100,000-ohm resistor (R1), the rf choke (RFC), and the 6,800-ohm resistor (R3) are added. Fig. 613-d shows the board at one stage of its assembly. R2, R4 and C4 are then added. The four .25- μ f electrolytics (C5, C7, C8 and C9) are then mounted. Check and double check the polarities on the electrolytics to avoid trouble later on. Resistors R5, R6, R7 and disc ceramic C6 are added next.

The diodes (D1 and D2) are then installed. Two precautions should be observed here. First, be sure diode polarities are correct. Second, use a heat sink, such as a needle-nose pliers or clip (Fig. 613-e), to prevent heat damage to the diodes.

Transistors come next in the assembly, with the surface-barrier unit soldered in first. A pencil-tip soldering iron with a micro-needle tip and alcohol-soaked cotton swabs as heat sinks permit soldering $\frac{3}{8}$ -inch transistor leads to the printed-circuit board with little possibility of damage (Fig. 613-f). The second and third stage transistors are soldered in next. If the receiver is to be used for stationary work only, such as garage-door control, the three transistors can be mounted in sockets and held down with clips.

A view of the completed receiver is shown in Fig. 613-g.

Testing the receiver

The receiver can be tested with either headphones or meter. A 6- to 10-volt full scale meter (or a 0-1 ma meter with a 10,000 ohm series resistor) can be used. A 2,000 ohm set of magnetic phones will be all right for a listening test. The phones or meter are connected between points A and B in Fig. 613-a. If phones are

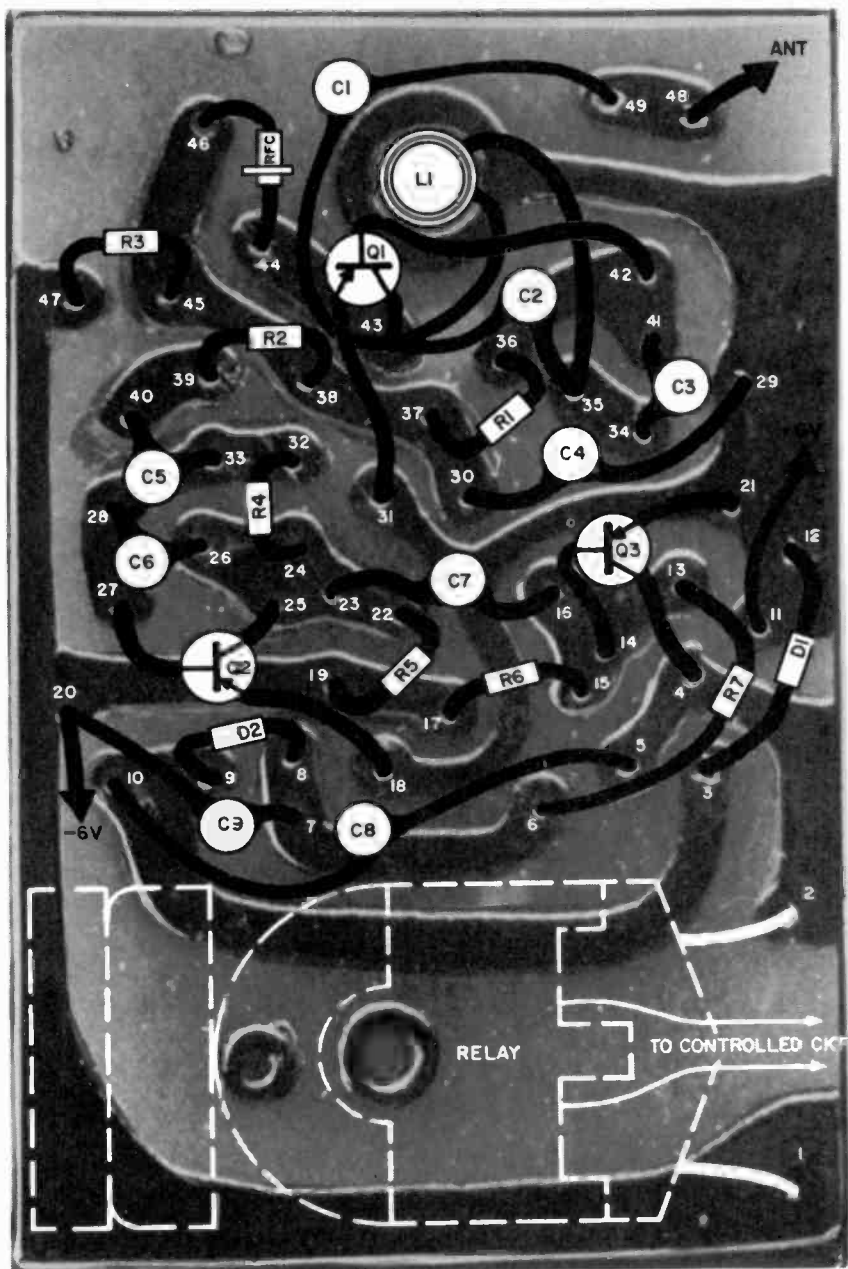


Fig. 613-c. Parts layout for the printed circuit board is approximately 4-times the size of the original 2 by 3-inch copper-clad phenolic board.

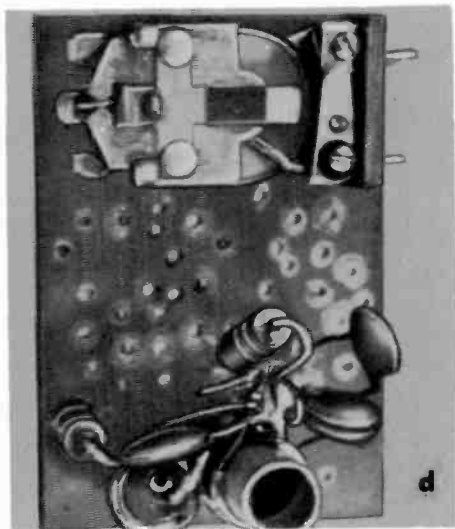


Fig. 613-d. R/C receiver chassis with the major components mounted.

Fig. 613-e. Heat sink is used to prevent heat damage to the component. Heat is absorbed by the mass of the pliers.

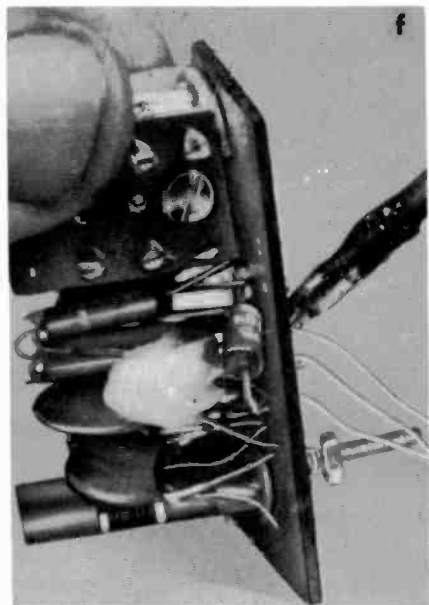
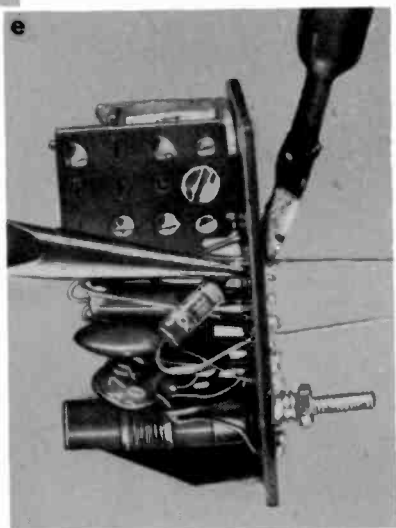


Fig. 613-f. Extremely short leads can be protected by alcohol-saturated cotton packed around the end of the component being soldered.

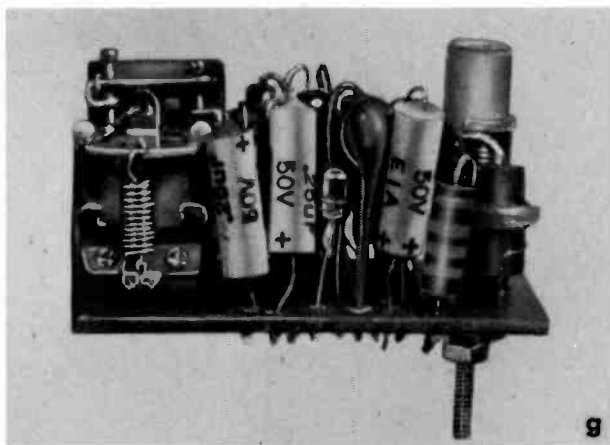


Fig. 613-g. The completed receiver is shown here slightly smaller than actual size.

used, the familiar "hiss" due to regeneration will be heard. With the transmitter *on*, the receiver coil (L1), is tuned to the right frequency by listening for the continuous carrier. As the slug passes through the tuning point, the "hiss" should disappear. When the transmitter is modulated with a 100- to 900-cycle audio tone, the tone should be heard on the receiver phones.

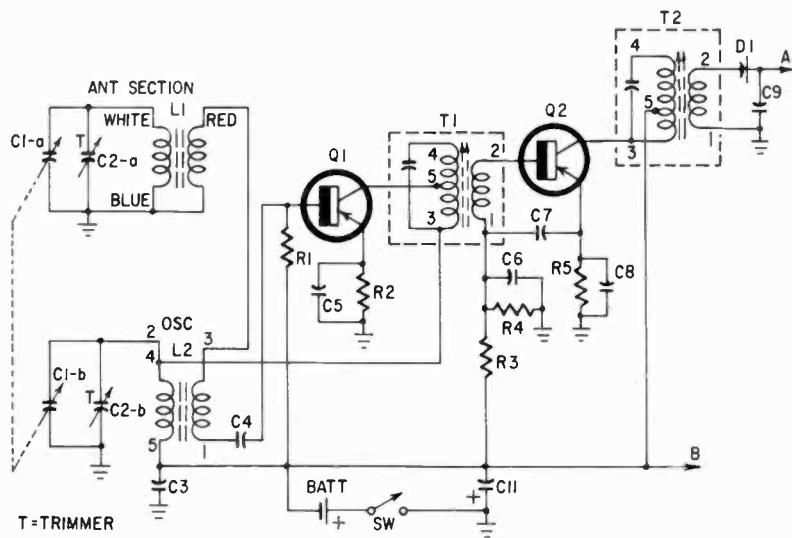
When a meter check is made, the voltage across RY (points A and B) should be measured. With a steady carrier *on*, the receiver coil is tuned to the transmitter frequency. The meter reading observed with the carrier off should now rise to 6 volts or slightly more. If the audio tone is now impressed on the transmitter carrier, the relay-coil voltage should drop off to 2 volts or less.

Pocket superhet

Fig. 614-a is the schematic for a three-transistor and diode superhet which fits in a case $2\frac{3}{8}$ x 4 x $\frac{15}{16}$ -inches. The receiver consists of a combined oscillator-converter stage, two i.f. transformers in a single i.f. stage, a diode detector and resistor-capacitor coupled single ended audio output.

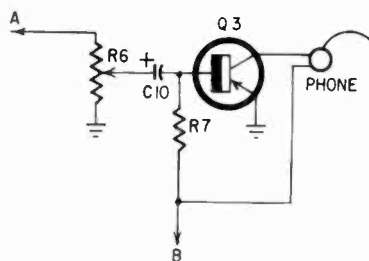
The pictorial diagram in Fig. 614-b should be referred to, along with the schematic, as construction proceeds.

