TRANSISTOR
ETCHED - CIRCUIT
PROJECTS

by

JAMES KYLE

With a specially written chapter for
the guidance of the English reader
by W. Oliver (G3XT)

TRANSISTOR ETCHED - CIRCUIT PROJECTS

It is essential that the English reader should read this chapter.

The advantages of "printed" or etched circuit technique are almost unquestionable where manufactured apparatus mass-produced in a factory is concerned.

This technique ensures that every set is virtually identical with the prototype as regards layout, wiring and connections. It also speeds up production and may reduce the degree of skill required.

This book, however, is not concerned with mass production of factory-made sets, but with the home construction of individual transistor etched-circuit projects of interest to amateur enthusiasts and hobbyists.

In this field, etched-circuit technique is up against some initial prejudice. As the author points out in his Preface, some experimenters still tend to view etched circuits for home construction with a high degree of suspicion.

To be fair, one must admit that many of the needs of mass production differ greatly from those associated with home construction, especially if a set is required for experimenting rather than ordinary use.

The rigid, unvarying uniformity that is a great merit in mass-producing models to a fixed pattern can be a drawback instead of an advantage if you want to keep altering a circuit for experimental purposes. The author has, however, dealt with this point on pp. 136-137, and in Fig. 8-4 (Chapter 8, "Designing Your Own Circuit Boards").

Where a fairly complicated circuit is concerned, especially if it is of a miniaturized type, such as a pocket transistor portable superhet receiver, etched circuit technique offers some great advantages and should be far quicker and easier than ordinary construction.

In the case of very simple projects, however, where there is a minimum of wiring; the position of the leads is not critical; the layout is relatively unimportant; and the whole job quick and easy using ordinary conventional methods, the present writer feels that there may be some justification for using the latter in preference to etching.

On the other hand, in the present book the very simple projects which form some of the examples undoubtedly serve as useful practice in mastering the art of etching circuits and are a necessary step towards attempting more ambitious jobs, such as the construction of an entire set or amplifier using etched-circuit technique.

The author does, however, point out that all of the projects described in this book can be modified for ordinary wiring methods instead of etched-circuit technique if desired.

As this book is of American origin, the materials specified are of American manufacture. Here in Britain supplies may differ in certain instances and the reader of this English edition *MUST* be prepared to make such adaptations as are necessary to suit the parts and materials available from British suppliers.

Therefore one should take a careful look at each project before starting on it, and note down any minor alterations that may be needed to make it fit British-made materials.

Fortunately there is a growing tendency for greater standardization in the size, shape and connecting-leads of small radio components nowadays, both on a national and international scale. So in the case of fixed resistors, fixed capacitors, etc. there should be no difficulty whatsoever about substituting British parts for the American ones specified.

In the case of somewhat larger and more complex components, such as i-f transformers, two-gang tuning capacitors and so on, there may be minor snags and one must be prepared for slight inconvenience here. But in most cases a little ingenuity will solve the problems.

As regards obtaining the kits or materials for the actual etched-circuit boards which form the foundation, so to speak, of each project, there are not at present very many sources of supply in this country. No doubt this is largely due to the prejudice already mentioned which, in the past, has tended to limit the demand where amateurs are concerned.

Among the firms which do, however, supply suitable outfits for etching your own printed circuits, there are at least two well-known mail-order firms.

One is Messrs. Stern-Clyne, whose address for mail orders and enquiries is:—3/5, Eden Grove, Holloway, London, N.7. There are retail branches at other addresses in London, as well as in Croydon, Bristol, Liverpool, Manchester, Nottingham, Sheffield, etc. At the time of writing, this firm is offering a complete kit of parts and chemicals for etching circuits *by direct-resist technique* at 19s. 6d. plus 2s. 3d. packing and postage; but be sure to check details from the firm's latest advertisements in the radio technical journals as prices are possibly liable to change from time to time.

Another firm which is currently offering kits for etching printed circuits at home, again by *direct-resist* method, is Messrs. Proops, 52, Tottenham Court Road, London, W.1. At the time of writing, this complete outfit costs a guinea post free, but here again the latest press advertisements should be consulted in case there may be any price change. This kit contains about 60 square inches of laminated board and enough chemical supplies to make dozens of printed circuits. The makers and suppliers state that the materials are "completely safe to handle".

In this respect the method scores over the photo-resist process which, as stated by the American author of this book, can entail the use of chemicals such as trichlorethylene and ferric chloride, *which cannot be described as completely safe* (see the warnings on p. 10 in Chapter 1).

Even when dealing with chemicals which *are* described as safe to handle, however, all reasonable and commonsense precautions should be taken against spilling or splashing liquids and against inhaling any fumes that may exist. There is no justification for carelessness in dealing with fairly powerful solvents, etching solutions, etc. Read and observe the full instructions which are supplied with the outfits.

Both the kits mentioned above are of the kind that employ a paint-type resist-fluid. They are not the photo-sensitive board type, and therefore the negatives at the end of this book cannot be used for direct printing on to the board. It is necessary to trace or carbon the design on to the board and then apply the resist-paint to the parts which are not to be etched away.

The American author is somewhat critical of the painted-on method of using direct-resist, in his remarks about it on p. 141. The materials in the kits mentioned above do not seem to have the drawbacks to which he refers, however, in that the paint employed is not unduly rapid in drying, nor is it "exceptionally difficult to correct" any mistakes that may be inadvertently made. As for the bottles, those in the kit which the present writer has obtained are of sensible shape and not unduly spillable. So it would appear that the drawbacks mentioned have been overcome in the case of these kits.

The writer has not so far been able to trace any source of supply for photo-etching materials, in this country.

If, therefore, it is necessary to trace the outlines from the negatives on to the copper surface, it is advisable to place a carefully-trimmed sheet of carbon paper of exact size under the cut-out negative and secure both, temporarily, to the board with narrow Sellotape, so as to prevent any inadvertent movement which would spoil the accuracy of the tracing.

For those who wish to experiment with alternatives to an actual etched circuit, but retain the advantages of certain features associated with printed circuit technique, there are several modern products which are readily obtainable.

One of these is Veroboard. This consists of a bakelite-type panel to which is bonded a number of copper connecting-strips. These strips have ready-drilled holes for wire-ends of components etc. The boards are also available in a non-metallised form—i.e., plain drilled, without copper strips. Veroboard is excellent for experimental work, prototypes, etc.

Another product, the Lektrokit Chassis Construction System, comprises perforated chassis plates, Veroboards, and—of particular interest—various small items of hardware which are extremely convenient for constructional projects. These include a variety of brackets, transistor heatsinks, lead-through insulators, spring-clips, plastic clips, transistor mountings in moulded PVC, tagstrips, etc.

Full particulars of these products (and literally thousands of other components) will be found in the catalogue issued by Messrs. Home Radio (Mitcham) Ltd., 187, London Road, Mitcham, Surrey. See latest advertisements in radio technical journals for price and postage of this catalogue.

The transistors specified in this book are, of course, American types, since the book is of American origin. It is, however, becoming increasingly easy to obtain many American transistors in this country.

One very useful source of supply, at the time of writing, is Messrs. M. R. Clifford & Co., 66 Old Oscott Lane, Great Barr, Birmingham 22a.

As stocks vary from time to time, readers should write to this firm for latest lists, ninepence. At the time of writing, the majority of the American transistors specified are available from this firm, mostly at a cost of only a few shillings; and in many cases not only the first choice specified but also the alternatives are on offer. In cases where the first choice is not available, suitable alternatives can generally be had.

Where the exact transistor-type specified proves to be unavailable in this country, or is subject to very long delay in supply, a good solution to the difficulty is to substitute the nearest "general purpose" transistor. A very useful range of general purpose transistors is currently available from stockists of the International Rectifier Company Ltd. This firm has established a chain of semiconductor centres throughout the country and would doubtless supply a list of addresses on request to head office at Hurst Green, Oxted, Surrey.

Chapter 6 deals with two transmitter projects. The first is an 80-metre C.W. transmitter for use on the 3.5 Mc. amateur waveband. This is one of the wavebands officially allocated to holders of British amateur transmitting (sound) licences, at the time of writing, so this small set is quite suitable for use by British readers without modification.

The second project, however, is a VFO intended for use on 6 metres (50 Mc.), a band that is *not* authorized for amateur transmitting in Britain. Therefore this set must *not* be used as it stands in this country; but a competent amateur could doubtless convert it (by suitable modifications—e.g., to the tuned circuits) for use on another waveband, such as the 70 Mc. band which is lawful for British amateur transmitters to work on.

Amateur transmitting licence regulations in Britain differ from those in force in America. Particulars of the amateur transmitting licence regulations are obtainable from the Radio Services Department, Radio Branch, General Post Office, London, E.C.1. Useful information on amateur transmitting is also available from the Radio Society of Great Britain, the address of whose headquarters at the time of writing is 28, Little Russell Street, London, W.C.1. Anyone seriously interested in taking up amateur transmitting would be well advised to apply for membership of the RSGB; particulars of the annual subscription etc. can be obtained from RSGB HQ.

The *unauthorized or unlicenced* use of a transmitter is a punishable offence under British regulations.

On p. 94, the author advises that "no substitutions should be made for the 2N2711's specified in Table 6-1". Fortunately the 2N2711 is readily available at present from Messrs. M. R. Clifford & Co. (address already given).

The tank-coils L2 and L4 could be home-wound; or doubtless one could adapt "Codar-Qoils" made by the Codar Radio Company of Bank House, Southwick Square, Southwick, Sussex. (The Q in "Qoils" is not a misprint—it refers to the low-loss, high-"Q" characteristics of the coils.) Particulars and prices are available from stockists—e.g., Messrs. Electroniques (Felixstowe) Ltd., of Pathfinder Works, Penfold Road, Felixstowe, Suffolk—a firm which can also supply many other items for amateur transmitting. See current advertisements for price of complete catalogue.

In all the projects in this book, individual components where specified by trade name and model number are, of course, American types. Some ingenuity, and a careful search through illustrated catalogues, should enable one to make successful substitutions of near-equivalents in British-made types.

Winding details of an antenna coil on p. 54 differ from those in the Parts List on p. 56. It would appear that some experimenting was done in making the prototype and one or two modifications were introduced in the final version. The British reader would be well advised to experiment, too, with the number of turns in the coils, to find the optimum values for maximum efficiency and suitable frequency-coverage to give the desired choice of stations. The required number for a given range of wavelengths is influenced by factors such as the gauge of wire used and the dimensions of the ferrite rod or slab.

Regarding the Frequency Standard on pp. 126-129, if you cannot receive WWV in Washington, D.C., or WWVH in Hawaii, a similar service is provided by our British GPO station at Rugby. The call-sign used for this service is MSF and the frequencies are 2.5, 5 and 10 Mc. Except for a 5-minute break at a quarter past each hour, this station works day and night. Another very accurate source of measurement is afforded by the BBC Light Programme transmitter on 200 kc. (1,500 metres long wave).

IMPORTANT—ERRATA

It is essential to note the following corrections to the numbering of the negatives as quoted in the Parts Lists:

p. 116. CB Field-Strength Meter. Negative 7-4, not 7-5 as stated.

p. 121. Audio-Frequency Meter. Negative 7-6, not 7-7 as stated.

p. 123. Transistor Voltmeter. Negative 7-7, not 7-8 as stated.

p. 128. Frequency Standard. Negative 7-8, not 7-9 as stated. (There is *no* 7-9.)

Regarding the CB Field-Strength Meter, one should note that there is, at present, no "Citizens' Band" allocation under British regulations; but the field-strength meter circuit is of course readily convertible to suit other wavebands.

Preface

One of the things I have found most surprising in my more than two decades of electronics experimenting has been the high degree of suspicion with which most experimenters view "printed circuits." As one who formerly shared that suspicion, I can testify that it's not so much based on any logical reasons as on a feeling that "these things just aren't much use to me." And unfortunately, too frequently this feeling has been correct.

Despite many articles in various magazines describing practical do-it-yourself "printed-circuit" construction, there just hasn't seemed to be much point in putting one of these things together for a one-of-a-kind project. Several enterprising small businessmen have, however, found it profitable to work up boards on popular do-it-yourself projects. Experimenters have found that these boards do, indeed, simplify the building of the projects.

So why not, I asked myself some time ago, publish a set of projects for which the boards were already worked out? It's not a new thought—circuit layouts have been published for years. But to the best of my knowledge, no previous collection has been arranged in a form in which you can literally cut out the layout and make the board directly from it, without intermediate copying steps or fussy resist-application techniques.

This volume is the result. You can build any project in these pages and know that your parts layout will be identical to the original proven circuit. No additional parts and materials, except for the board material itself and the electronic components are needed.

In a very real sense, this volume is an experiment. It is a new, different, and improved approach to do-it-yourself construction of not-so-simple electronic projects. I'd like to express my appreciation to the publishers for having the courage to participate in this experiment; it has required some drastic modifications of their normal printing procedures. My thanks also to Stan Isaacs for his assistance in

locating sources for the components used in these projects. And, of course, to you, for deciding to give the experiment a try. Let us know how you make out with it!

JIM KYLE

Contents

Chapter 1

Preparing Etched Circuits

The starting point in all etched-circuit electronic construction is the preparation of the etched-circuit board. This board provides the physical support for the circuit components and the electrical interconnections of the circuit.

What Are Etched Circuits?

Etched circuits, more commonly known as "printed circuits," consist of insulating boards which contain the wiring pattern of an electronic circuit. The pattern may be on one or both surfaces of the board.

The etched-circuit technique offers the possibility of making every unit exactly the same, while the older "hand-wiring" technique introduces unavoidable variations from unit to unit since no two will be wired exactly the same. Etched circuits are widely used in commercial, industrial, and military equipment, but they have not been used so widely by experimenters and hobbyists, because the full advantages of etched circuits have not been conducive to "one-of-a-kind" construction. In this book, however, all the advantages of etched circuits are made available to the experimenter; the negatives provided at the back of this book are identical to those from which the original units were constructed. Parts layout and wiring variations cannot be a problem to the builder of these circuits.

A typical etched-circuit unit is shown in Fig. 1-1. This unit is one component of a digital computer; it actually in-
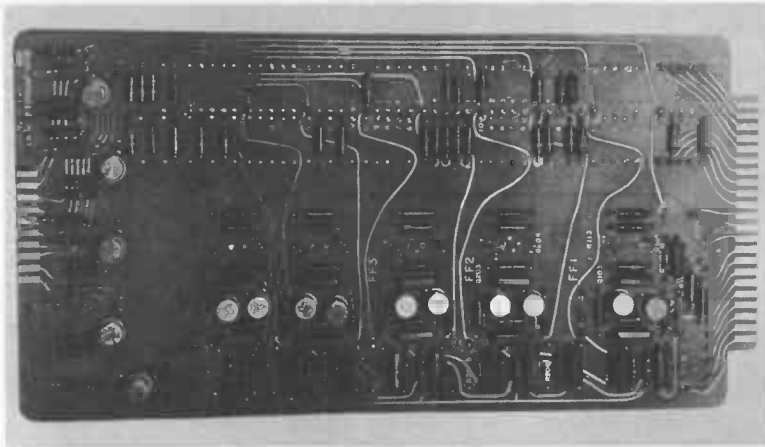
Fig. 1-1. A computer subchassis, using an etched circuit.

cludes a dozen separate circuits on the single board. In use, when any circuit on the board develops a defect, the entire board is replaced with a spare, allowing the system to continue in operation while the original circuit is repaired. Frequently, such boards are offered on the surplus market (from which the one pictured was obtained), and the experimenter has a chance to obtain etched-circuit components at bargain rates.

All etched circuits consist of three parts bonded together as shown in Fig. 1-2. The most prominent of the three is the insulating board itself. It may be made of any of a number of materials; for critical work, epoxy-fiberglass insulating boards are used, but for routine commercial circuits and hobby use the less expensive paper-base phenolic material is adequate. In addition to the board, there
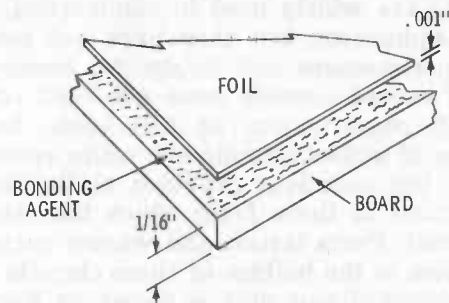

Fig. 1-2. Exploded view of a blank board.

is a copper-foil coating that provides the circuit wiring, once it has been etched into the desired pattern. Most boards have foil 0.001-inch thick; thicker foil, up to 0.003 inch, can be had upon special order in production quantities. The final part, never seen by the user but of great importance, is the bonding agent that holds the foil to the board. The bonding agent is generally heat sensitive. It is capable of withstanding soldering temperatures but will not hold up under them for an indefinite length of time.

To produce the wiring pattern, an insoluble "resist" coating is applied to a blank board in the desired pattern. The resist protects the copper foil directly underneath it. The board is then placed in an etching solution, which dissolves the copper foil from the surface of the board except where the resist has protected it. The result is a copper pattern, exactly the same as the resist pattern, remaining on the board.

The resist may be applied in a number of ways. For experimeters, the "mechanical-resist" and "photo-resist" processes are the most practical. Mechanical-resist techniques are covered in a later chapter. All of the projects in this book are designed for construction by the photo-resist process.

In the photo-resist process, the resist is initially sensitive to light. That is, where light strikes it, an insoluble coating is formed. Thus, the sensitized board must be kept protected from light until it is used. To apply the pattern, the sensitized board is placed in close contact with a photographic negative having the desired pattern and is exposed to light. Where light passes through the negative, the resist becomes hard; elsewhere, it remains unaffected. The board is then placed in a developing solution, which dissolves away the unhardened resist but leaves the resist pattern where it has become hard. After drying, the board is etched and cleaned. It is then ready for use.

Material Required

The sensitized boards, the developing solution, and the etching solution are the only materials required to prepare etched-circuit boards by the photo-resist process. The tools needed include a printing frame (any type of device for holding the negative in firm contact with the board for a period of time up to 5 minutes), an aluminum developing tray large enough to take the board, a plastic or enamel-

ware etching tray of similar size, a photoflood bulb in a reflector, and a clock or watch with sweep-second hand for timing exposures. For washing the boards free of etching solution, a sink is necessary, but it need not be located in the darkroom.

Manufacturers of etched-circuit supplies furnish all the required materials in kits of various sizes, as well as separately. For the initial work with etched circuits, the smallest size of photo-resist kit is recommended. It will provide the trays, print frame, and a beginning supply of boards, developer, and etching solution.

The developer used with most photo-resist materials is an industrial solvent known as trichlorethylene. When a large number of boards is to be processed, this solvent may be obtained from nonelectronic sources at considerable savings over the cost of packaged developer.

The etching solution is a saturated solution of ferric chloride in water. The packaged form is easier to obtain from an electronic supply store than trying to locate a local source of this solution.

Both the developer and the etching solution can be dangerous. Trichlorethylene vapor should not be inhaled, nor should the liquid be allowed to contact the skin if it is possible to avoid it. Overexposure to the fumes will result in a persistent headache: continued overexposure can result in permanent injury.

The etching solution is both corrosive and staining. Its corrosive action on skin is slow enough that it may be rinsed off without harm, but the solution should never be poured down the drain. Instead, it should be flushed away with generous amounts of water. Any spilled etchant should be mopped up and the area flooded with water repeatedly, until no trace of stain remains. The etching solution is one component of many of the older formulas for permanent ink!

Project Negatives

The first step in the production of the board is to obtain the negative. Ready-to-use negatives for all of the projects in this volume are included on the thin paper at the back of this book. Each negative is identified by a two-digit number which appears (mirror-imaged, naturally) somewhere on its face. A typical number would be "3-6." The digit preceding the dash indicates the chapter in which the

project is discussed, while the digit after the dash indicates the project within the chapter. Thus, "3-6" is the negative for the sixth project in Chapter 3, the all-purpose hi-fi preamplifier.

Throughout the book, you will be referred to the proper negative for each project. These negatives can be clipped from the book and used as supplied. However, if you prefer, a photocopy of the negatives can be made. Be sure the conductor lines are clear and the background opaque in any photocopy. Thus, a positive transparency should be specified when ordering. Boards are available in 3×3-inch and 3×6 inch sizes. More than one of the projects can be arranged on a single board and exposed simultaneously.

Exposure and Processing

Exposure and development of photo-process boards require a work area in which the light can be subdued. The boards are primarily sensitive to ultraviolet and can be handled for brief periods under relatively strong incandescent light. However, especially for the initial work with the process, it's safest to darken the work area almost completely, and work under red light from either a photographic safelight bulb or a 40-watt incandescent bulb covered with red cellophane.

Trim the negative (back of books) to size, but leave enough margin around the edges to allow for handling the board during the processing steps.

Next, working under safelight conditions, remove the photo-sensitive board from its light-tight shipping cover. Handle it only by the edges; otherwise, fingerprints may appear in the finished board.

Place the negative(s) on the glass of the printing frame, with the printed side up if you are using the negatives from the book, and with the emulsion (dull) side up if you are using a photographic negative. Be sure the glass is clean and free of dust; a single speck of dust can ruin the board, if it cuts through a conductor line.

Next place the board over the negative, with the copper side of the board in contact with the negative. If you are using the glass-and-clamp printing frame supplied with commercial kits, the blank light-sensitive board itself provides the back pressure. Clamp the board and glass together with the U-shaped clamps, as shown in Fig. 1-3. A photographic-style printing frame may be substituted for
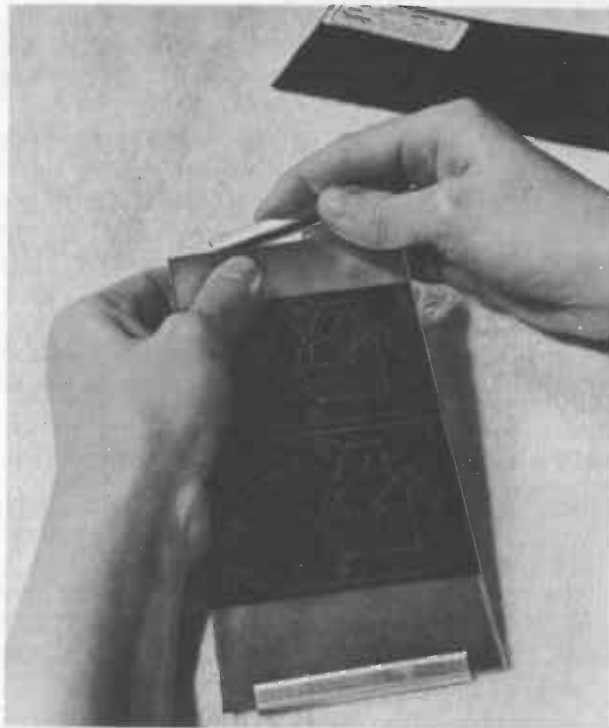
Fig. 1-3. Using a kit-type printing frame.

the one supplied in the kit. With this type of frame, most
of the light sensitive board can be used, and, in addition,
better contact between board and negative is possible. Such
a frame can usually be purchased (used) for less than $2.
As shown in Fig. 1-4, it has a hinged back, which is closed
against the board and secured with a spring-clamp fasten-
ing device.

With the negative and board in the frame, you are ready
to expose the resist. For this, a photoflood bulb in a reflec-
tor (or a reflectorflood bulb, which combines the two) is
used. Position the bulb about 18 to 24 inches above the
printing frame so that the light will hit all parts of the
board with about the same strength.