The first step is to insert the transistor sockets in the chassis. The collector contacts should be facing the end of the chassis having the variable capacitor. The sockets are held on with a



T=TRIMMER

a



Resistors: R1—100,000 ohms; R2—1,100 ohms; R3—470,000 ohms; R4—22,000 ohms; R5—330 ohms; R7—220,000 ohms (all $\frac{1}{2}$ watt) R6—25,000-ohm potentiometer

Capacitors: C1, C2—2-gang variable (Lafayette MS-270); C3, C4, C5, C6, C7, C9—.01 μ f disc ceramic; C8—.002 μ f disc ceramic; C10, C11—2 μ f, 10-volt electrolytic

Transistors: Q1—2N136; Q2—2N135; Q3—2N107 (or equivalent)

Diode: D1—1N34 or 1N60

Transformers: T1—Pri 25,000 ohms, sec 600 ohms, 455 kc i.f. (Lafayette MS-268A); T2—pri 25,000 ohms, sec 1,000 ohms, 455 kc i.f. (Lafayette MS-269A); L1—ferrite antenna (Lafayette MS-307); L2—oscillator (Lafayette MS-265)

Phone: 2,000- to 10,000-ohm dynamic type

Battery: Batt—9 volts (VS309A)
Misc: Phenolic chassis; case; dial; spst switch; mounting hardware; (L1, L2, C1, C2, T1, T2, available as matched set, Lafayette MS828)

Fig. 614-a. This is the circuit diagram of the three-transistor superhet. Q1 is the converter transistor, Q2 the first i.f. amplifier and Q3 the single-ended audio. The signal is rectified by diode D1, with the audio voltage appearing across potentiometer R6. Q3 can also be used as a driver for the push-pull circuit of Fig. 605. To do this, remove the earphones and substitute the primary of T1 in Fig. 605. The disadvantage of this arrangement will be the use of separate batteries for the two projects.

Although the switch [SW] is shown in this and other projects as a separate unit, it is convenient to have it as part of volume control R6.

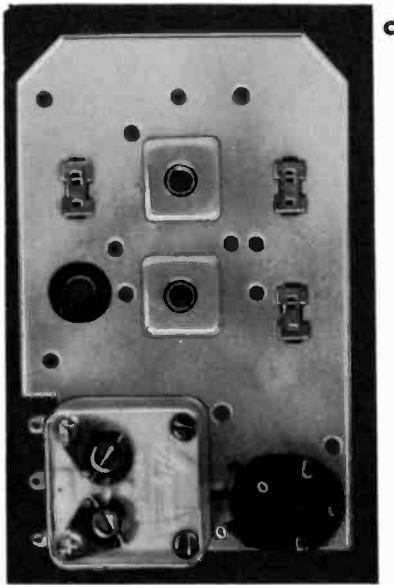


Fig. 614-c. Miniature chassis with most of the major components mounted is close to actual size.

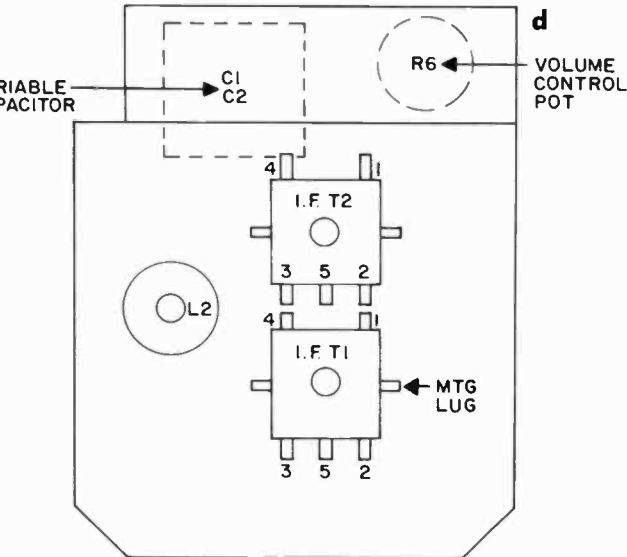


Fig. 614-d. Reverse side of chassis showing the location of the major components. This is not drawn to scale.

retainer or with cement. The subminiature variable capacitor (C1-C2) is mounted next with machine screws. The lugs on the variable should point to the right as you look at the top of the chassis. The potentiometer (R6) is mounted next with its lugs pointed in the same direction as the lugs on the variable capacitor.

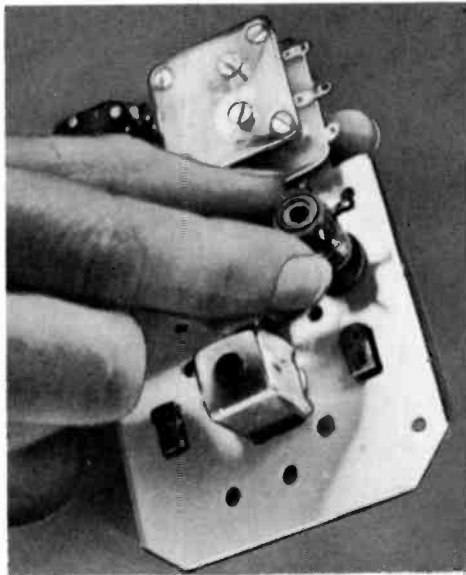


Fig. 614-e. Copper-clad phenolic can be used instead of a metal chassis for shielding.

The i.f. transformers are then mounted in the positions shown in Fig. 614-c, bending the case lugs over on the chassis to fasten them. Check the orientation of the terminals on the i.f. transformers with Fig. 614-d.

The oscillator coil is mounted next in a grommet (Fig. 614-e). The circular edge of the hole in the chassis fits into the groove of the grommet, and the coil is positioned so that the colored dot is in the upper right corner and the coil form moved until its bottom is about $\frac{1}{8}$ inch off the underside of the grommet. The battery holder is mounted next, using 2-56 machine screws and hex nuts.

Wiring from oscillator coil to variable capacitor should be partially completed next.

The components on the bottom of the board are next in order, mounting the 6-lug terminal strip first and proceeding with the resistors and capacitors (Fig. 614-f). Earphones and ferrite slab antenna are added after the resistors and capacitors are wired in. Earphones are added next and the chassis is mounted in the case with 4-40 machine screws. The tuning dial and volume control knob complete the set.

The transistors are plugged into their sockets, taking care not

to reverse the leads. Follow the collector, base, and emitter connections closely on the schematic and pictorial. The battery is placed in the holder and snap-fastened (Fig. 614-g). Carefully check the wiring and polarity of the battery connections to avoid possible damage to the transistors.

Superhet alignment without a signal generator

While it is best to have an rf signal generator for optimum alignment of any superhet receiver, a satisfactory alignment job can be done by following these steps:

1. Adjust the oscillator coil slug with an alignment tool until it is flush with the bottom of the coil form. Then turn the slug

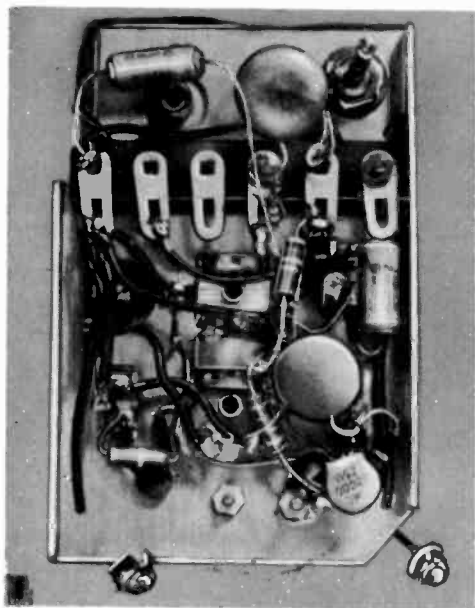


Fig. 614-f. Terminal strip is needed to provide insulated tie points. Perforated phenolic (or holes drilled) can accept push-in terminals. Be careful of shorts when copper-clad board is used. Copper must be removed near terminals that are not ground connections.

inward about $4\frac{1}{2}$ turns. Next, adjust the oscillator trimmer (bottom section of the variable capacitor) until the movable plate is about halfway across the stationary plate. Adjust the antenna trimmer (top section of the variable capacitor) until the movable plate covers three-fourths of the fixed plate.

2. Turn the receiver on, and turn the volume control about

halfway around clockwise. Turn the tuning dial completely counterclockwise to 1,600 kc and then slowly back until you hear a station. Check the station identification for frequency and adjust the oscillator trimmer for calibration and the antenna trimmer for greatest volume.

3. Now turn the dial to the low-frequency end and this time adjust the oscillator slug only if the station frequency does not

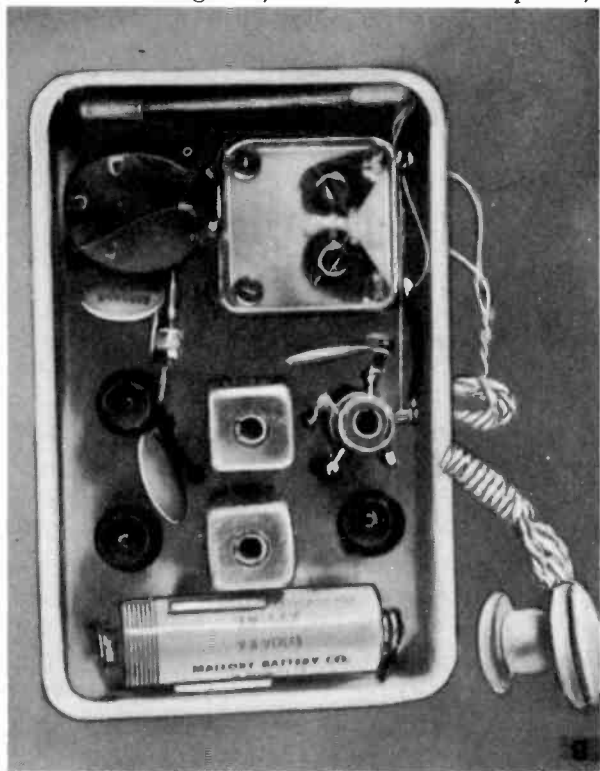


Fig. 614-g. Rear view of completed three-transistor and diode superhet.

agree with the dial frequency. If the dial settings and station frequencies check on both high and low ends, adjust the antenna trimmer for maximum loudness on a station at the high frequency end of the dial, and adjust the oscillator coil slug for maximum volume on a low frequency station.

4. Tune in the weakest station you can get at the high frequency end of the dial and adjust the antenna trimmer for loudest signal. Next, adjust both i.f. slugs for maximum volume. Alignment is completed.

Aligning with an rf signal generator

The steps to follow in using a generator are:

1. Connect a 50–100 $\mu\mu\text{f}$ (pf) mica capacitor in series with the “hot” lead of the generator and the base connection of Q1. Connect the signal generator “ground” to the chassis of the receiver.

2. Set the generator to 455 kc, turning the signal generator attenuator all the way *down* (lowest output) to start with. Bring the attenuator up slowly until a signal can just be heard in the receiver phone.

3. Turn the receiver’s tuning dial to 1,600 kc. This is where the variable capacitor’s plates are open or unmeshed.

4. Rotate the volume-control for maximum volume, and adjust i.f. T2 for maximum audio on the phone, with the signal generator output still *as low as possible*. Then adjust i.f. T1 for maximum volume.

5. Remove the series capacitor from the generator and chassis, and wrap about 5 turns of hookup wire around the ferrite antenna coil core. These should be loosely coupled and should not touch the coil. A few wraps of paper over the coil will help. One end of this hookup wire is then connected to the “hot” side of the generator output; the other end to the generator “ground” terminal.

6. Set the generator to 1,600 kc and adjust the variable capacitor plates until they are only $\frac{1}{16}$ inch in mesh. Next, adjust the oscillator trimmer capacitor until a signal can be heard on the phone. The antenna trimmer capacitor is then adjusted for maximum signal volume.

7. Rotate the tuning dial until the plates the fully meshed and set the generator for 550 kc. Now adjust the oscillator-coil core (slug) for maximum output on the phone. Repeat steps 6 and 7 one or two times for maximum signal. Alignment is finished.

Troubleshooting the set

The first thing to do is to double check all wiring. In a set of this size, it is very easy to misplace one or two connections if you are not very careful. Be sure to check the connections to all transistors to see that emitter, base, and collector leads have not been reversed. Putting the i.f. transformers on in the wrong position can cause all sorts of trouble.

One possible “bug” might creep in at the secondary of the first i.f. transformer. If transistor Q1 is too “hot” or sensitive, the set will oscillate. This can be remedied in most cases by reducing

the value of resistor R4 from 22,000 ohms to about 10,000 ohms. The best value of R4 must be determined by experiment.

A handy way to find the source of trouble is the "Signal Squirter" described in Chapter 5.

Try making it smaller

All of the foregoing advanced projects are just a sampling of what can be done with subminiature components. With the exception of high-powered amplifiers in the multiwatt range, many conventional circuits can be constructed in miniature.