The exposure time will depend on the size of the bulb and
the distance from the bulb to the frame. About 4 minutes
is a good starting point for the first exposure. The goal is
to expose long enough for all the desired pattern to fully
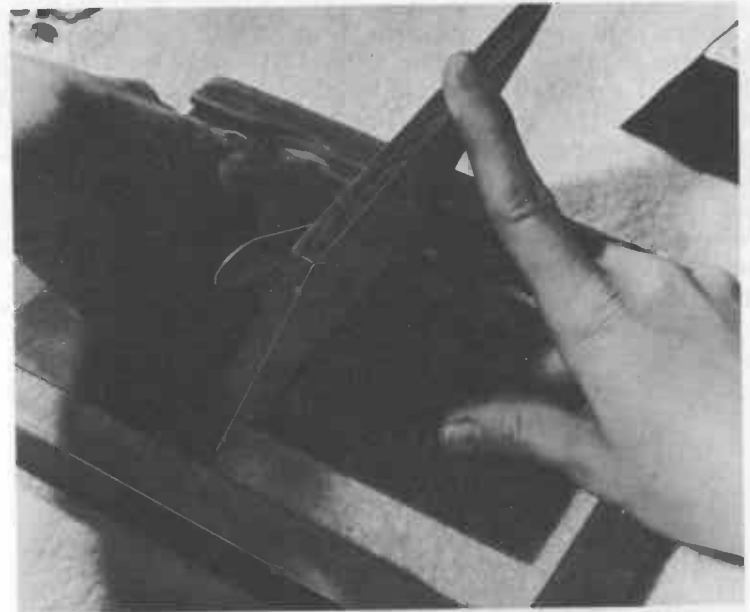harden, yet not so long as to allow hardening of the resist

Fig. 1-4. Using a photographic printing frame.

in the protected areas of the board. Too short an exposure
time will result in "dropout" of fine detail, while too long
an exposure will make the lines too broad. Actually, the ex-
posure time is not very critical; it can usually vary over at
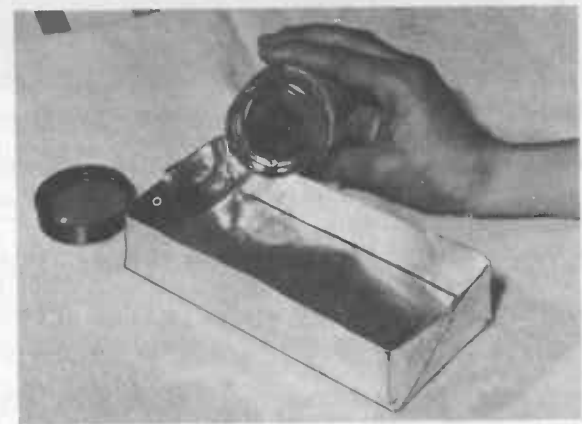least a 2-to-1 ratio with no difference in results.

Fig. 1-5. Developing the exposed board.

After exposure, remove the board from the frame and immerse it in the developer (Fig. 1-5). Make sure that all the board surface is covered, and agitate the developer by rocking the tray gently during this step. Leave the board in the developer for 60 seconds, then tip the tray so the developer is shifted to one end, and lift the plate free. *Do not touch the face of the board* while it is wet with developer; the "hardened" resist is extremely soft at this point. Fig 1-6 shows what happens to the resist coating; in this example, it was deliberately picked up by grasping
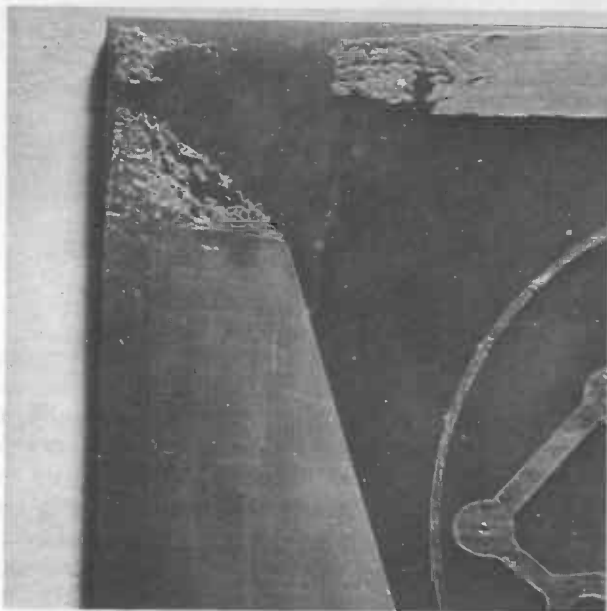

Fig. 1-6 The effect of touching the (unhardened) resist.

the corner instead of the edges. The photograph was made after etching, but shows clearly how the touch of a finger removes the resist pattern.

Allow the developed board to drain and then to air dry. Do not shake the board or blow on it to hasten drying. The developer evaporates within 45 seconds anyway, and any disturbance while the resist is wet may damage the pattern.

Do not reuse the developer more than once. Extended use of the developer will result in the formation of a mysterious coating of resist over the surface of the boards

that will prevent proper etching. If any boards appear to have resist on them anywhere except where light struck them during exposure, discard the developer and clean the developing tray with a small amount of fresh developing solution on a cotton ball.

When the developed board is dry, it is ready to etch. Pour enough etching solution into the etching tray to completely cover the face of the board, and immerse the board

Fig. 1-7. Etching the board.

with the copper side up, as shown in Fig. 1-7. The copper will immediately turn dark, except where protected by resist. Allow the etching to continue until all the copper not protected by resist is etched away; this will take from 30 to 90 minutes at room temperature. For faster etching, the etching solution may be heated to approximately 200° F (simmering point). At this temperature, the average etching time is reduced to 15 minutes.

As the etching proceeds, the solution discolors until it becomes opaque. However, the solution is usable as long as it will dissolve copper.

Take care not to over-etch. Be especially careful when using hot etching solution. Etching too long will destroy
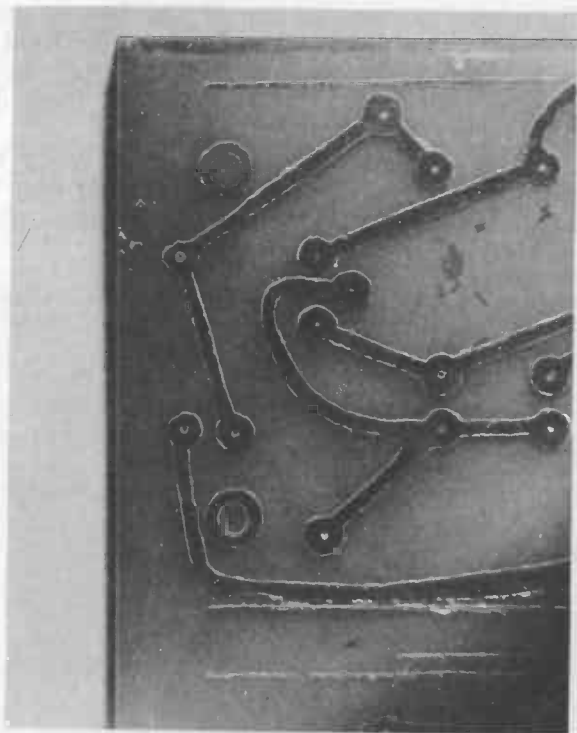
Fig. 1-8. An over-etched board.

fine detail in the circuit pattern and weaken the foil due to undercutting of the edges. Fig. 1-8 shows an over-etched board. Etching for too short a time is even worse than over-etching. Fig. 1-9 shows the effects of under-etching; the remnants of copper foil remaining can short-circuit the project.

A properly etched board is shown in Fig. 1-10. Other defects which may occur are shown in Figs. 1-11 and 1-12. Fig. 1-11 shows dropout of resist resulting from an air bubble on the board during the developing process. Fortunately, in this case, there was no serious damage to the board—a complete copper path still exists around the bubble. Fig. 1-12 is the result of a speck of dust in the printing frame, which cut a conductor line. This defect can be remedied by flowing solder over the break, but it is better to avoid it in the first place.

After etching is completed, the board should be washed (Fig. 1-13) for 5 minutes (or until all traces of discolora-

tion in the wash water disappear), and dried. The board is then ready for the mechanical work.

Cutting, Drilling, and Cleaning

All mechanical work on a phenolic-base etched circuit board can be done with ordinary hand tools. All holes should be drilled before the board is cut to size, because
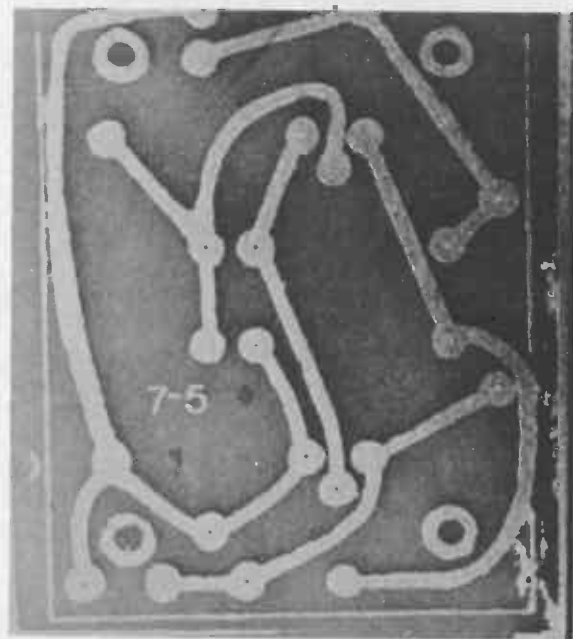

Fig. 1-9. An under-etched board.

this leaves a larger workpiece to use with the drill. A No. 60 drill is used for drilling the holes for parts leads. These tiny drills are somewhat more fragile than the larger sizes more conventionally used, but with a little caution they can be successfully used in an ordinary electric drill. Simply be sure that the drill bit (which is only .040-inch in diameter) is never stressed sideways, or allowed to carry the weight of the drill motor.

The one essential of tools used to cut and drill circuit-board material is that they be sharp. The phenolic board stock is rather brittle, and it breaks easily. Sharp tools, carefully used, will prevent any problems.

Because of the brittleness of the board, do not attempt to punch or break it. Instead, saw and drill. For large holes, drill a number of small holes with 1/8-inch or 1/4-inch bits; then use a fine-tooth coping saw to cut the large opening.
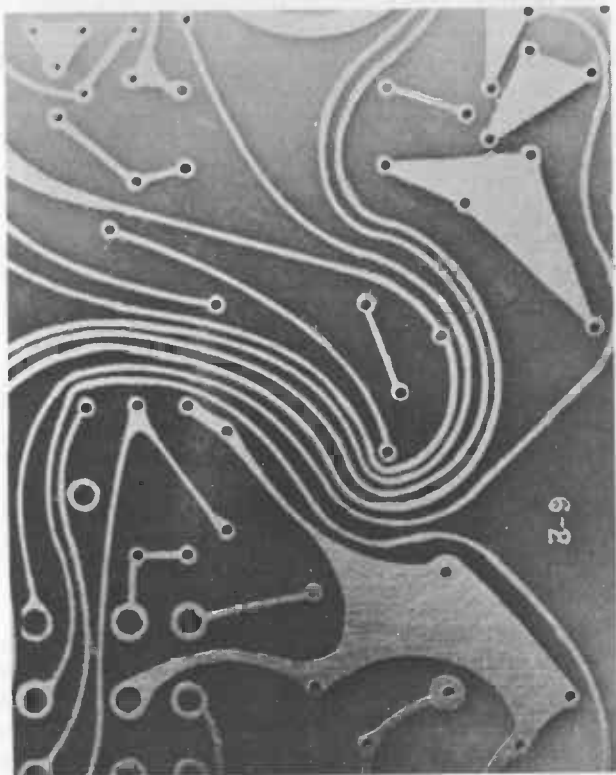

Fig. 1-10. A properly-etched board.

The author's set-up for drilling parts-lead holes is shown in Fig. 1-14. It consists of an inexpensive hand drill and drill-press accessory frame.

No. 60 drills are not commonly stocked by either hardware stores or electronics parts houses, but industrial-supply hardware dealers have them. Lacking one of these establishments, try a hobby shop; model makers have frequent need for such small-size drill bits. If No. 60's cannot be found, larger bits can be used; however, the smaller the hole, the more firmly the component will be held during assembly, and a No. 60 makes a hole just large enough for

resistor leads (all other components have smaller-diameter leads than resistors).

After all holes are drilled, cut the board to size. Clamp it in a vise and use a hacksaw with a fine-pitch blade, similar to that used for a thin aluminum sheet. Fig. 1-15 shows a board being cut.
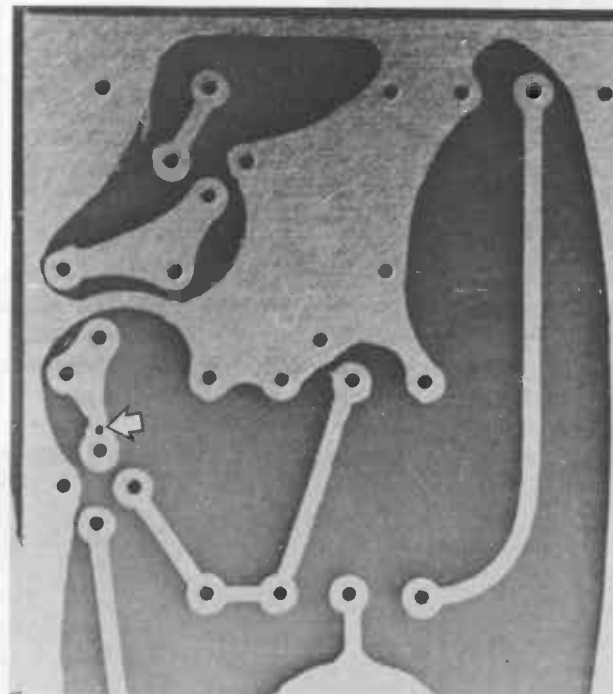

Fig. 1-11. The effect of a bubble on the board.

The final step before installation of components is to clean the resist from the copper wiring pattern. Board manufacturers recommend scouring with steel wool, under running water (Fig. 1-16). This not only removes the resist, but de-burrs the parts-lead holes. However, the resist can also be removed by scrubbing with a cotton ball soaked in developing solution. Once the resist is removed, the copper surface will begin to tarnish. If the board is to be stored some time before use, leave the resist on it until assembly time. A summary of the steps in the preparation of etched boards is given in Table 1-1.
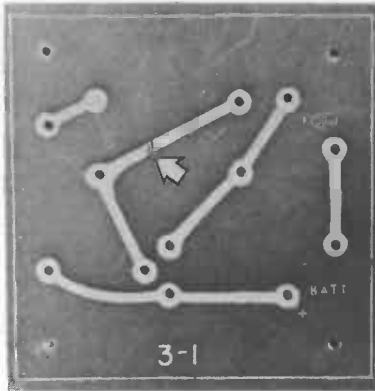
Fig. 1-12. A cut conductor
caused by a dust particle
on the board.

Final Assembly

With the board itself complete, final assembly of the project consists simply of bending parts leads to shape, inserting the leads through the proper holes, soldering them to the wiring pattern, and clipping off the excess lead lengths.
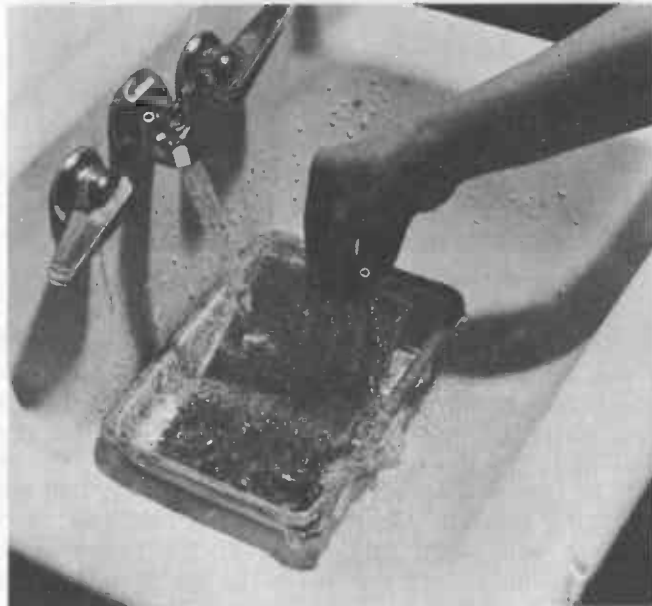

Fig. 1-13. Washing the etched board.

Table 1-1. Summary of Steps in Preparation of Etched Boards

Step	Description of Action
1	Place the negative and board in printing frame, with printed side of negative away from glass and in contact with copper side of board. Be sure negative makes good contact with board.
2	With glass up, expose for approximately 4 minutes to No. 2 photoflood (2 minutes to No. 2 reflectorflood) at distance of 18 to 24 inches.
3	Develop board for 60 seconds with constant agitation. Do not touch face of board while it is wet with developer.
4	Allow board to dry (about 45 seconds). Do not shake or blow to speed drying.
5	Etch until all unprotected copper is removed. About 30 to 90 minutes if etching solution at room temperature; about 15 minutes if solution is kept heated to simmering point. Discoloration is normal.
6	Wash board until water runs clear. Wipe dry.
7	Drill parts-lead and mounting holes with sharp No. 60 drill. Use larger drills for coil-form holes and mounting screws, after starting with No. 60.
8	Cut board to size with sharp hacksaw. Take care to avoid chipping or breaking brittle board material.
9	Remove resist from board by scrubbing with steel wool under running water or by scouring with developer-soaked cotton ball. Wipe dry.
10	Install all components.
11	Solder component leads, using hot iron and working quickly to avoid softening board bonding agent. Allow board to cool after soldering.
12	Clip off excess lead length with flush-cutting pliers.

In most cases, component leads can be bent at right angles close to the component body, as shown in Fig. 1-17. Transistor leads should be straightened out so that they fit the holes directly.

If you are substituting transistor types, you may find that the type you are using does not have the same lead arrangements as the TO-5 and TO-33 configurations for which these negatives are prepared. However, this is no problem. Fig. 1-18 shows the lead configurations of the TO-5 (3-lead) and TO-33 (4-lead) cases as used here. If your transistors have different lead arrangements, simply insulate the leads with 1/2-inch lengths of sleeving and route the proper leads of the transistor to the appropriate holes in

the board. To facilitate replacement of defective transistors and to try out different transistors in these projects, transistor sockets can be soldeered into the circuit pattern instead of the transistor leads.

Components should be pushed down snugly against the noncopper side of the board, for neatest appearance and best protection against vibration. Due to the size of capacitors, their leads must be bent down and under the capacitor

Fig. 1-14. Drilling holes in the etched board.

to reach their respective hole on the circuit pattern. Grasp the lead with long-nose pliers close to the capacitor before starting the bend, moving the pliers to each succeeding bend in the lead. In these cases, draw up the leads as snugly as possible.

To hold components in place while soldering, bend the leads slightly outward on the copper side of the board. To

Fig. 1-15. Sawing the board to size.

Fig. 1-16. Removing resist and deburring holes on completed board.

prevent the foil from separating during the soldering operation, use a small, hot iron and work rapidly. If each joint is made in 10 seconds or less, no difficulty with softening should be encountered.
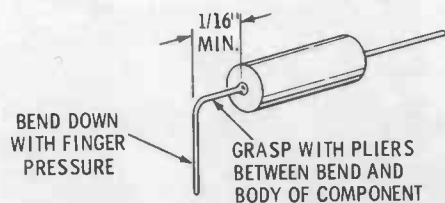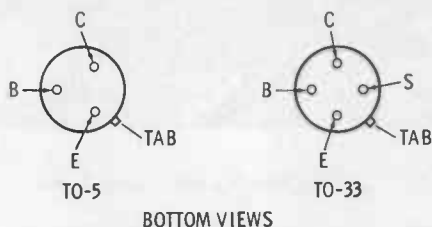

Fig. 1-17. Bending component leads.

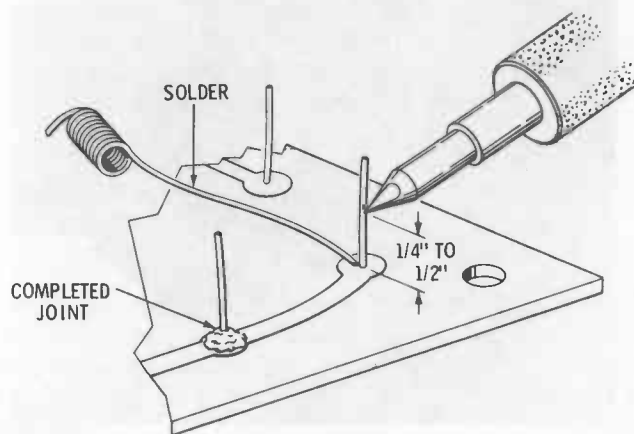Fig. 1-18. Transistor lead configurations.

Fig. 1-19. Method of soldering leads to board.

A trick which helps get a good connection is to apply the tip of the iron to the component lead (not to the copper foil) about a half inch above the foil surface (Fig. 1-19). The lead is allowed to become just hot enough to melt the solder at the foil. As soon as the solder flows out into a uniform fillet on the foil surrounding the lead, the iron is removed and the joint allowed to cool. Avoid excess solder, since it can short adjacent circuit patterns.

After all joints are cold, clip off the excess lead length with diagonal cutters, and the assembly is complete.

Connections from the board itself to external components, such as input or output connectors, are best made with stranded wire. In most cases, this wire need not be insulated.

When mounting the board in a box, do not depend on the mounting hardware to provide a good ground if one is needed. Prepare a jumper strip consisting of two solder lugs connected by a length of stranded wire. Place it on one mounting bolt so that one lug contacts the board foil and the other contacts the metal box.

Explanatory Note

The projects described in this book, are intended primarily for etched-circuit construction. However, they may be built following standard point-to-point wiring techniques as well. If you do it this way, attempt to maintain substantially the same parts arrangement and wiring routes; otherwise, especially when dealing with r-f energy, results may not be what you expect. Once you work with the etched circuit, though, it is extremely unlikely you will ever want to return to "conventional" point-to-point wiring!
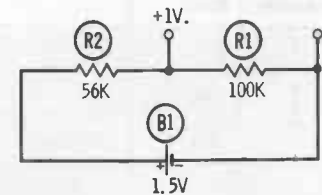
Chapter 2

Starter Projects

The three projects described in this chapter are intended to familiarize you with the photo-resist etched-circuit process, but all three are also highly useful items for experimenters and service technicians. Don't let apparent simplicity keep you from building them!

The Volter

Simplest of all is "The Volter," a 1-volt reference unit for vtvm calibration. As shown in the schematic diagram (Fig. 2-1), it consists of only two resistors, a penlight cell,

Fig. 2-1. Schematic of the Volter.

the circuit board, and a battery holder. Its accuracy depends primarily on the tolerance of the resistors, and can reach three significant figures (1 ± 0.01 volt) with 5-percent resistors.

The circuit (Fig. 2-1) consists of a voltage divider, made up of a 100K and a 56K resistor in series. The total resistance is 156K, while the no-load voltage of a fresh dry cell is 1.56 volts. With the 156K load, the current drawn from the cell is 10 microamperes, so small that the voltage re-

mains virtually at its no-load value. The 10-microampere flow through the 100K resistor produces a 1-volt drop for meter calibration.

The same circuit and board can be used for calibration of vom's by changing the resistance values to 1000 ohms for R1 and 330 ohms for R2, and using a 1.34-volt mercury cell. This version, however, will discharge the cell much more rapidly so that the cell should be removed except when the unit is in use.

The Volter requires a 1-1/8 × 2 inch piece of circuit board, plus an additional 1/4-inch on each side for the clamps which hold the board and glass together during exposure (if you use the glass-and-clamp type of printing frame; see Chapter 1). The smallest standard-size photosensitive board is 3 inches square. This material can be cut to smaller sizes if you work in red light only and do not touch the sensitive surface, but it is simpler to expose and etch several circuits at a time, choosing them to fit into the available area.
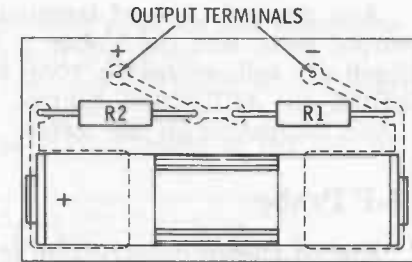
All three projects described in this chapter are arranged together for exposure at the same time on a single 3 × 3 board. The projects for other chapters, however, are presented individually and fitting together for multiple exposure is left to you, since only you can determine which projects you want to build at one time.

Table 2-1. Parts List for The Volter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 2-1)
1	B1	1.5-volt penlite cell
1	R1	100,000-ohm, 1/2-watt resistor
1	R2	56,000-ohm, 1/2-watt resistor
1	—	Penlite cell holder (Keystone Type 171 or equiv.)