The reduction of size is a challenge to any amateur or experimenter. Like anything else, it requires experience. After building some of these projects, the constructor should have acquired that experience.

Regard the layouts and the components used in the projects which have been described as a beginning, not an end point. Examine parts catalogs carefully. Take a good look around the next time you go into the store of a radio parts distributor. Talk to him. There is just so much display room and your distributor may not have the tiniest units where his customers can see them.

With new subminiature components appearing almost daily, there is no such thing as a project which just can't be made any smaller. Take time out to arrange the components for greatest compactness, keeping in mind the possibility of interaction between circuits and parts.

Chapter 7

Construction and Repair Hints

That there are two sides to every question has a familiar ring to many. To the electronic technician, it usually means that for every new idea, component or novel approach to a service or construction problem, there is some bitter pill to swallow sooner or later. No device has 100% advantages and no disadvantages. The ratio is usually 50–50—with luck, anyhow.

The novelty in miniature and subminiature electronic devices and kindred equipment is the small size and closeness of parts. It means that technicians and experimenters must get the most from their tools and extend their methods. This chapter is intended to help the reader find his way through the world of shrinking electronics, and acquire a “feel” for working with smaller components and devices.

Hand tools

Fig. 701 shows an assortment of hand tools required at one time or another in work with small electronic assemblies. These include

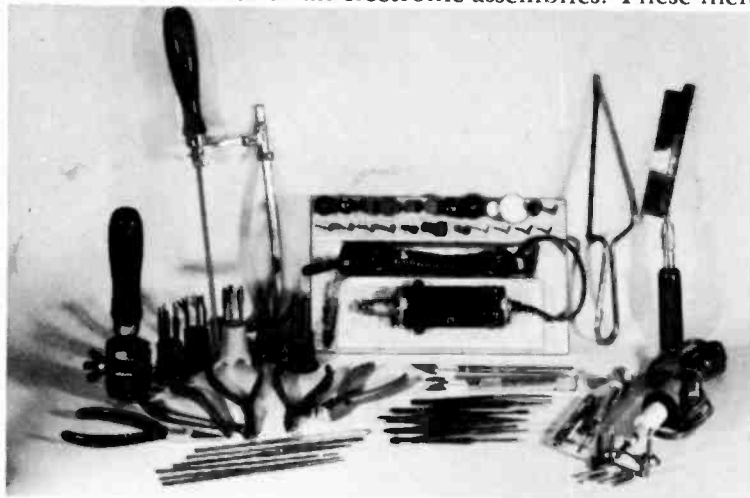
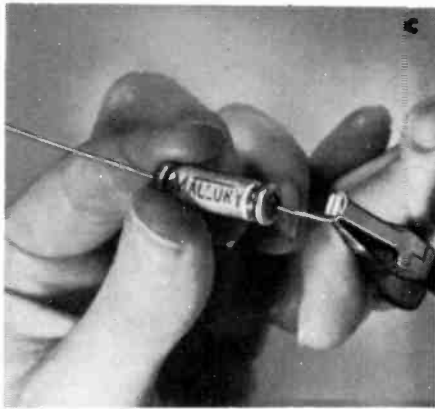
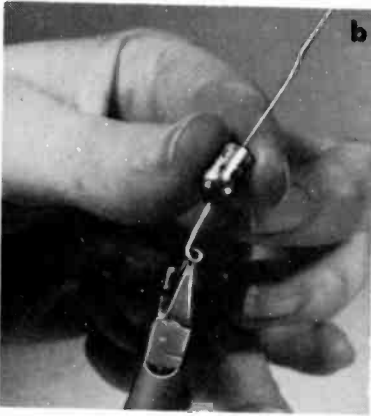
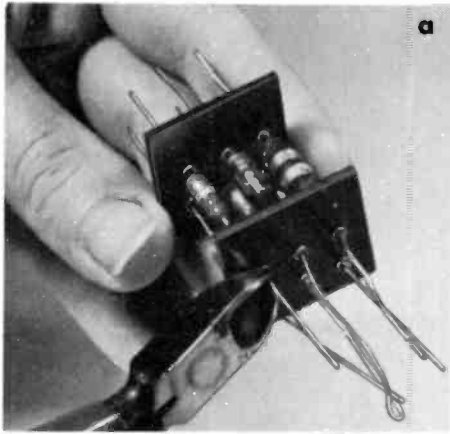


Fig. 701. Using specialized tools for the proper job always makes work easier.

Fig. 702. The main purpose of pliers is cutting, holding and forming. Special shaped jaws make lead forming easier.



a variety of pliers, soldering irons, tweezers, optical accessories, probing and picking tools, files and a variety of clamping devices.

Pliers

A set of 4½-inch pliers are very useful for work on miniature electronic and electromechanical assemblies. Each plier weighs about 4 ounces and is proportioned for easy access to smaller components.

Fig. 702-a demonstrates the use of the diagonal cutting pliers in close-quarter work where one wire in a group has to be cut.

A "round-nose" plier (Fig. 702-b) is used where a "rounder" radius loop is desired than the chain-nose produces. Fig. 702-c is a

“flat-nose” and forms still a different wire pattern. The “nose” types of pliers are used for forming and rearranging wires and small metal shapes and have no cutting edges.

Soldering irons

Several soldering irons for miniature work are shown in Fig. 703. The main point to remember in soldering small work is never to use an iron that can get hotter than necessary. A consequence of this is that the part will be overheated and ruined.

Two voltage systems are available in midget soldering irons—the 115-volt and the low-voltage types that use a transformer. The



Fig. 703. *Small soldering iron tips are needed to reduce the possibility of forming short-circuiting solder bridges between printed circuit conductors and contacts.*

soldering iron shown at the top in Fig. 703 is a 115-volt iron rated at 25 watts and capable of temperatures to 700°F. For very fine work in crowded spaces, there is a 6-volt iron that is very handy. This has a tip diameter of only $\frac{1}{16}$ -inch and is especially good for soldering coils using a No. 40 wire, and finer.

A soldering iron should also be chosen for comfort. Several manufacturers offer special grips which are either knurled or composed of soft material such as cork. The irons at the center and bottom of Fig. 703 use cork grips.

You should also have a soldering-iron holder which guards the iron and prevents accidental burns. Use one that can be adjusted for ease in reaching.

The iron shown at the bottom of Fig. 703 uses several interchangeable tips designed for special soldering and desoldering tasks. These are explained in detail under printed-circuit repairs later in this chapter. Some of these are available in plated versions for longer life. A special *anti-seize* compound is used to prevent corrosion and “lockup” on the threaded end of the iron tip.

Tweezers

A variety of tweezers can be purchased from any hardware, radio or hobby supply house. You can get quite a selection, including plain pointed, self-locking cross-action, blunt-point self-locking and slide lock types.

Fig. 704 is a blunt-point self-locking type. The self-locking

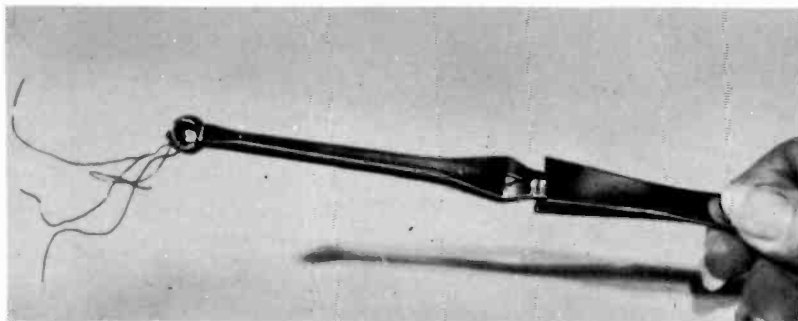


Fig. 704. Tweezers can, with practice, be a very useful extension of your fingers.

types depend on the insertion of the object being held. The slide-lock type locks with a slot and rivet in the handle of the tweezers.

Optical accessories

Working with small components can be eye-straining to many experimenters. To begin with, the light over the work area should be as glare-free as possible, and “evened up” to eliminate shadows and dark spots. Don’t work “into” the light. Get the light over your shoulder, preferably concentrated on the unit you are working on. You’ll need a light you can adjust so you can “chase” shadows. And if you normally wear glasses, put them on. A hobby is no fun if you end up with eyestrain and a headache.

The familiar jeweler’s eye loupe can be used to examine printed-circuit assemblies. If you’ve never used a loupe before, you may find that it takes a little time getting used to it.

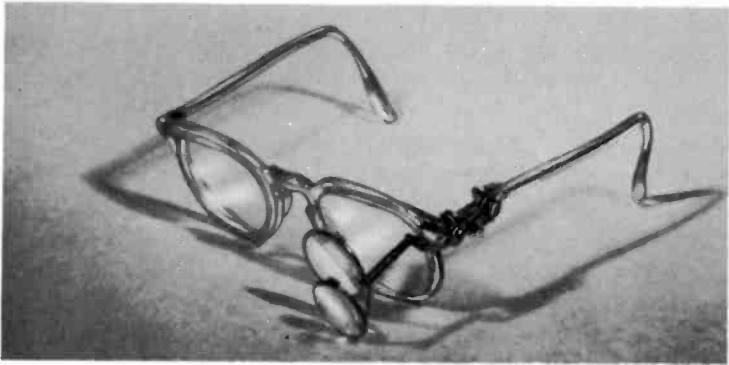


Fig. 705. To be able to work with, repair or replace Lilliputian components you must be able to see exactly what you are doing.

a



b

Another form of magnifier is the lens spectacle shown in Fig. 705-a. This can be attached to an ordinary pair of glasses, and flipped down when in use or back up for normal sight. You'll find this much more convenient than the loupe, but it is also more expensive.

When a combination of light and magnification is needed, the illuminated magnifier (Fig. 705-b) is handy. Costing little more than just a flashlight, it provides from two- to five-power magnification, depending on the model, and it is lightweight. The purpose of the combined light and magnifier is for inspection. You'll find it difficult to work and hold the light-magnifier at the same time. A clamp-type stand, either home-made or purchased, will give you a pair of free hands to work with.

Knives and cutting tools

An assortment of hobby-craft knives, razor blades and pocket knives are useful for cutting and for scraping parts clean prior to soldering. A feature of the hobby-craft knives is the variety of handle and blade shapes. When dull, a new blade restores easy cutting.

Abrasives for smoothing and polishing

Sometimes scraping leaves a surface too rough or else does not remove the finer deposits of dirt and oxides. Sandpaper, emery cloth, crocus cloth and steel wool can be used for finer cleaning and polishing. Steel wool comes in a variety of grades, from very coarse to fine. Use fine steel wool. The coarse is much too rough



Fig. 706. Cleaning of surfaces becomes increasingly important as terminals and leads get closer together. Etching fluid residues can eat away foil conductors. Solder flux and similar substances can form leakage paths.

for this kind of work. Also watch out for steel wool impregnated with soap. Stay away from it to avoid ending up with a handful of soap suds and soap scum all over your project.

All work should be cleaned with a solvent (F.g. 706) to remove stray particles of abrasive, flux or steel wool left behind. Such particles can cause shorts or high-resistance connections, a very difficult condition to locate in servicing. This is particularly true if you use steel wool. A good trick is to go over your project with a permanent magnet to pick up any steel dust or filings. Also be sure to use your light-magnifier for inspection.

Files

An assortment of small files are a necessity in all electronics work. The occasion often arises for an odd-shaped opening in a chassis or the shaping of a mounting lug on a component to fit a certain space.

Known as Swiss needle files, they come in a large variety of sizes and shapes—oval, square, round-edge joint, three square, warding, crochet, knife, half round and barrette. Some have teeth on all faces. Others, such as the round-edge joint file have teeth only on the two smaller faces, which makes it easy to lengthen a slot in one direction only.

These files need very little pressure to cut brass, plastics and soft steel and should not be forced or bent in use.

Probing and picking tools

Fig. 707 shows some picks and probes used around electronic assemblies. One of these has a brush at one end and the pick at the other, so that material picked off the work can be brushed aside.

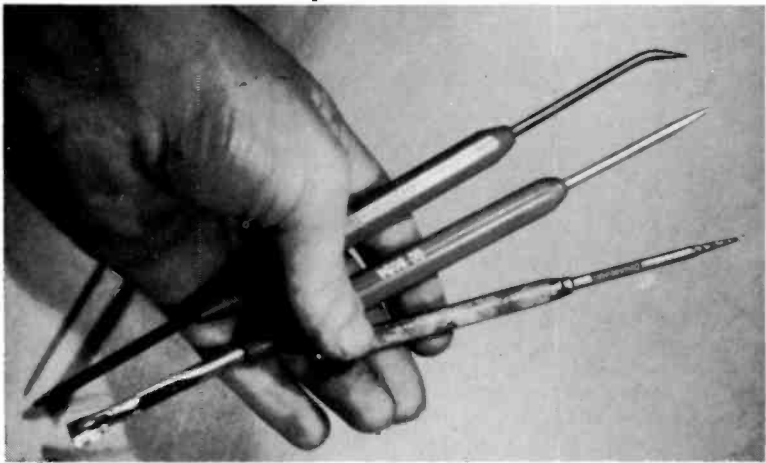


Fig. 707. This handful of tools can be a great help during soldering or de-soldering.

These are available at hobby and electronics supply houses. Dental supply houses can also furnish a wide variety of picks with assorted handles and point shapes for different jobs.

Probing and picking tools are useful for removing tiny stray bits of solder or for separating wires or components. You will need to be careful, though. It doesn't take much effort or push behind a picking tool to damage conductors on a printed-circuit board.

Saws and saw blades

There are three saws that are useful in miniature work in electronics. These are the razor saw, the miniature triangular saw with a $\frac{1}{4}$ - by 6-inch blade and the jeweler's saw. The triangular saw is used to cut small sections of plastic and metal. The razor saw can be used for fine cuts across sheet material and the jeweler's saw for very fine line and irregular shape cutting.

A variety of jeweler's saw blades are shown in Fig. 708. The most novel of these is the "spiral" type, shown at the top which is approximately .010 inch in diameter and will cut in any direction.

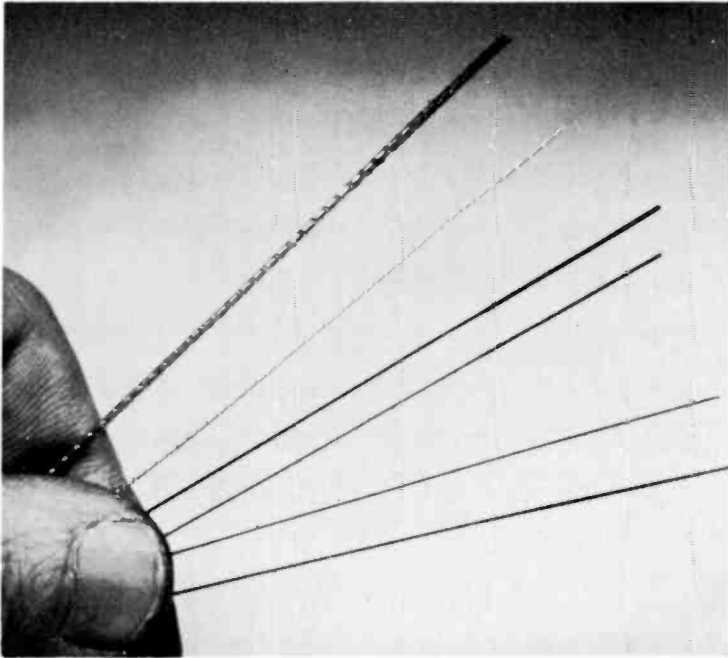


Fig. 708. These hairlike sawblades make very fine cuts. Spiral types can cut in any direction without turning saw. For longest life the blades must be kept under tension in a frame.

The basic difference between the blades shown in Fig. 708 and ordinary hacksaw blades is that those used for miniature work are much more fragile and much more easily bent or broken. After you insert the blade, sight along the cutting edge to make sure the blade has been put in straight and that there is no twist in the blade, from start to finish. In use, the motion of the saw should be forward and back. Any side motion may very well snap the blade.

Clamps and clamping devices

Sometimes it is helpful or even necessary to have a "third hand" when working on small electronic assemblies. Spring clothespins are economical gadgets to use, and Fig. 709 shows two of the ways in which a very ordinary household clothespin doubles as a clamp for electronic work. Use clothespins made of wood or plastic. However, be sure to get the kind that have curved or serrated inner surfaces since these give the best gripping action.

A jeweler's vise (Fig. 710) is also handy for small electronic assemblies. Felt should be glued to the jaws of the vise to prevent

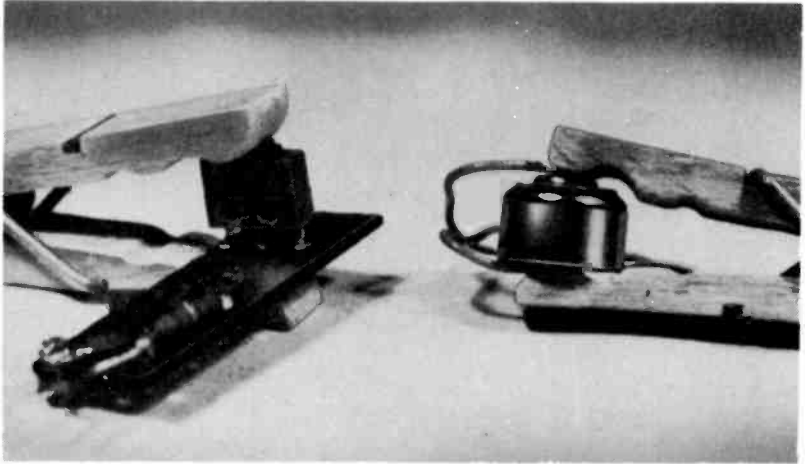


Fig. 709. Even non-electronic items can have a useful application. For electrical contacts (unpainted) thumb tacks can be pressed into the inside of the jaws of spring-loaded clothespins.

damage to delicate parts. Before using the vise, make sure that the moving parts are lightly lubricated and that the vise opens and closes easily and smoothly. A vise that grips or binds may force you to use too much pressure, with the ever-present danger of damaging your project.

Adjustable C-clamps (Fig. 711) are useful and quickly change for different size assemblies or parts. The advantage of a C-clamp is that it enables you to set up the work in almost any position.

Sometimes one part has to be held firmly in one hand, and the hand vise of Fig. 712 is one answer to this problem. If the part is small, a chuck or pin vise (Fig. 713) is often used to get a good grip on the work.

Many times an assembly has to be worked on from more than one side or from an otherwise awkward position. A device to make

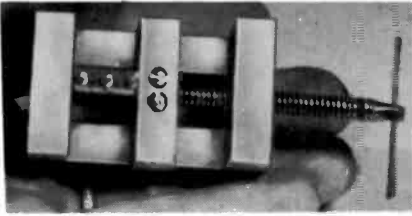


Fig. 710. Small vise can be assembled from five pieces of bar stock and machine screws if a suitable size cannot be purchased.

Fig. 711. Inexpensive clamp can be obtained in hardware and variety stores as well as mail-order houses. Grooves filed or cut into the jaw faces will make it easier to hold the circuit board.

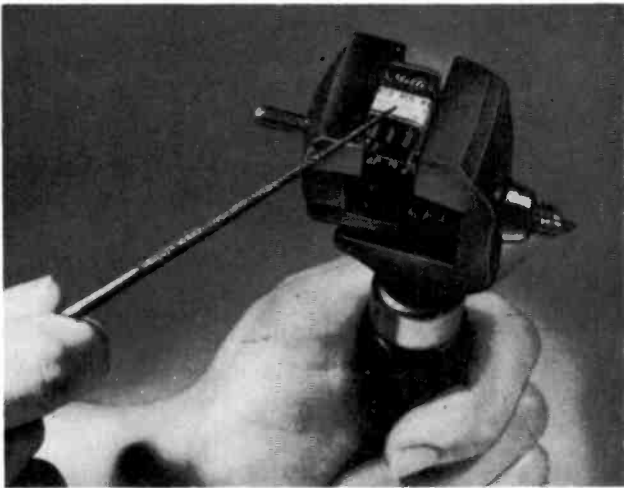
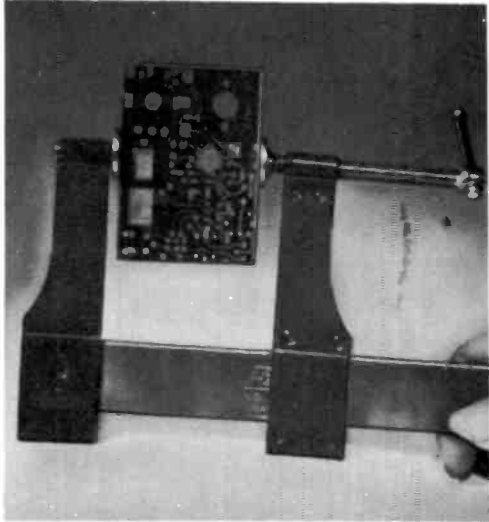


Fig. 712. Notches filed or cut; holes drilled into or through the jaw faces will make it possible to hold irregularly-shaped objects.

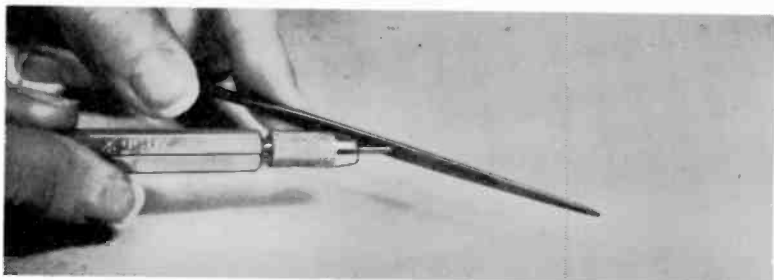


Fig. 713. Pin vise can be used to hold small diameter drills in a large chuck, as a more comfortable handle for small files or hold a spiral saw blade for a difficult cutting job.

positioning easier is the home-made chassis rack shown in Fig. 714. This can be constructed from pieces of $\frac{1}{4}$ -inch and $\frac{1}{2}$ -inch thick wood and assembled with wood or machine screws. Its versatility is limited only by the needs of the builder.

A unique tool for clamping and "third-hand" purposes is the lock-grip pliers shown in Fig. 715. This resembles a miniature

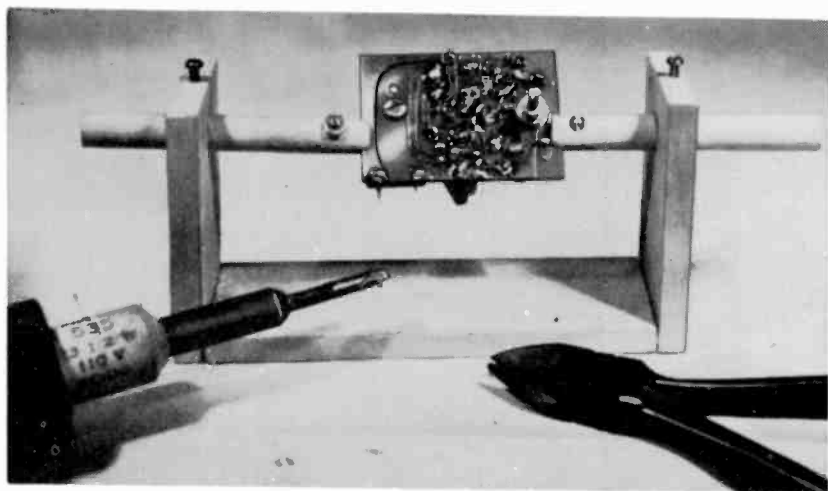


Fig. 714. Home-made chassis rack. Screws in the side pieces keep the dowel from turning.

gun and, when the trigger handle is pulled and the locking key moved, parts can be clamped between the pliers' jaws. The pliers are useful also as a heat sink for semiconductor leads and for crimping miniature solder lugs.