To build the Volter, gather the parts listed in Table 2-1 and Negative 2-1 from the back of the book. Expose and etch the board as described in Chapter 1. After the board is drilled, cut to size, and cleaned of resist, bend the component leads and insert the leads from the blank side of the board, following the parts layout shown in Fig. 2-2. Then solder the leads to the etched "pads" as described in Chapter 1. When all four connections are soldered, clip off excess leads.

Fig. 2-2. Parts layout for the Volter.

The battery holder mounts by folding the end terminals (after rotating the terminals 180° from their normal position) over to lay against the large etched pads, on the bottom, and soldering the bent-over tips as shown in Fig. 2-3. The completed unit is shown in Fig. 2-4.
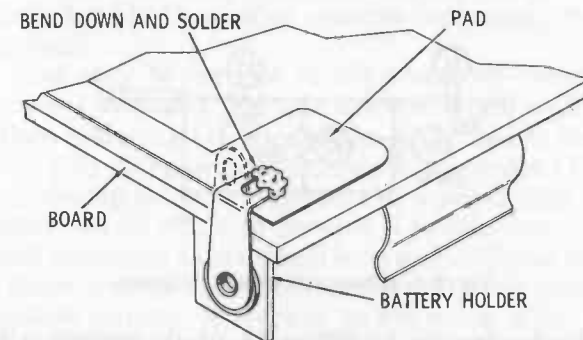

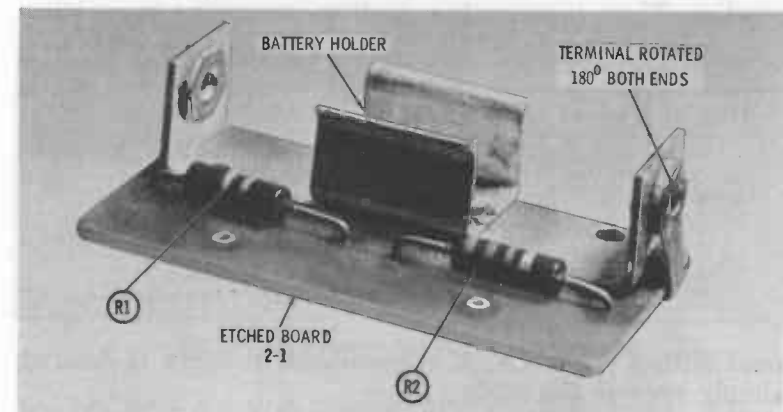Fig. 2-3. Attaching battery holder to board.

Fig 2-4. The completed Volter.

Any desired type of terminals can be connected to the output pads, and the Volter is finished. To use it, insert a fresh dry cell, connect a vtvm to the output terminals, and adjust the calibration control of the meter for an exact 1-volt indication on the meter.

R-F Probe

Etched-circuit construction is ideal for a vtvm or oscilloscope r-f probe because of the inherently low capacitance and built-in shielding action of the construction. This probe is a half-wave peak-detection device, giving accurate indications beyond 200 mc. The diode is used as a shunt detector, as shown in the circuit of Fig. 2-5. The probe can be used
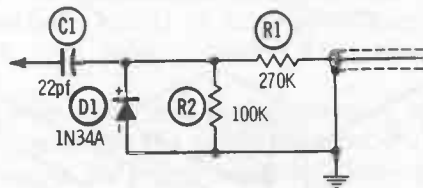

Fig. 2-5. Schematic of the r-f probe.

in circuits having up to 500 volts (d-c) present, although maximum r-f voltage should be kept below 50-volts peak.

Unlike most commercial probes, the output voltage is positive. Thus, it presents a positive-increasing trace when

Table 2-2. Parts List for R-F Probe

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 2-2)
1	C1	22-pf ceramic capacitor (radial leads)
1	DI	Type 1N34A crystal diode
1	R1	270,000-ohm, 1/2-watt resistor
1	R2	100,000-ohm, 1/2-watt resistor
1	—	3-foot length RG-58A/U coaxial cable

used with a d-c scope; if conventional polarity is desired, simply reverse the diode.

The parts required for the probe are listed in Table 2-2. Etching (using Negative 2-2) is done as described in Chap-

ter 1; if all three starter projects were etched simultaneously, you already have the board prepared.

Attach and solder the two resistors and the tubular ceramic capacitor first, following the layout diagram in Fig. 2-6. Then attach the coaxial cable that connects to the test in-
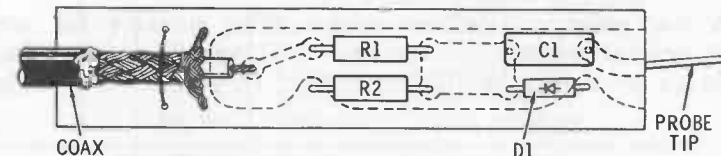

Fig. 2-6. Parts layout for the r-f probe.

strument. RG-58A/U is recommended for the cable, since it is more flexible than other quarter-inch coax. Its length is not critical.

The coax may be secured to the board by "sewing" the hookup wire over and into the shielded braid and into the holes, then soldering the wire to the braid and to the circuit foil (Fig. 2-6) or running the shield to the holes (Fig. 2-7).

The probe tip is made from part of a paper clip, cut with side-cutters at an angle to provide a needle-sharp tip. The other end is formed into a small loop and soldered to its pad.

The diode is connected last to protect it from excess heat. For positive output, connect it as shown in Figs. 2-6 and 2-7. No heat sink is necessary while soldering, if you work rapidly.
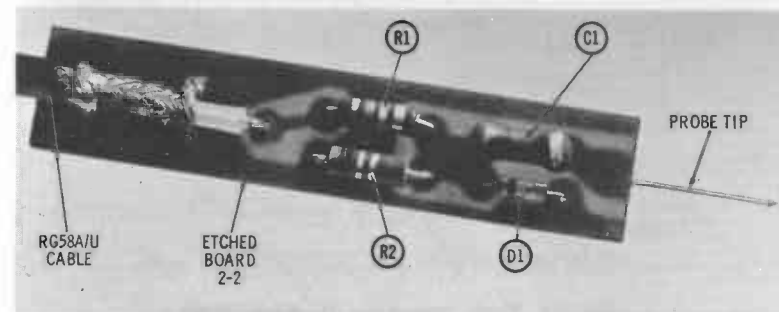

Fig. 2-7. The completed probe, less housing.

The probe housing can be made from 5/8-inch tubing, two 7-pin tube shields, or tin stock. Whatever you use, bond the housing to the ground area of the board, and wrap

the completed probe with insulating tape for both protection against shock and appearance. Front and back openings may be sealed if desired with epoxy auto-body putty.

Mike Preamplifier

A low noise microphone preamplifier suitable for use with crystal, ceramic, or dynamic microphones of any impedance level and having an output in excess of a high-
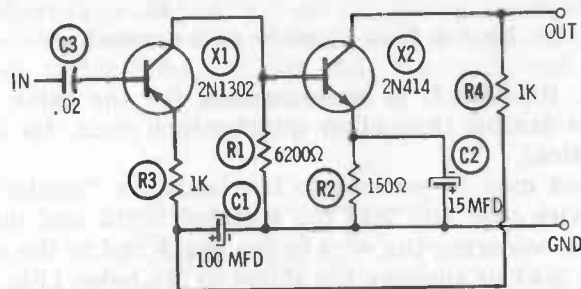

Fig. 2-8. Schematic of the microphone preamplifier.

output carbon button has many uses. It is the third of our starter projects and illustrates how the etched circuit process converts a rather complex parts arrangement (Fig. 2-8) into a simple soldering task.
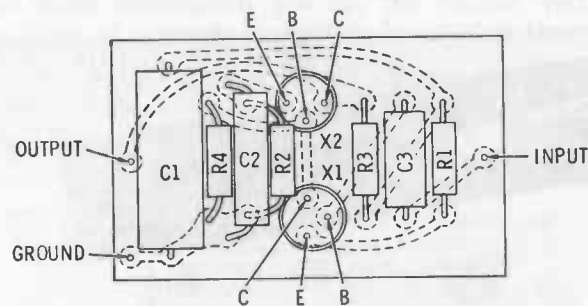

Fig. 2-9. Parts layout for the microphone preamplifier.

Etch the board (using Negative 2-3) as described in Chapter 1. The four resistors are mounted in place as shown in Fig. 2-9 and then soldered. Next, connect the three capac-

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Table 2-3. Parts List for Microphone Preamplifier

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 2-3)
1	C1	100-mfd 15WVDC electrolytic capacitor
1	C2	15-mfd 15WVDC electrolytic capacitor
1	C3	.02-mfd 200WVDC paper capacitor
1	X1	Npn transistor, 2N1302 or equiv.
1	X2	Pnp transistor, 2N414 or equiv.
1	R1	6200-ohm, 1/2-watt resistor
1	R2	150-ohm, 1/2-watt resistor
2	R3, R4	1000-ohm, 1/2-watt resistors

itors, being sure to observe polarity on the two electrolytics. Finally, install the two transistors.

While the board is laid out so that the transistors may be soldered directly into the circuit, and the prototype was constructed in this fashion, as shown in Figs. 2-10 and 2-11, experimenters may prefer to solder transistor sockets into the board and then plug in the transistors. This can be done
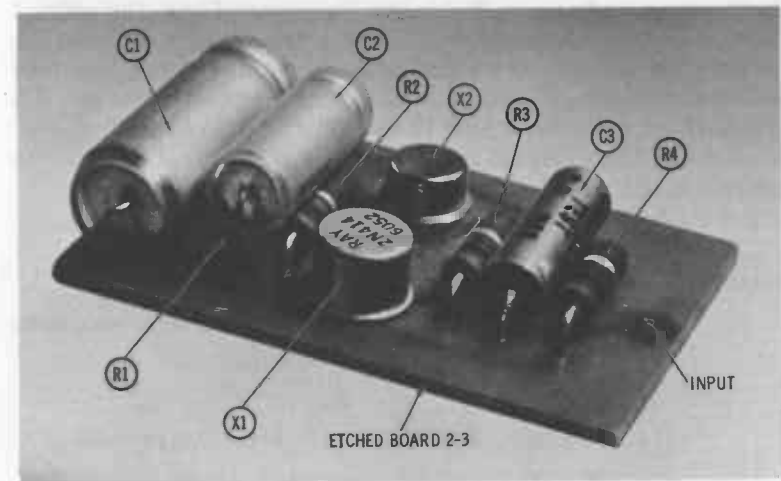

Fig. 2-10. Top view of the microphone preamplifier.

with no change, if the unused lead or leads on each socket is clipped off. (This modification may be made on all circuits in this volume with the exception of Project 6-1.) When installing transistors, be sure that the pnp and npn units are not accidentally transposed.
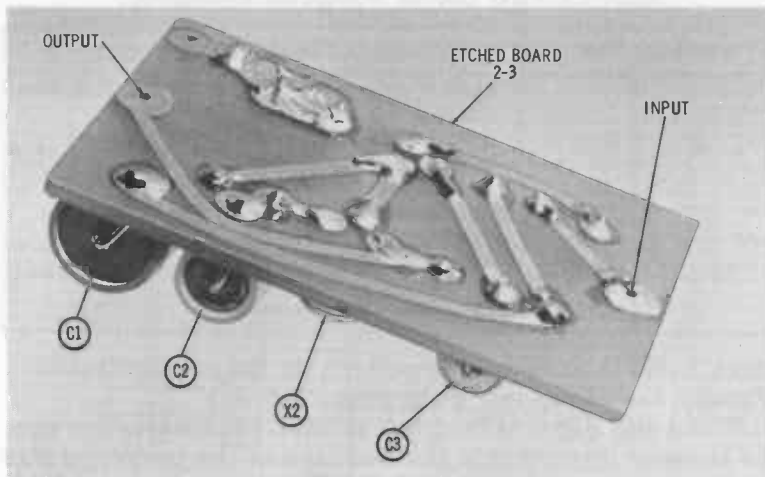
33

Fig. 2-11. Bottom view of the microphone preamplifier.

This circuit was originally designed to replace a carbon-button microphone and obtains its power from the output terminal. When using it in this manner, simply connect the output terminal to the existing carbon-mike input line and be certain that the voltage at this point is positive to ground (anywhere between 3 and 12 volts). For other applications, add one of the external power-and-signal separation circuits shown in Fig. 2-12.

(A) R-c coupling.   (B) Transformer coupling.