The right holding device is just as important as any one of your other tools for working on miniature projects, and should be considered as such. Whether the clamp you are using at the moment is to be fastened to the bench so that your hands are free, or whether the clamp (such as the one shown in Fig. 712) is to be held, depends on just what it is you are trying to do. Sometimes

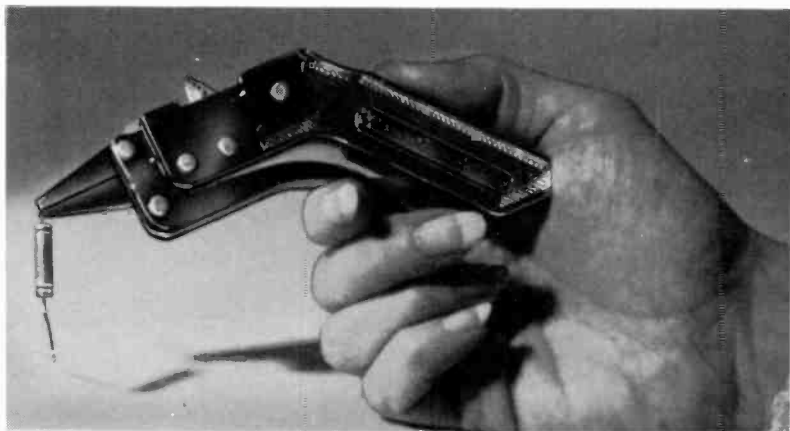


Fig. 715. *A base added to these locking-jaw pliers makes them an exceptional third hand.*

the only way, or the proper way, to work on an assembly will be to do it with one hand, with the other hand holding the clamp. This will probably be the case when the work requires constant turning.

Don't try to save time or money (for you will save neither) by using your fingers as substitutes for clamps. Clamps are not just a convenience—they're a necessity.

Chemicals

You will need an assortment of chemicals for your subminiature and printed-circuit work. These include solvents, dope, insulating sprays, cleaning solutions, etc. The group of solvents includes carbon tetrachloride (carbon tet) and trichloroethylene (trichlor), all-purpose solvents for removing traces of flux and dirt on electronic components and assemblies. These can be purchased locally from a drugstore, chemical supply house or dry cleaner. All *solvents should be used in a well-ventilated room*. If your skin is allergic to chemicals, the simplest procedure is to avoid direct contact. If you do get some on your skin wash promptly and

thoroughly with soap and water. Some forms of chemically-produced skin rashes (dermatitis) can take a long time to cure.

Fig. 716 shows a *freon* dispenser used to locate intermittents. When the suspected part is sprayed with this chemical, a refrigerant, it is temporarily cooled. By cooling one component at a time, the intermittent can be pin-pointed.



Fig. 716. Freon aerosol dispenser helps pinpoint temperature-sensitive components.

A resin type insulating spray is made for covering repairs or replacements on printed-circuit boards. This chemical forms a protective coating over the component and prevents shorts. At the same time, it helps waterproof the component.

A contact-cleaner solution (Fig. 717) which is a combination lubricant and solvent is useful on relay contacts and volume controls as well as small bearings and rotating parts.

Sometimes a wire is too delicate to be stripped with a knife or razor blade. Several chemicals, usually strong organic solvents, including a chemical known as methylene dichloride, are made for this purpose. This type of chemical insulation "stripper" is also useful where burning the insulation would leave carbon



Fig. 717. *Aerosol sprays are useful for cleaning all contacts and controls.*

deposits that could foul up circuit operation. Most of these "strippers" are nonflammable.

Another wire stripping device, using soldering-iron heat, is shown in Fig. 718. This is an adapter type heat-stripper and can be mounted on your iron as shown in the photo. Once it is put into

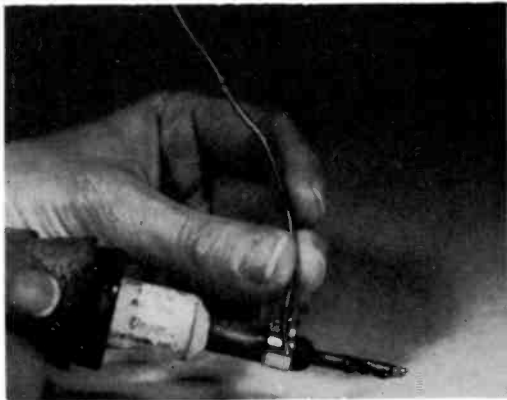


Fig. 718. *Adapter type heat-stripper can be mounted permanently on the soldering iron.*

position it need not be removed. When putting a heat stripper on your iron, make sure it is tight and makes good contact all around with the body of the iron. Since this part of the iron is generally not cleaned, prior preparation by cleaning with sandpaper or steel wool will be helpful.

Cements

Of the wide variety of cements available for miniature repair work, the most familiar are bakelite (phenolic) cement, rubber-to-



Fig. 719. The collet chuck type grip of a pin vise makes it easy to hold the smaller sizes. If the exposed end of the twist drill bit is kept as short as possible ($\frac{1}{4}$ inch, or so) it is possible to make small diameter holes just by carefully rotating the pin vise.

metal cement and nitro-cellulose type (celluloid-solvent) cements. Vinyl-base cements are available for plastic work, and lucite cements for acrylics such as lucite and plexiglas. A special cement, Polyweld, is used for cementing polystyrene, the material used widely for high-frequency low-loss coil forms.

Another class of cements are the epoxies. These are usually "two-part" mixtures which are stirred together just before being used. One part is a resin, and the other a catalyst or chemical promoter that speeds up the reaction.

Epoxy cements are packaged in two tubes. Half the total amount of cement needed is squeezed from each tube and the

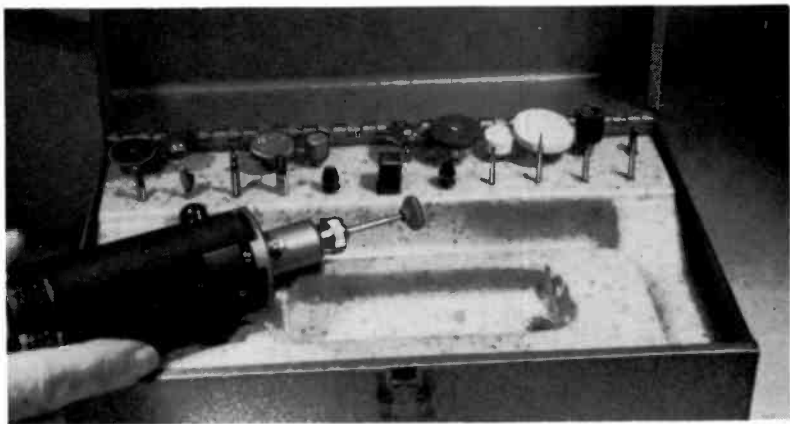


Fig. 720. The high speed of the power hand tool is helpful when drilling with small diameter bits. Accessories make it a versatile tool.

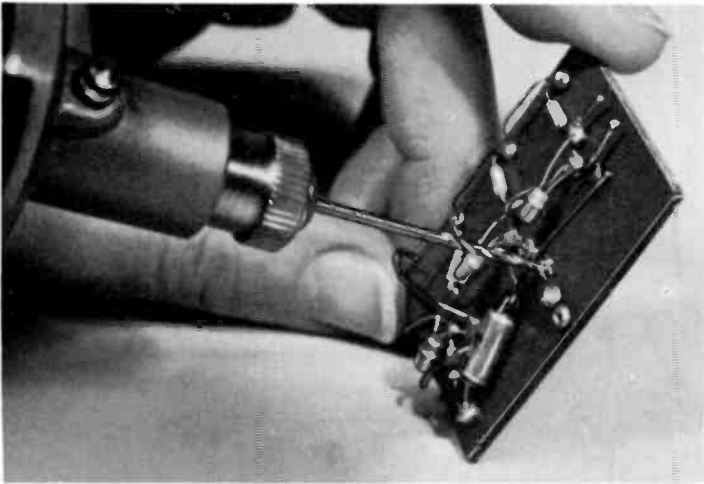


Fig. 721. With care, many difficult boring and drilling jobs can be accomplished. Special drills or adapters are required to fit the limited adjustment of the chuck.

two “globs” of cement are then mixed together. The resulting mixture is applied to the parts to be cemented together and, depending on the type of epoxy cement, will take from 4 hours to a few days to set hard. Epoxies are also made with brass, steel and aluminum powders mixed in for use as cements and fillers.

Hand drills

You will find it useful to have on hand an assortment of miniature twist-drill bits and burrs. The most common sizes run from No. 50 (.070-inch) to No. 80 (.0135-inch). Sizes No. 60 through No. 80 should be used in a pin vise such as that shown in Fig. 719. If used in a standard size drill chuck, they should first be clamped in a small chuck adapter. Hand drills and pin vises come in various sizes from No. 44 to No. 80, and adapters are made to permit standard drill chucks to be used over this entire range.

Smaller drills of the *spade* or *pivot* type can be used for holes from .010- to .003-inch diameter. They are available from jewelers' supply houses at very nominal cost.

Small power tools

Occasionally, it is necessary to drill a hole in an awkward spot on a small electronic assembly, and it is impractical and sometimes dangerous to use large power tools.

The handiest tool in this case is the compact power hand tool

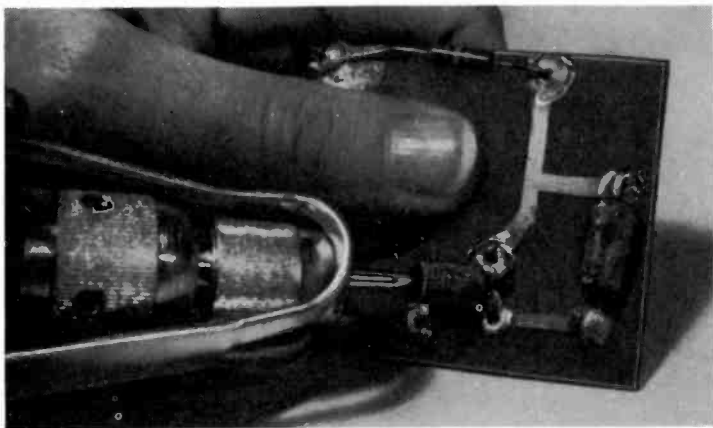


Fig. 722. Small grinding wheels require high speeds. Solder, aluminum and brass can clog the fine grit wheels. Guard around chuck helps to protect fingers and provides a means of steadying the rotating chuck.

shown in Fig. 720. Basically a high-speed motor with a chuck for holding various tool bits, the power hand tool can be used for countless jobs. Fig. 721 shows the tool being used to drill a $\frac{1}{32}$ -inch diameter hole in the middle of a group of components. Fig. 722 demonstrates how excess metal is ground off a part hard to reach by hand-filing methods.

All sorts of materials can be sawed with compact power hand tools, and Fig. 723 shows a piece of copper-clad laminate board being cut for the Tinkertoy modules described in Chapter 4.

One technique possible with such a power tool is shown in

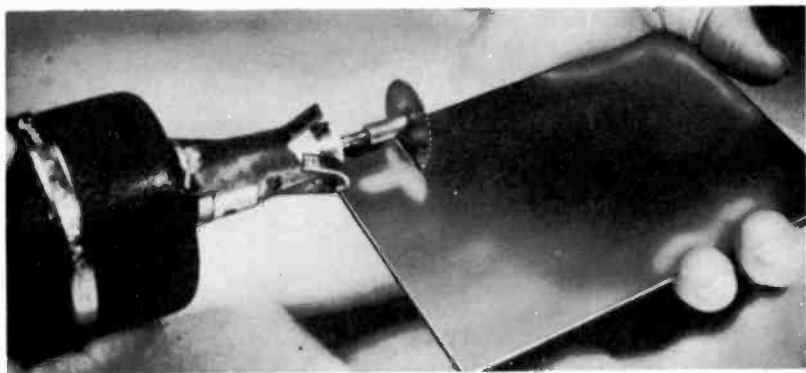


Fig. 723. Circular saw blade chucked in the power hand tool makes it easy to cut thin materials. Excessive friction and abrasive materials can shorten blade life considerably.

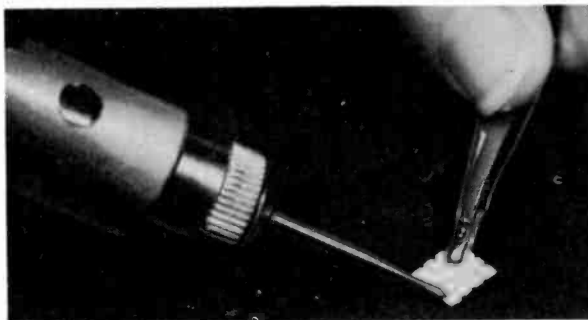


Fig. 724. A grinding stone loaded with solder can be an asset in tinning hard-to-solder surfaces such as ceramic and aluminum. Thicker materials may need pre-heating with a soldering iron or torch.

Fig. 724. Here a coat of 50-50 tin-lead solder is being applied to a ceramic surface by first abrading the ceramic surface, loading the grinding wheel with solder and then applying the grinding wheel to the ceramic. Solders which contain indium work very well for this.

Fig. 725 shows a grinding bit used to make notches in a Tinkertoy module.

In all of the photos demonstrating various uses of a power tool, you may have noted that the work was held in the hand. It takes

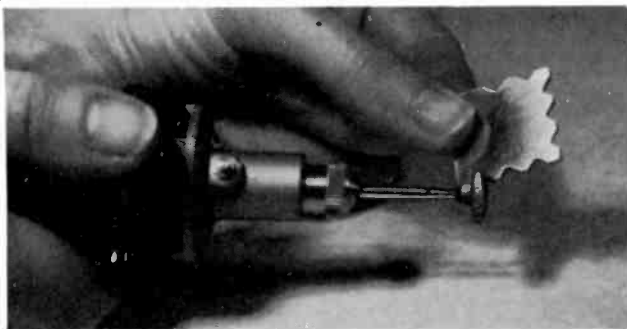


Fig. 725. Abrasive wheels can be used to cut o- shape materials too hard or brittle for saw blades. Similar, large-diameter wheels are used to cut cinder block and drainage tile.

a steady hand and a bit of experience to be able to work like this. Time saving is the most attractive feature of working this way, but until you get the required amount of "know-how", try practicing on projects that are headed for the junk pile. At the start you will undoubtedly find it much safer and more convenient to use one of the clamps described earlier.

Taps and reamers

Once in a while, a threaded hole must be put in a component or chassis. The most useful taps for subminiature work are sizes 0-80, 1-72, 2-56, 3-48, and 4-40, and these are shown with a tap holder in Fig. 726. These taps are brittle and the proper tapping procedure and a simple jig is sketched in Fig. 727. It is important

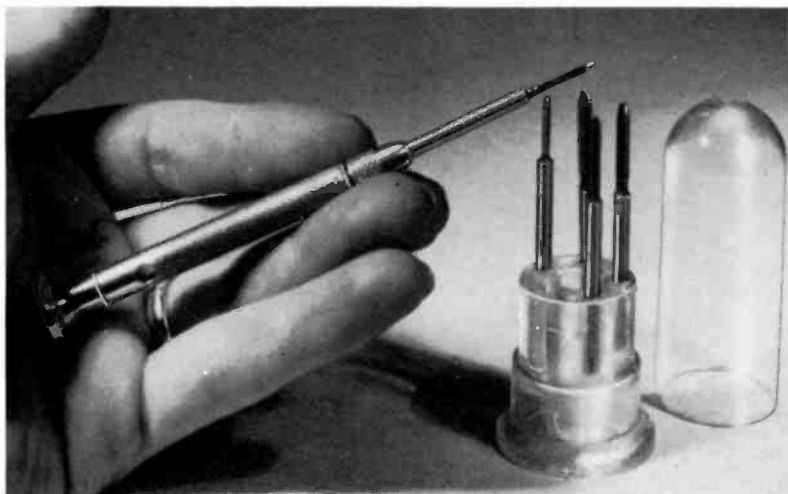


Fig. 726. The tempering process that makes steel hard enough to hold a sharp cutting edge also makes it brittle. These small taps will break, not bend. A drop to a concrete floor can be enough to make them fracture like glass.

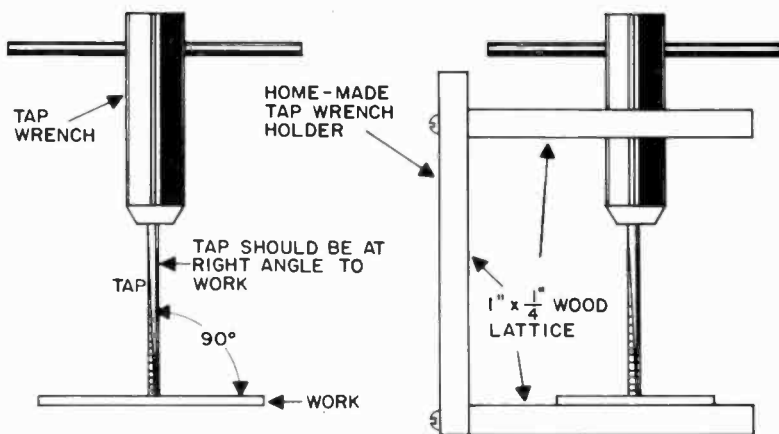


Fig. 727. A simple tapping jig will soon pay for itself by reducing tap breakage. Usually it is difficult to remove a broken piece of a tap from a deep hole.

to keep the tap at right angles to the work. Two things can happen if this is not done. The screw to fit the resulting tapped hole will go in at an angle. This means that the screw head will not be flush with the work. Not only will this appear unworkmanlike, but the screw may not serve its purpose of holding some component securely to the chassis. Another possibility of tapping at an angle is that the tap might snap. Some experimenters, noting the tap going in at an angle, consciously or unconsciously, try to force the tap into a more vertical position. The tap wrench holder shown in Fig. 727 removes this possible element of failure. When con-

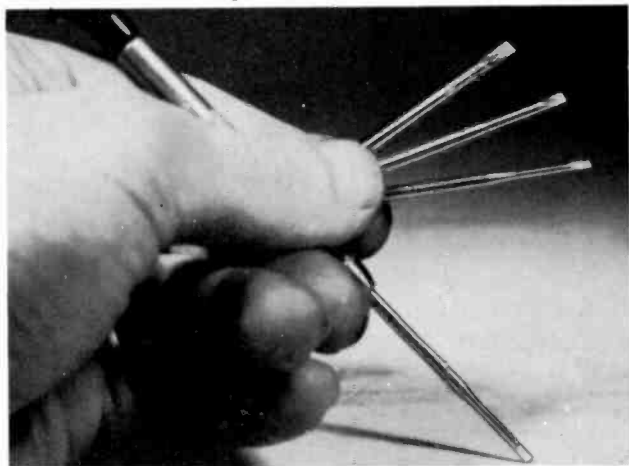


Fig. 728. The screwdriver blade must be as small and delicate as the machine screw it is used on. As sizes get smaller it becomes more and more important to have the blade fit the slot properly.

structing the tap-wrench holder, drill a clearance hole slightly larger than the diameter of the tap wrench. Too much play will defeat the purpose of the holder. For greater strength and rigidity, use angle brackets to support the two horizontal wood members of the jig. After the unit in Fig. 727 is completed, check it for proper angularity (the pieces should form right angles) by using a right-angle triangle of the type used by draftsmen.

You will find it helpful to have on hand a subminiature steel reamer. This can be used to enlarge a hole from $\frac{1}{64}$ - to $\frac{1}{16}$ -inch in diameter.

Screwdrivers

Of course an assortment of screwdrivers is a must for the experimenter, and Fig. 728 shows a basic set of commonly used

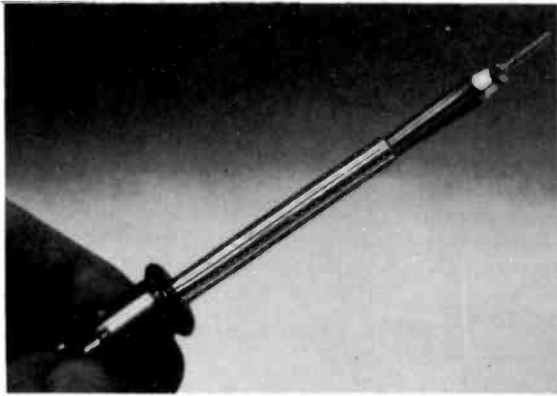


Fig. 729. Larger size machine screws can be held to the screwdriver with a split blade that holds with a wedging action.

jewelers' screwdrivers. The tips vary in width from $\frac{1}{10}$ inch to a little over $\frac{1}{16}$ inch and are replaceable.

Sometimes it is necessary to replace or remove a small screw in a place where the screw might drop back into the work. Fig. 729 shows a screwdriver designed to grip the screw until it is safely away from the work. When a lock under the handle is flipped, the

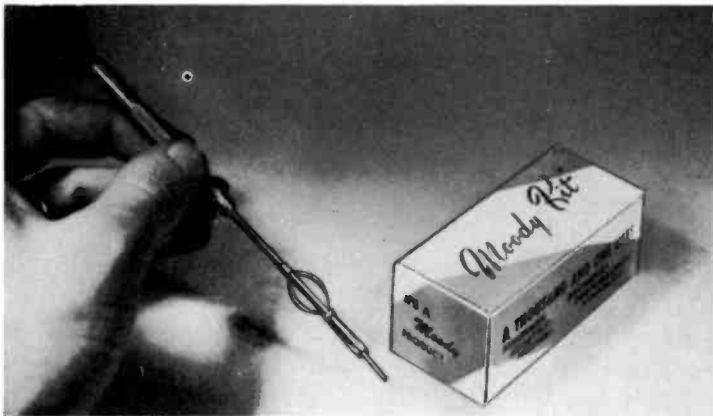


Fig. 730. Smaller varieties of screws are held with a light spring pressure to prevent damage.

blade releases the screw. Another variety of screwdriver (Fig. 730) which does the same trick fits screws from sizes No. 0 to No. 4. Subminiature Phillips-head screwdrivers (Fig. 731) come in No. 0, No. 1 and No. 4 sizes.

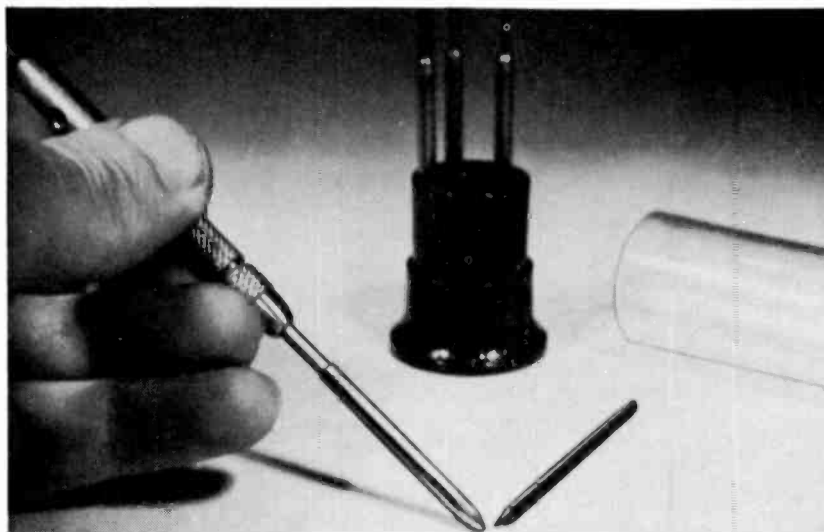


Fig. 731. Small Phillips-head screwdrivers are also needed frequently.

Sometimes you will find that you have on hand machine screws which are too long for the purpose you have in mind. If you try to cut these to size with one of the blades described earlier, you may find that the corresponding nut will no longer engage the threads of the screw. To avoid this, put the nut on the screw before cutting the screw. Rotate the nut until it is up near the head of the screw and out of the way of the cutting blade. After the cutting is finished, removing the nut will deburr the threads of the screw.

Wrenches

Fig. 732 shows a miniature socket-wrench kit containing five subminiature hex-socket wrenches. The wrench handles have magnets for removing steel nuts or screws in hard-to-get-at spots. Tightening or removing nuts with pliers is poor practice in ordinary work. With miniature projects this technique can result in damage to components adjacent to the hardware.