Fig. 2-12. Power/signal separation circuits.

Use of this preamp is not confined to microphones. It will amplify any a-c signal in the 1-to-30 millivolt region and in the frequency range from 50 cps to 15 kc. It can also be used as an instrument amplifier. The exact gain will depend on the individual transistors used and the supply voltage. For its intended purpose, the gain of the amplifier is ample and free of audible distortion.

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Audio-Frequency Projects

When transistors first appeared on the scene, most were for operation at audio frequencies. Although modern transistors function nicely up into the gigacycles, they still perform many useful functions in the audio range. The six projects in this chapter are for audio use; they range from general-purpose applications to some rather specialized functions.

Headset Booster

While it's not at all complicated, the headset booster amplifier shown in Fig. 3-1 and diagrammed in Fig. 3-2 is

Fig. 3-1. The completed headset booster.

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a handy item for any experimenter or technician. Using a single transistor and a handful of other components (Table 3-1), it will work with any headset from 600-ohms impedance up to 5000 ohms or so, and from any source impedance from 4 ohms on up.

Fig. 3-2. Headset booster schematic.

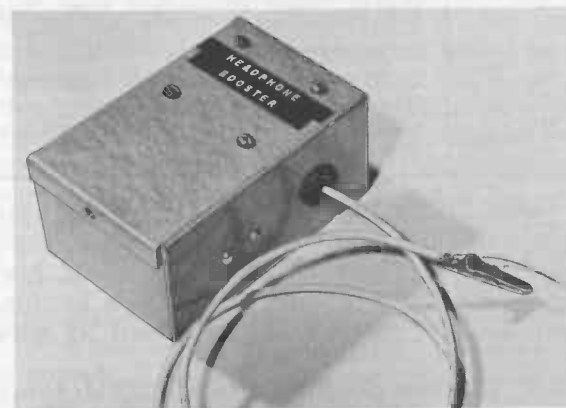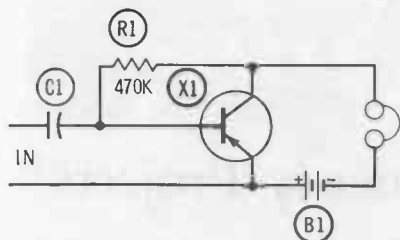The wide range of operating characteristics is made possible through the base-bias arrangement used. The single resistor from collector to base provides both d-c and a-c feedback, as well as bias voltage, so that the transistor automatically adjusts to the proper operating point.

To build the headset booster, etch the board as described in Chapter 1, using Negative 3-1 in the back of the book. Any size case can be used; the one listed in Table 3-1 and shown in Fig. 3-1 provides ample room, but smaller cases can be used if you prefer.

Table 3-1. Parts List for Headset Booster

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 3-1)
1	B1	3-volt battery
1	C1	6-mfd 10WVDC electrolytic capacitor
1	X1	2N404 or equiv. pnp transistor
1	R1	470,000-ohm, 1/2-watt resistor (see text)
1	—	Chassis box (if desired)

After etching, drilling, and cleaning the board, use it as a template to mark the positions for the mounting holes in the box and drill these holes with a 1/8-inch drill. Also drill 3/8 inch holes for the input and output jack at this time. Next install X1, R1, and C1 on the board as shown in Fig. 3-3.

Use 4-36 × 1/2-inch machine screws with 1/4-inch-long spacers to mount the board in the box temporarily while measuring leads from the terminal pads to the jack and

Fig. 3-3. Parts layout for the headset booster.

battery holder. Remove the board from the box to solder the leads; then reassemble and complete the wiring.

No power switch is necessary; removing the phone plug from the output jack disconnects the battery. In use, with some resources, a resistor (not shown) must be connected across the input cable to provide a dc path for the source. The value of this resistor, if used, should be equal to the impedance of the phones with which the source was intended to be used. It can be conveniently mounted in the plug at end of the input cable.

Inexpensive Intercom

This project is a two-transistor intercom, using inexpensive a-f power transistors and low-cost replacement-type speakers. Fig. 3-4 shows the completed board for this project; the complete unit appears in Fig. 3-5.

In this intercom, the speakers function as both speakers and microphones, depending on the position of switch S1— a 4pdt unit. As drawn in Fig. 3-6, speaker SP1 is connected as a microphone to the base of transistor X1, and speaker SP2 is used as a speaker in the collector circuit of X2. When S1 is operated, the connections of the two speakers are reversed. Speaker SP1 is located at the "master" position together with S1 and the board, while SP2 is the "slave" at a remote location. Only two stations may be used in this circuit.

Etch the board (using Negative 3-2) as described in Chapter 1. All lead holes, except those for the base, emitter, and collector connections of the two transistors, are drilled

Fig. 3-4. **Intercom circuit board.**

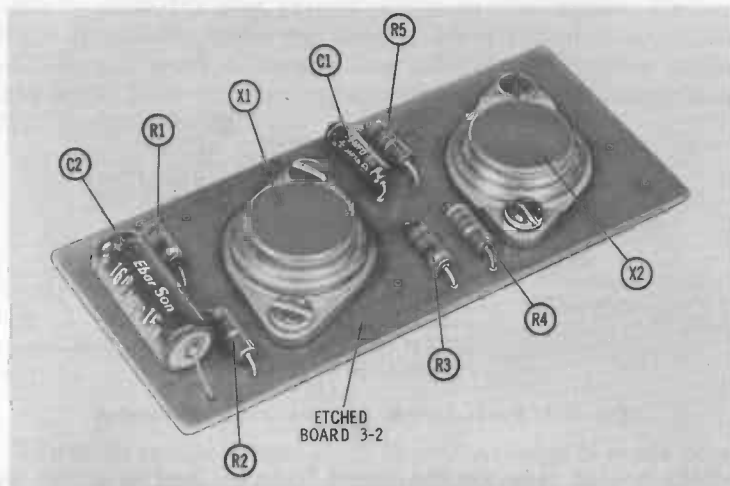Fig. 3-5. **The completed intercom.**

with a No. 60 drill. The base and emitter holes are 1/16 inch in diameter, while those for the collectors are 5/32 inch.

Fig. 3-6. **Intercom schematic.**

Mount the parts (Table 3-2) on the board, following the guide in Fig. 3-7. Solder all connections except the collectors. The collector connections are made by using 6-32 by 1/4-inch machine screws and nuts through the transistor mounting holes.

Note: In the parts layout drawings in Chapter 2, outline drawings of the various components and the proper connections are given. In this and the following chapters, only the connections to the proper holes and parts location are shown. This has been done to simplify the drawings and to prevent confusion resulting from showing the outlines of many parts in a small area.

Table 3-2. Parts List for Intercom

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 3-2)
1	B1	6-volt lantern battery
1	C1	10-mfd 6WVDC electrolytic capacitor
1	C2	160-mfd 15WVDC electrolytic capacitor
2	X1, X2	Pnp a-f power transistor in TO-3 case, such as 2N255, 2N301A, or equiv.
1	R1	470-ohm, 1/2-watt resistor
1	R2	100-ohm, 1/2-watt resistor
2	R3, R5	22-ohm, 1/2-watt resistor
1	R4	1000-ohm, 1/2-watt resistor
1	S1	4PDT switch (Lafayette 99 G 6175 or equiv.)
2	SP1, SP2	3-4-ohm pm speakers
2	—	Speaker boxes
1	—	4-terminal terminal strip
1	—	2-conductor wire from master to remote unit

Fig. 3-7. Parts layout for the intercom.

Next, wire SP1 and S1 as shown in Fig. 3-6, and make the connections for SP2 to a four-terminal barrier strip which will be fastened to the back of the speaker case housing the board, S1, and SP1.

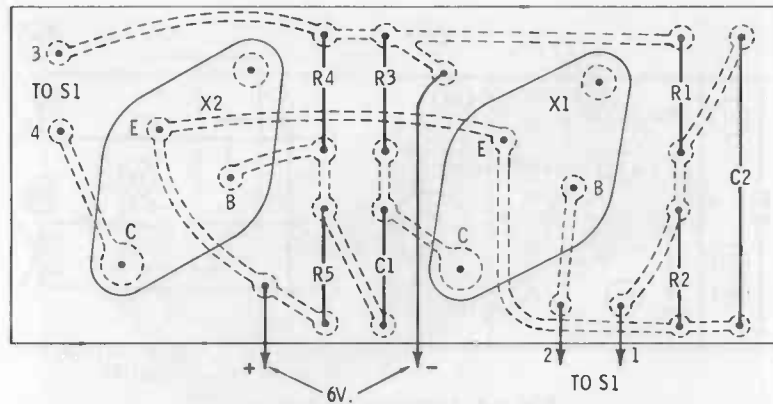Power is furnished by a 6-volt lantern battery; power connections are made to the remaining two terminals of the four-terminal barrier strip. If desired, a low-voltage d-c supply can be built as shown in Fig. 3-8.

Fig. 3-8. Alternate power supply.

To use the intercom, install SP2 in the desired remote location, connect it to its terminal strip, and apply power. Normally, SP2 acts as microphone and SP1 as speaker; to talk from the "master" location, operate S1. Volume is not excessive, but it is ample for most installations.

Three-Channel Mike Mixer

Tape-recording enthusiasts, as well as hams and CB operators who use more than one microphone, frequently find need for a multichannel mixer to allow the sound out-

put from several mikes to be balanced. The three-channel mixer performs this function.

As shown in the schematic diagram (Fig. 3-9), the three inputs are applied directly to separate gain controls (R11,

Fig. 3-9. Three-channel mike mixer schematic.

R12, and R13). The outputs of these gain controls go to transistors X1, X2, and X3 respectively. The three transistors have a common collector and a common emitter resistor, so the three channels all appear at collector resistor R6. From here, they are amplified by X4 and X5 and delivered to output jack J4.

Interaction between channels is virtually nil, and total distortion of the entire circuit is exceptionally low due to the feedback provided by unbypassed emitter resistor R7 and through the loop formed by R2 and C2.

To build the mixer, etch the board (using Negative 3-3) as described in Chapter 1. All lead holes are No. 60, while the corner mounting holes are 1/8-inch diameter. If the mounting technique shown in Fig. 3-10 is followed, only the

two 1/8-inch holes on the "input" side of the board need
be drilled.

Table 3-3. Parts List for Three-Channel Mike Mixer

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 3-3)
1	B1	9-volt battery
5	C1, C3, C4 C5, C6	3-mfd 12WVDC electrolytic capacitors
1	C2	1-mfd 12WVDC electrolytic capacitor
4	J1, J2, J3, J4	Phono connectors
5	X1, X2, X3, X4, X5	Pnp a-f transistors in TO-5 case, such as 2N109 or equiv.
1	R1	470-ohm, 1/2-watt resistor
1	R2	15,000-ohm, 1/2-watt resistor
1	R3	1000-ohm, 1/2-watt resistor
1	R4	100-ohm, 1/2-watt resistor
1	R5	180,000-ohm, 1/2-watt resistor
1	R6	3300-ohm, 1/2-watt resistor
1	R7	150-ohm, 1/2-watt resistor
3	R8, R9, R10	1-megohm, 1/2-watt resistors
3	R11, R12, R13	10,000-ohm audio-taper volume controls
1	—	Chassis box
3	—	Knobs for R11, R12, and R13
1	—	2-terminal barrier strip or battery holder (if small battery is to be used)

Fig. 3-10. The completed three-channel mike mixer.

Fig. 3-11. Parts layout for the three-channel mike mixer.

Mount the components (Table 3-3) on the board (Fig. 3-11) and solder them in place. Install the four jacks, three gain controls, and the battery holder as desired, following the general arrangement shown in Fig. 3-10. Mount the board by using two small angle brackets, cut and bent from scrap aluminum.

Wiring the jacks to the gain controls, the gain controls and output jack to the board terminals, and connecting the battery completes the construction. No switch is used in this unit. The battery drain is low enough that the possibility of forgetting to turn the unit "on" during a complicated recording session outweighs the shortening of battery life. However, if you prefer, connect a spst slide switch in series with the battery, or substitute a switch-type gain control for R11—there's ample room.

An Active Filter

The device shown in Fig. 3-12 is an "active filter," which uses frequency-selective feedback to provide filter action.

Fig. 3-12. The completed active filter unit.