Open-end wrenches for subminiature work are shown in Fig. 733, and are made in sizes $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$ and $\frac{7}{32}$ inch. The wrench size is marked on the side of the tool. Incidentally, many of these small tools such as the hex-socket wrenches and open-end wrenches come with a tool holder which can be covered with a glass or plastic shield. It's advisable to have this shield in place when the

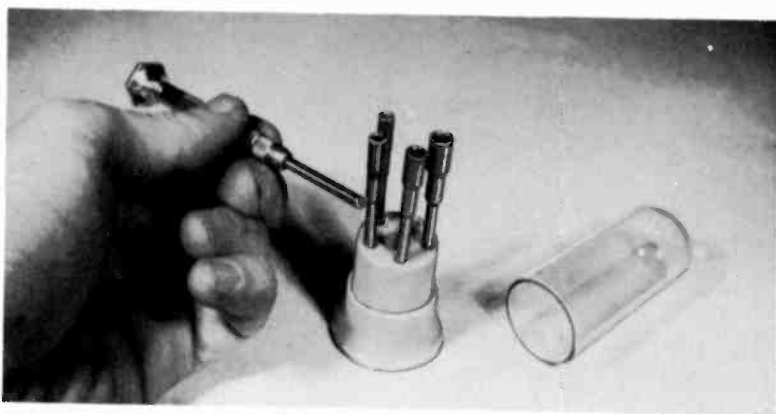


Fig. 732. Socket wrenches are available in small sizes needed for the small-diameter nuts.

tools are not in use. This will protect them from plastic or metal dust accumulated during work.

Another wrench used often in equipment is the hex and spline types. These are used for socket type setscrews.

Printed-circuit and subminiature repairs

Many subminiature electronic assemblies utilize a printed-circuit base. This section describes some of the many techniques that are useful when servicing subminiature and printed circuits. It is a good idea to know when to use the many tools available.

Locating troubles

Most troubles will be either component failure or inter-connection problems. The printed-circuit or subminiature assembly can be inspected with a magnifying glass or jeweler's loupe under a strong light. Obvious component failures such as cracked component bodies, charring and discoloration will show up in this type of preliminary inspection. The connections between components should be inspected next, looking for "cold-solder" joints and mechanical breaks.

The handiest instrument for checking miniature electronic devices is a vtvm, and it should be equipped with a pair of subminiature prods. For on-the-spot checking where an ac power supply is not handy, a pocket volt-ohm-milliammeter (vom) or multimeter is a convenient test instrument. If the experimenter has no commercial test prods handy, he can make a pair from $\frac{1}{8}$ -inch wooden dowel and sewing needles.



Fig. 733. *Open-end wrenches can be used in places where socket wrenches can't fit.*

It is usually better to make a point-to-point voltage check on the assembly under test. Some resistance checks can be made, but two precautions must be observed here: First, the component should be rated to take at least the voltage of the battery used in the ohmmeter. Second, all parallel connections should be opened to avoid false readings. If two resistors are in parallel with each other or if a resistor is paralleled by a transformer, one end connection of the resistor has to be opened to prevent incorrect readings.

Precautions with components

As components become smaller and smaller, their mechanical and electrical capabilities usually suffer. A low-level audio transistor cannot be expected to take the same abuse as a modern power output tube. A subminiature electrolytic cannot be soldered with a 150-watt iron like its big brother—the 40-40 at 600 working volts dc job—without a greater chance of disastrous results.

Here are some points to watch when working with the subminiature components:

1. Watch polarities on batteries and electrolytic capacitors.
2. Keep excess heat away from all semiconductors. Use heat sinks such as pliers or tweezers when soldering or unsoldering transistors and diodes.
3. Don't grab components unmercifully between the jaws of gas pliers, and expect them to work after being squeezed too hard. Use tweezers wherever possible.

4. You can use a soldering gun for working with miniature projects although this is inadvisable and is not recommended. There is no denying the convenience of a gun, but again, this depends entirely on your own experience and skill in handling it. If you have limited know-how in working with miniature construction, use one of the irons described earlier in this chapter.

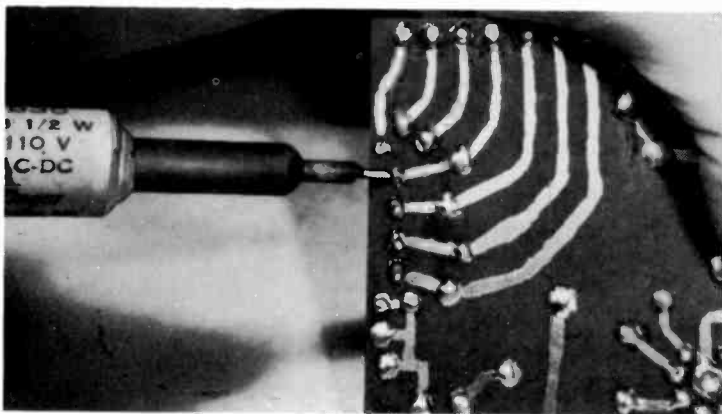


Fig. 734. *Thinnest portion of soldering iron tip is about the diameter of component pig-tail leads. It is used to solder fine wire.*

Because of the way it is made, a soldering gun is surrounded by a strong magnetic field. This field can induce voltages in nearby components, such as transformers and coils. In completed circuits, the resulting current flow could damage components, including transistors.

5. Take it easy on leads, connecting lugs and terminals. Twisting transistor leads or bending the i.f. can's mounting lugs too much can be the end for these tiny components.

6. Don't remove or insert transistors in a circuit that is under power. The transients this action produces can cause a lot of damage.

7. Check transistor terminations carefully for proper emitter, base and collector connections. All multiple-lead components should also be checked for proper connections. Don't be afraid to read the manufacturer's spec sheets more than once. Observe mechanical or color-coding instructions for locating terminals.

Printed-circuit and subminiature electronic soldering techniques

The crowded spaces in small electronic assemblies make it absolutely necessary to use smaller tools. Fig. 734 shows a *micro-*

needle soldering tip in use on a subminiature assembly. This tip, only $\frac{3}{64}$ -inch across at its smallest diameter, is made of iron and nickel-plated alloy copper. Note that this particular soldering-iron tip is narrower in diameter than the conductors on the printed-circuit board. The iron with which it is used is a $23\frac{1}{2}$ -watt type.

Fig. 735 shows a chisel or tapered solder tip being used. This tip is only $\frac{1}{8}$ -inch across the end. The tip is a screw-in type and is one of a complete set of tips of different shapes that can be used with this particular iron.

For jobs that are a little smaller than that shown in Fig. 734 a long tapered needlepoint is available. This is $\frac{1}{16}$ -inch in diameter

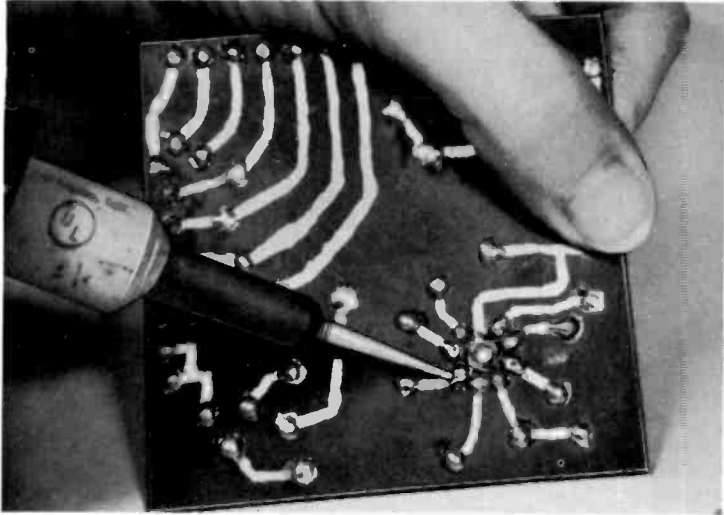


Fig. 735. *Tip temperature is important when soldering. Too thin a tip will not be able to conduct enough heat to the junction to give a proper solder joint.*

at the point. When other components get in the way an offset point is useful for working around corners. This tip is $\frac{1}{8}$ -inch in diameter.

Desoldering

Sometimes it is more trouble to unsolder or desolder components than to solder them together in the first place. However, a wide variety of tips have been manufactured just for this purpose. One of these is a slotted tip that can be used to straighten a component lead while desoldering. The slotted feature eliminates the need for a pliers in many cases, and may be the only solution to a situation where both the soldering tip and pliers

won't fit at the same time. Another version of the slotted tip is the offset. The bend of the tip permits working close to the board, and wires can be "scooped" up more easily with this tip than with the straight type.

When it is necessary to remove a center pin socket that has been soldered to an assembly, the cube tip does the best job.

A very common problem is removal of socket contacts. One way is to unsolder one socket lug at a time, prying it gently up

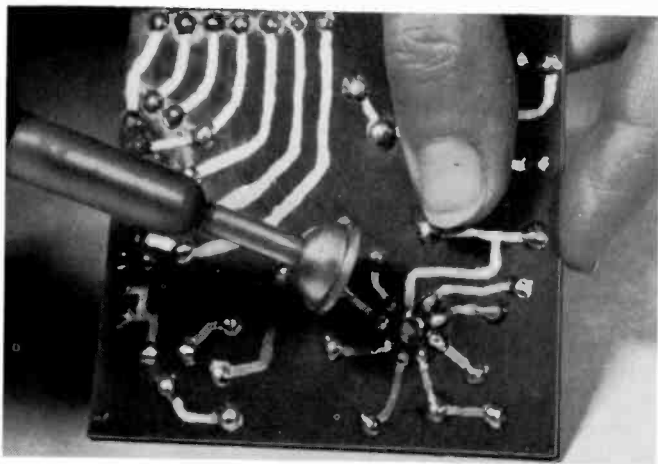


Fig. 736. Desoldering triplet will melt solder at all terminals at once making it easier to remove defective sockets and connectors. Range of heat element must be high enough to provide additional heat dissipation.

and away from the base board. However, this takes too long, and there is a good chance of breaking off one or several of the remaining lugs. The cup, or disc, type tip, shown in Fig. 736 unsolders all lugs at the same time.

The bar type tip (Fig. 737) is useful for desoldering multi-lead components such as printed-circuit component plates and relay terminals. This tip can be used lengthwise or endwise, and can be cut down or shaped to fill your particular needs for special desoldering setups. A "cousin" to this kind of tip is the triangular-shape unit shown in Fig. 738 for leads that are on the corners of a triangle.

Care of soldering iron tips

Although these tips are specially made copper alloy, they can be abused and ruined very quickly by carelessness. The tip should

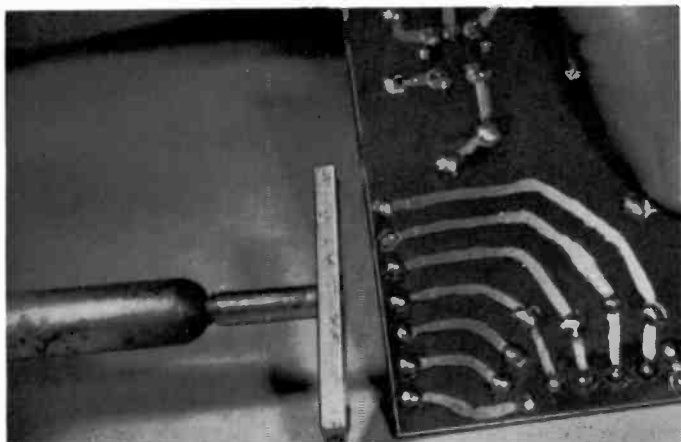


Fig. 737. Bar-shaped tiplet will unsolder many in-line connections at once.

be properly tinned before use. In the case of two-sided or multi-sided tips such as the chisel, cube or triangle, only one side (the working side) need be tinned. This prevents excess heat from getting away from the tip. Tinning all sides will help preserve the tip, but the tinned portions must be kept clean during use. A

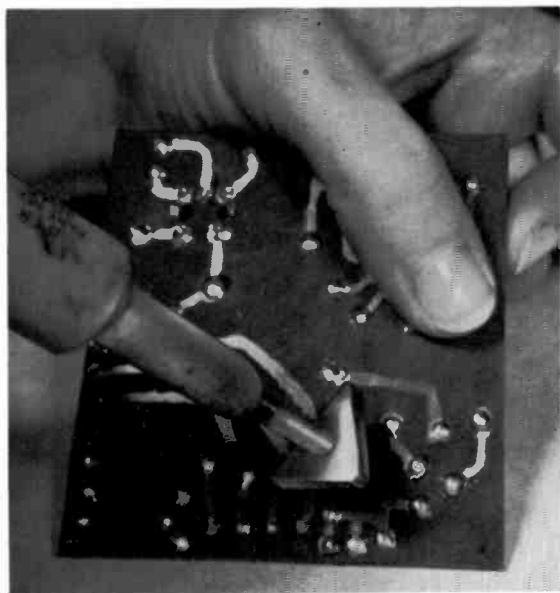


Fig. 738. Triangular tiplet's ability is in de-soldering can type electrolytic capacitors.

piece of steel wool or glass wool can be used to clean the tip, but be sure to brush them over the tip lightly and rapidly, so as not to leave residues.

One of the best aids for tip care is a specially treated sponge. This comes in a tray and can be fastened to a convenient spot on the workbench.

Don't use files or sandpaper to clean soldering tips! They remove the plating on those tips that have it, and leave a rough surface behind, which doesn't help the work any.

Resistance soldering irons

In addition to soldering by heat conduction, another method, called *resistance soldering*, is used. The basic principle is akin to the heating effect in a resistor. In resistance soldering, the *work*

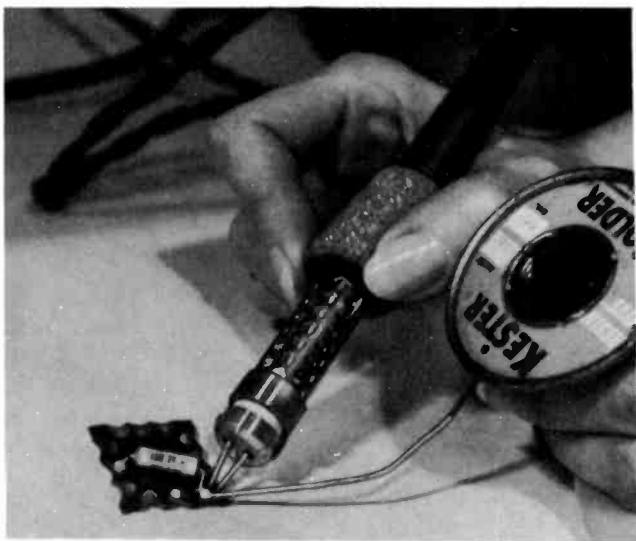


Fig. 739. With resistance soldering the tip remains relatively cool. Heat is generated only when the iron is applied to the work.

itself is made the resistance and current flow through the work does the melting job on the solder. A transformer supplies voltage in the range of 3 to 6 volts and currents from about 20 to 40 amperes. A heat control on the transformer changes secondary current for various job conditions.

In Fig. 739 a capacitor is being resistance-soldered to a modular assembly board. The soldering iron tip is a double metal electrode. Each electrode is $\frac{1}{16}$ -inch diameter alloy metal.

Resistance-soldering technique

For the worker used to a conventional conduction or "straight-heat" type of iron, the resistance iron is a little tricky to use at first. Once mastered, resistance irons will give very satisfactory results and are less likely to cause accidental burns since they are "hot" only when put across the work.

Here are some hints on resistance soldering:

1. A thin wire solder is best. Try both $\frac{1}{16}$ - and $\frac{1}{32}$ -inch rosin-core solders.
2. Be sure to get as good a mechanical joint as possible before soldering. Soft solder is not used for strength!
3. The work should be cleaned carefully.
4. Don't put the solder across the electrodes—put it on the work. Solder should be applied just ahead of the heating electrodes.
5. Don't overheat. A little practice on sample joints of similar size to the work will give you the feel for a resistance iron.
6. Don't jar the soldered joint after soldering. Give it a chance to cool, and remove the iron gently.
7. Pressure on the joint affects heating. Increased pressure causes more current and heat, and vice versa.

A single metal electrode, shown in Fig. 740, is useful for very crowded quarters. It is necessary, however, to ground the work in

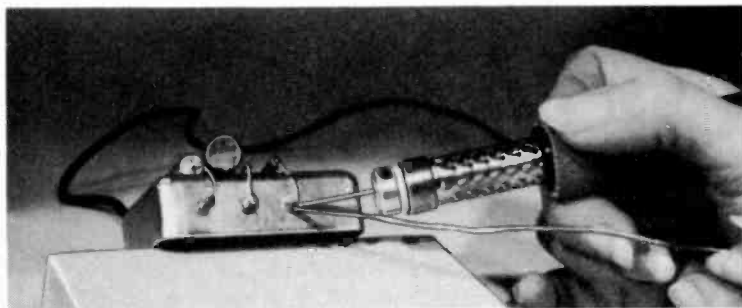


Fig. 740. Resistance soldering is similar in principle to resistance welding.

this case, and many times this is not too convenient. One handy use of a single metal electrode is a series of chassis grounds such as shown in Fig. 740. Here, the case is made one side of the circuit and the heat generated when the electrode touches the case is enough to melt the solder and make the joint.

Pieces of wire, nails and other substitute materials *should not* be used as electrodes in a resistance soldering iron.

Conduction vs resistance soldering—pro's and con's

Although resistance soldering is newer, it still has some features worth taking a second look at. If a production job is involved, the resistance iron can often do a faster job and give a little bit "fuller" joint—that is, more solder and less voids in joints where cups and eyelets are used. The resistance iron also heats faster—almost instantaneously—making work on delicate components such as transistors and diodes a "heat quick" and "fast getaway" proposition, cutting down the need for heat sinks such as pliers

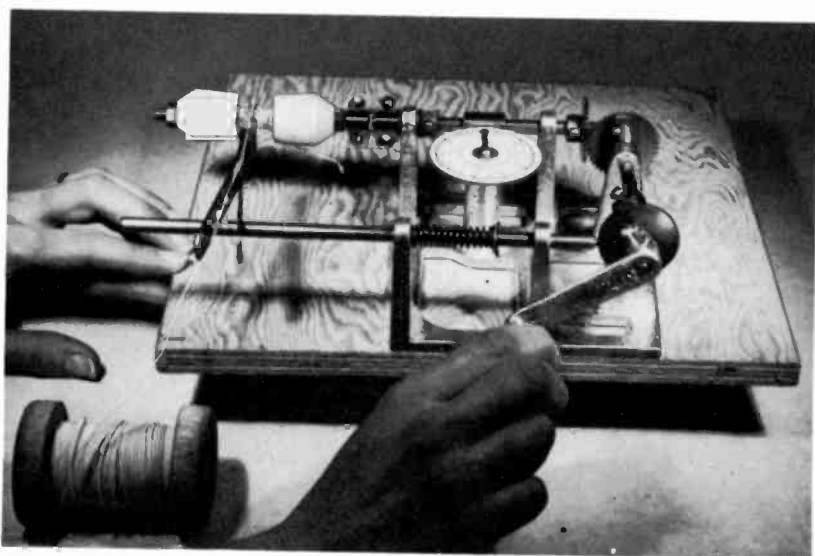


Fig. 741. Hand operated coil winder takes much of the drudgery out of making inductors. Accessories make it possible to make professional-looking coils.

and clips. One of the biggest attractions of resistance soldering irons is their "no work—no heat" feature which reduces the chances of accidental burns.

On the other side of the ledger is the versatility of conduction irons and the wider assortment of tip styles available. In general, a conduction iron of the same wattage has a lower first cost or purchase price than a resistance iron. Another point in favor of conduction irons is the smoothness with which their temperature can be raised and lowered by connection to variable auto-transformers. Conduction irons are still favored slightly for printed-circuit work.

Coil winding

A commercial coil winder is shown in use in Fig. 741. Basically, this is a rotating coil form on a cam-driven shaft. As the coil form rotates, it moves back and forth, distributing the winding in a uniform layer. A variety of cams are supplied to change the "throw" of the shaft and the length of the winding. Additional cams can be obtained and shaped to suit the experimenter's individual needs. Another feature of this winder is a wire guide which

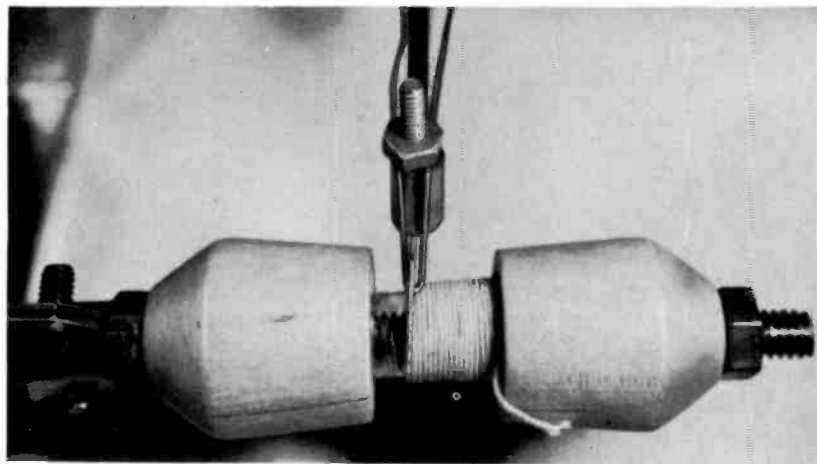


Fig. 742. Wire guide can be cam driven to make neat looking multilayer coils.

is centered vertically over the coil and lies flat on the coil during winding as shown in Fig. 742. A coil counter keeps track of the number of turns.

For extreme subminiature work, the winder shown in Fig. 743 can be made from odd parts around the shop. The wire is guided by hand, so this winder can be used for wire sizes down to No. 44.

The photo in Fig. 743 is fairly self-explanatory, but even a simple jig such as this one requires some care in its construction. The unit is made of three scrap blocks of wood. A long machine screw is used as the shaft on which the crank handle and coil form or bobbin are mounted. To make sure that the holes in the two blocks of wood supports line up, drill them both at the same time. Do this by clamping them together so that the same drill piece bites through both of them. A pair of internal-tooth lock washers

placed on both sides of the crank (where it is mounted on the shaft) will help hold the crank and machine nuts together.

A small modification, not shown in the photo, will help hold the wire taut during the winding. Drive a U-shaped brad into the wood on the base near the coil. Have the wire come through the brad. Instead of holding the wire in a downward position (as shown in the photo) hold the wire at some upward angle.

In addition to cotton-covered, enamel and special plastic-covered magnet wires, *Litz* wire has found revived use in miniature and

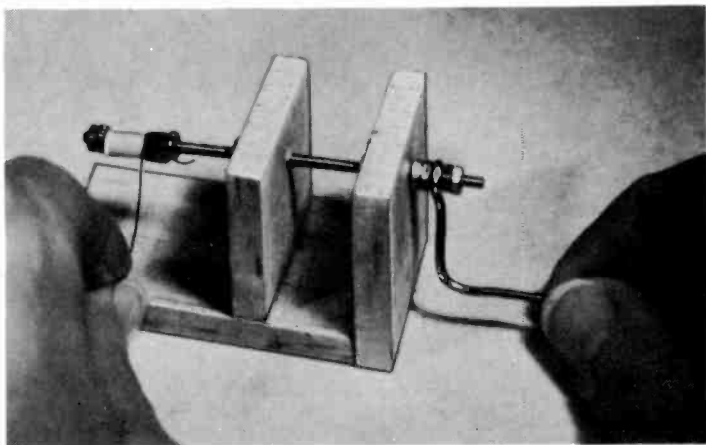


Fig. 743. This simple jig will make the winding of single layer coils much easier.

subminiature coil work. *Litz* or *Litzendraht* wire is a multi-stranded wire that has the properties of lower skin losses and lower rf impedance at high frequencies. This is achieved by winding 6 or 7 strands of individually insulated wire in parallel and tying their ends together. The wire is used widely for winding midget i.f., rf and antenna coils, and improves the *Q*'s of these components.

Silver plating

The experimenter can sometimes plate small coils to improve their rf properties. Another use for plating is to improve conductivity on switch and relay contacts.

Fig. 744 shows a simple brush plating setup that can be used to put a coating of silver on odd-shaped objects. The brush is the type known as an acid or tinner's bristle brush, and is connected to the positive terminal of a 3-6-volt battery. The work, in this



Fig. 744. Silver plating will increase the Q of inductors by reducing their dc resistance.

case, the wire for a coil for a pocket FM transmitter, is connected to the minus terminal of the battery. The bristles should be dipped in the plating solution frequently and the brush kept moving as much as possible. The wire, of course, is bare copper.

Another silver-plating technique consists essentially of a silver plating "powder." This is wetted and rubbed on the work. Cotton-tipped swabs, available from drugstores, are very useful for this job.