It has uses in communications (to reduce reception of interfering c-w signals) and for special effects in recording.

The circuit shown in Fig. 3-13 employs a single transistor with a parallel-T network in its collector circuit. The output of this network is fed back to the transistor input in such a manner that gain is reduced.

Fig. 3-13. Active filter schematic.

However, at one frequency (known as the "null"), the parallel-T network blocks signal transfer. Thus, at this frequency, no feedback is present and full stage gain results.

Selectivity is controlled by varying the series base resistance (R2), while some control of frequency is possible through varying resistance in the parallel-T (R8). With the values listed in Table 3-4, the frequency range is from about 900 cps (maximum-resistance setting of R8) to around 2000 cps (R8 maximum).
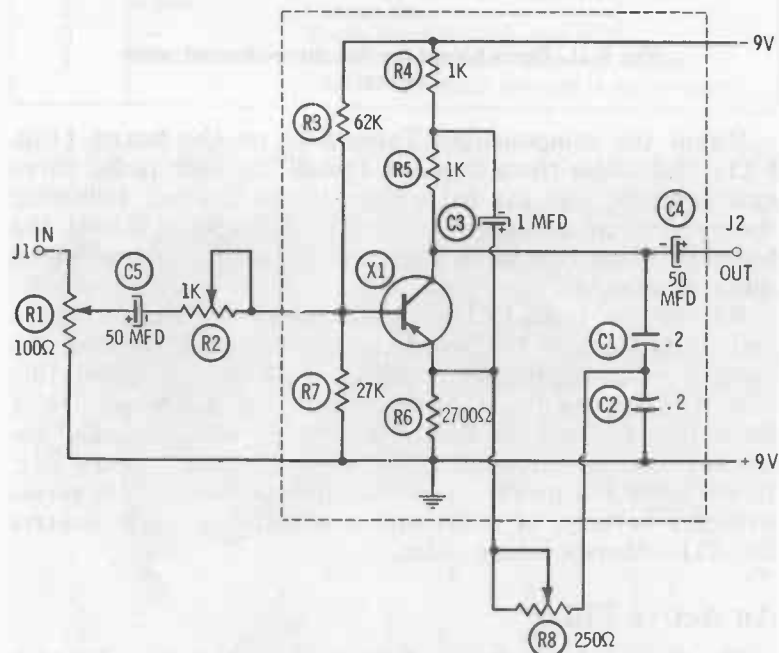
Table 3-4. Parts List for Active Filter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 3-4)
1	B1	9-volt battery
2	C1, C2	.2-mfd 75WVDC capacitors*
1	C3	1-mfd 15WVDC electrolytic capacitor*
2	C4, C5	50-mfd 15WVDC electrolytic capacitors
2	J1, J2	Phono connectors
1	X1	Pnp a-f transistors, such as 2N404 or 2N107 (different lead arrangement, see Chapter 1)
1	R1	100-ohm, linear-taper potentiometer
1	R2	1000-ohm, linear-taper potentiometer
1	R3	62,000-ohm, 1/2-watt resistor
2	R4, R5	1000-ohm, 1/2-watt resistors
1	R6	2700-ohm, 1/2-watt resistor
1	R7	27,000-ohm, 1/2-watt resistor
1	R8	250-ohm, linear-taper potentiometer
1	—	Chassis box
1	—	Battery clip
3	—	Knobs for R1, R2, and R8

*Values for center frequency of 1100 cps; see text for other frequencies.

Some interaction exists between R1, R2, and R8, but the effects are not serious.

When R8 is adjusted for operation at 1250 cps, the response of the circuit is 6 db down at 600 and 2400 cps. At frequencies farther removed from the null, rejection is approximately 20 db. This response is adequate to provide many special audio effects, such as simulating the sound of a telephone voice.

To build the active filter, etch the board (using Negative 3-4) in Chapter 1, and mount all components except the gain controls and C5 as shown in Fig. 3-14. Mount the input and output jacks and the three controls in the box, and wire them as shown in Fig. 3-13. As in the previous project, the
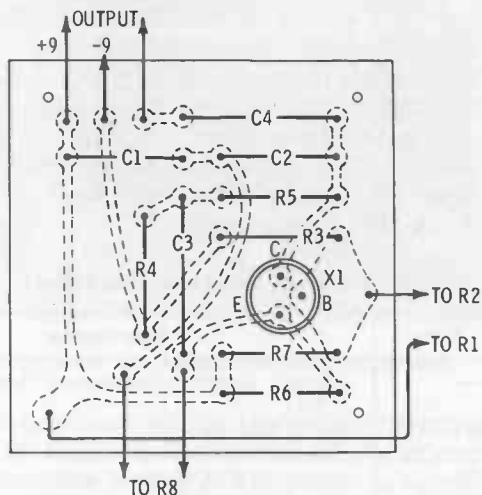
Fig. 3-14. Parts layout for the active filter.

board is mounted in the box by the use of angle brackets. No switch is used; one could be attached to either R1 or R8 if desired.

In operation, set R2 to minimum resistance, and adjust R8 for maximum response at the desired frequency. If different frequency coverage is desired, the values of C1, C2, and C3 may be changed; doubling the values of these capacitors will halve the frequency, and vice versa.

If the unit oscillates, increase the resistance of R2. This resistance can also be increased to provide a wider response. For maximum response, operate the unit with R1 at the lowest setting which provides sufficient output.

General-Purpose Amplifier

For many uses, the general-purpose amplifier shown in Fig. 3-15 is a handy item to have around. Using only three inexpensive transistors and a single transformer, it can provide up to 1 watt output at reasonable audio quality.

The circuit, shown in Fig. 3-16, uses one transistor (X3) as an emitter follower to provide reasonable values of input impedance. The second transistor (X2) is a driver, while the output stage (X1) operates class-A and has the speaker voice coil as its only collector load.

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Fig. 3-15. The completed general-purpose amplifier.

Fig. 3-16. General-purpose amplifier schematic.

While 1-watt output levels may be obtained by using a 12-volt supply, for most uses the output given with only three flashlight cells is ample. With this lower voltage the output transistor runs much cooler.

With 4-1/2 volts supply, the total current drain is only 100 milliamperes, and the output is about 1/4 watt. Raising the supply voltage to 6 volts increases the output to 1/2 watt, but the current drain is 250 ma. This results in some heating of the output transistor.

The amplifier can be driven from any source which supplies about 1 volt of audio. It's a natural to operate from a crystal or ceramic phono pickup, or with the mike preamp of Chapter 2.

To build the unit, etch the board (using Negative 3-5) as described in Chapter 1, and mount the components (Table 3-5) in place. The output transistor (X1) is mounted in the same manner as the transistors of the "inexpensive

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Table 3-5. Parts List for General-Purpose Amplifier.

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 3-5)
1	B1	6- or 12-volt lantern battery (see text)
1	C1	.25-mfd 75WVDC ceramic capacitor
1	C2	30-mfd 15WVDC electrolytic capacitor
1	X1	Pnp a-f power transistor in TO-3 case, such as 2N255, 2N301A, etc.
2	X2, X3	Pnp a-f transistors in TO-5 case, such as 2N109, etc.
1	R1	2700-ohm, 1/2-watt resistor
2	R2, R3	100-ohm, 1/2-watt resistor
1	R4	5000-ohm, audio-taper potentiometer
1	R5	270,000-ohm, 1/2-watt resistor
1	T1	Output transformer, 500 ohms CT to 8 ohms (1/2 primary used), miniature type (Argonne AR-164 or equiv.)
1	SP1	Speaker (3-16-ohms impedance)
1	—	2-terminal barrier strip

Fig. 3-17. Parts layout for general-purpose amplifier.

intercom" described earlier in this chapter. Fig. 3-17 shows parts locations. As specified in Table 3-5, the speaker impedance can be between 3 and 16 ohms. With a lower impedance the power is greater, but with a higher impedance the quality is better.

The transistor transformer is the only new mounting problem. Drill holes to fit its mounting feet, and either bolt or press them over (depending on the transformer you obtain). Take are not to drill through a conductor line, or short out the conductors, when doing this. Epoxy cement can also be used for mounting the transformer.

When connecting the speaker to the output terminals, take care not to short it out to the transistor case. The clearance is not excessive, but it is ample if you're cautious about melting insulation off the wires.

To use the amplifier, connect the audio source through a shielded cable to the input terminal, and adjust the volume to suit. If distortion appears, reduce the level at the source. Distortion should not be a problem with most sources, however, since nearly 2 volts input are required to run the input transistor into distortion.

All-Purpose Hi-Fi Preamp

For high-fidelity use, transistors have a number of advantages over tubes, including freedom from hum, excessive noise, and microphonics. The three-transistor preamp shown in Fig. 3-18 makes full use of these advantages, and adds some of its own over many preamp circuits. Table 3-6 lists the parts necessary to construct the unit.

Fig. 3-18. The completed hi-fi preamp.

Equalization—a necessary function in any preamp—is done entirely by feedback, which both reduces distortion to an almost unmeasurable level and offers rapid change

Table 3-6. Parts List for Hi-Fi Preamp

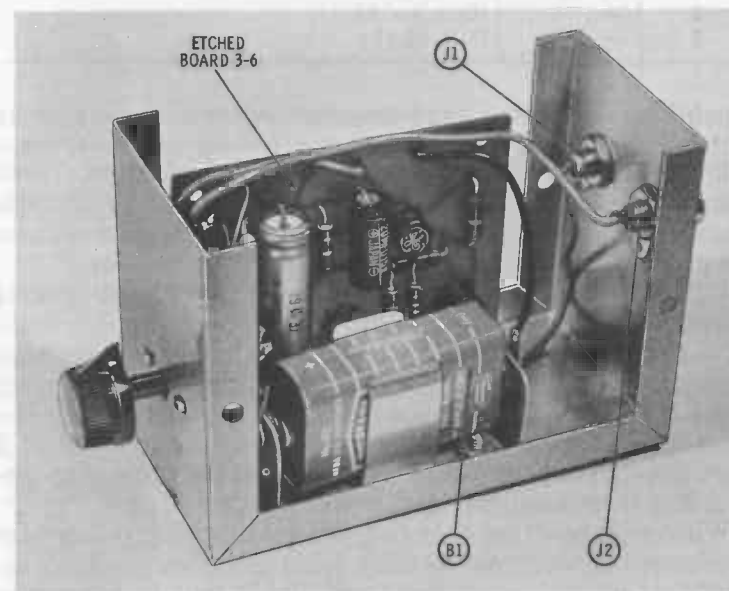| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 3-6)
1	B1	22-1/2-volt battery
2	C1, C4	20-mfd 15WVDC electrolytic capacitors
1	C2	100-mfd 6WVDC electrolytic capacitor
1	C3	200-mfd 3WVDC electrolytic capacitor
	E1, E2, E3, E4	See Table 3-7
2	X1, X2	2N508 transistors (do not substitute)
1	X3	2N322 transistor (do not substitute)
1	R1	5000-ohm, audio-taper potentiometer
1	R2	8200-ohm, 1/2-watt resistor
1	R3	100-ohm, 1/2-watt resistor
1	R4	27,000-ohm, 1/2-watt resistor
1	R5	100,000-ohm, 1/2-watt resistor
1	R6	18,000-ohm, 1/2-watt resistor
1	R7	47-ohm, 1/2-watt resistor
1	R8	1800-ohm, 1/2-watt resistor
1	—	Chassis box
2	J1, J2	Phono jacks
1	—	Knob for R1
1	—	Battery clip

capability. The same circuit may be used as a phono preamp with all pickups, as a tape preamp for all heads, or as a mike preamp, with change of only four components. These components are identified as E1 through E4 in the schematic diagram (Fig. 3-19). The proper values for the various uses are give in Table 3-7.

When set up for RIAA phono equalization, the preamp delivers in excess of 1-volt output with only about 5 milli-volts. input. Thus, it is ideal for use with low-output pickups. If gain is excessive, it can be reduced by changing the values of E1 through E4; resistors should be reduced to 1/5 the value called for in Table 3-7, and capacitors increased to 5 times the indicated values. This maintains the same equalization, but it reduces the total gain by a factor of 5.

When equalized for tape use, the sensitivity is 1.5 mv for full output. The signal-to-noise ratio is better than 55 db. When set up for microphone use, the output is flat across the audio spectrum. The input impedance for this connection is about 25,000 ohms.

As presented, the preamp is for single-channel use, allowing it is to be built for either mono or stereo systems. For stereo, of course, two are required. The only other change for

Fig. 3-19. Schematic of the hi-fi preamp.

Table 3-7. Equalization Table

Item	RIAA Phono	NAB Tape	15-mv Mike	5-mv Mike
E1	82K resist.	20K pot.	7.5K resist.	270K resist.
E2	.04 mfd ±10%	omit	omit	omit
E3	7.5K resist.	680K resist.	omit	omit
E4	.01 mfd ±10%	.005 mfd ±10%	5 mfd	5 mfd

stereo is to use a matched, ganged volume control for R1 so that single-knob control of output is maintained.

To build the preamp, etch the board (using Negative 3-6) as described in Chapter 1. Install the components following the layout in Fig. 3-20, but note that the base lead from X3 is not cut off short. Instead, it is insulated with a half-inch length of cambric tubing (spaghetti) and brought over as a jumper to the collector end of R2. This avoids a complex routing problem which introduced excessive noise in earlier layouts.

Mount the gain control, battery holder, and board in the chassis box, and wire them together. Connect a shielded lead from the output jack to the input of the power amplifier, and plug in the appropriate source.

Fig. 3-20. Parts layout for the hi-fi preamp.

If the source is not connected, the preamp may oscillate. This is the result of the heavy feedback employed. With any source, however, stability is excellent. Distortion measures less than 1/2% IM at 1-volt output; noise is completely inaudible when using phono equalization, and better than 55 db below maximum output with either tape or mike hookups.

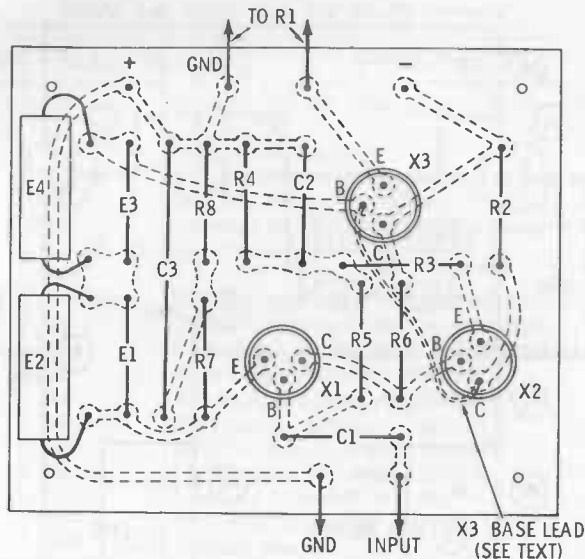If desired, equalization components E1 through E4 can be mounted on a multiposition rotary switch rather than on the board so that various equalizations can be obtained. To obtain equalization other than RIAA for phono (in case you have a large collection of old recordings), experiment with values. E1 controls the mid-frequency gain, and the value of E2 in relation to that of E1 provides high-frequency roll-off. E4, in relation to E1, provides low-frequency boost, and E3 in relation to E4 provides the low-end "flat-top." Thus for the older 78's with no high-frequency roll-off required, E2 would be omitted. Increasing the value of E4, while maintaining E1 constant, will reduce the turnover frequency, and vice versa.

Radio Receiver Projects

Even though audio amplifiers formed the first wide field for the application of transistors, the earliest experimenters in the field rapidly pushed solid-state amplification on up into the radio-frequency range.

Today's transistors perform well at frequencies up to several thousand megacycles—solid-state circuits are no longer restricted to the a-f region. The projects in this chapter include three broadcast-band receivers, two high-frequency converters, and one vhf converter. They by no means exhaust the potential of transistor etched-circuit receiver projects, but instead offer a wide-range sample of the possibilities.

Regenerative Receiver

Dear to the hearts of old-timers in radio is the "one-tube blooper," a single-tube regenerative receiver with amazing sensitivity for such a small number of components used.

Our initial receiver project (Fig. 4-1) is a transistor equivalent of the old "blooper," with a bare minimum of parts required and a maximum of performance.

In its initial tests, the unit pictured in Fig. 4-2 pulled in XELO, from Juarez, Mexico (about 800 miles distant) with only a two-foot test lead for an antenna, and in the face of interference from a local station only 130 kc away.

Subsequently, connected to an outdoor antenna, consistently strong signals were received in Oklahoma City from
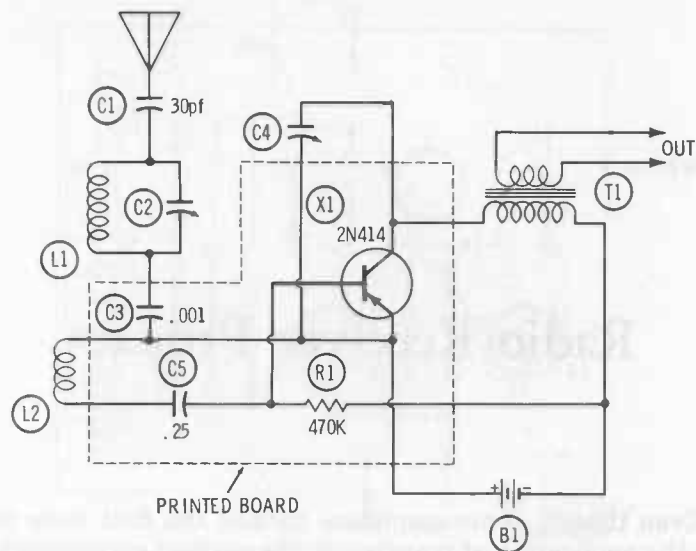
Fig. 4-1. Regenerative receiver schematic.

stations all over the midwest, including Omaha, St. Louis, and Salt Lake City.

At the best setting of the regeneration control, selectivity is great enough to cut out high-frequency components of the received signal, giving the audio a sound similar to that produced by a good crystal filter.

Like all regenerative circuits, operation is a bit more critical than that of a superhet. However, even if you have a prejudice against such circuits (as the author had prior to building this unit) you may find it fun!

To build it, etch the board (using Negative 4-1) as described in Chapter 1, and drill the parts holes with a No. 60 drill. Mount the two midget variable capacitors (Table 4-1) on a sheet of insulating material; because it was available, *Vectorboard,* was used on the prototype. Any similar material will do. Install the transistor and other components on the board as shown in the layout drawing (Fig. 4-3), and mount the board to the insulating sheet, holding the capacitors with a small angle bracket.

Wind the coil and mount it on the insulating board. The core of a discarded ferrite-rod antenna, was used on the prototype, with 80 turns of No. 30 enameled wire scramble-wound on one end as the L1 winding, and 10 turns of the

Fig. 4-2. The completed regenerative receiver.

same size wire solenoid-wound about 3/8 inch away for coupling link L2. The rod was mounted with a nylon fixture also salvaged from the old antenna. It appears probable that a standard transistor ferrite-rod antenna could be used as well, if the link winding is added at one end of the rod.

If the phones you're going to use are rated at 6000 ohms impedance or higher, transformer T1 (Fig. 4-1) may be omitted. For conventional phones, or to feed an outboard amplifier, the transformer must be included, or no regeneration can be obtained. If the transformer is to be included, mount it on the capacitor board, and connect its leads to the "phone" terminals on the circuit board.

The assembled unit should be mounted on a metal plate to reduce the "hand capacitance" effects that make accurate tuning difficult. The holes for the capacitor shafts should clear all metal of the shaft and mounting nut to avoid shorts. However, if the unit is put in a box, as was the prototype, the back of the box must be removed during

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operation. When the box is completely enclosed, regeneration ceases.

Table 4-1. Parts List for Regenerative Receiver

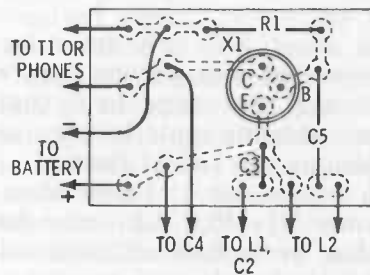| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 4-1)
1	B1	4-1/2-volt battery (3 size D cells)
1	C1	30-pf ceramic capacitor
2	C2, C4	365-pf polyethylene-type miniature variable capacitors (Lafayette 99 G 6217 or equiv.) equiv.)
1	C3	.001-mfd disc ceramic capacitor
1	C5	.25-mfd 75WVDC ceramic capacitor
1	J1	Phone jack
1	L1	Tuning coil, wound on 1/2 inch diameter by 4-inch long ferrite rod cut from stock (Lafayette 32 G 6103 or equiv.) with 60 turns No. 24 enameled wire on primary and 8 turns on secondary. See text for winding instructions.
1	R1	470,000-ohm, 1/2-watt resistor
1	T1	Transformer (high-impedance primary; for example, Argonne AR-100, or equiv.)
1	X1	2N414 or equivalent pnp r-f transistor
1	—	Plastic box
1	—	Binding post for antenna connection

Fig. 4-3. Parts layout for regenerative receiver.

When everything is hooked together, attach an antenna to the binding post, and set the regeneration control (C4) to minimum capacitance. If a howl issues from the phones, increase the capacitance of the regeneration control until it just ceases. Then tune across the band with C2. As a station is approached, a whistle should be heard. Increase the capacitance of the regeneration control (C4) until the whistle just stops; this setting will normally vary with the incoming signal strength.

With strong signals, the regeneration control can be operated at maximum capacitance. With weaker signals, increasing the regeneration by reducing the capacitance will improve reception. After a little practice, you will become adept at judging the point at which regeneration is best.

Two-Transistor Portable

The second receiver project, like the first, is an adaptation of the older vacuum-tube circuits. This two-transistor portable (Fig. 4-4) uses the base-emitter junction of one transistor as a diode detector, and follows it with an effective two stages of audio amplification.

Fig. 4-4. Two-transistor portable schematic.

With a high-impedance earpiece (2000 ohms or greater), it is a true portable for strong local signals. Performance improves greatly, however, if the clip-lead antenna is hooked to the metal dial stop of a telephone instrument, or to a 25-foot outdoor antenna. Equal improvement can be had by feeding audio from this project into a high-gain audio amplifier; it makes an excellent tuner for use with a hi-fi system, although a slight lack of bass can be noted (due to the tiny interstage transformer).

To build it, etch the board (using Negative 4-2), and mount all components (Table 4-2) except the tuning capacitor. Transformer T1 can be held in place with epoxy cement, but in the original unit it was retained merely by its leads without problems.

Table 4-2. Parts List for Two-Transistor Portable

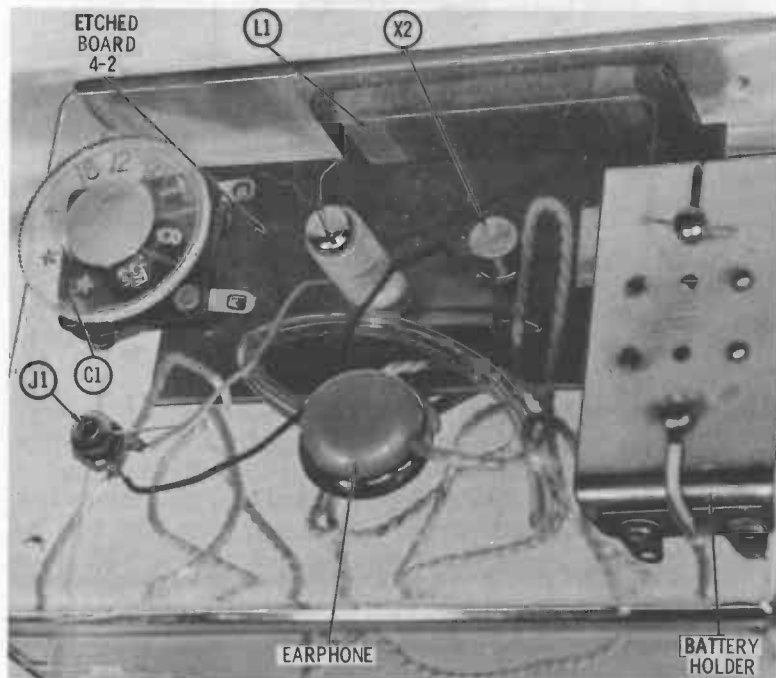| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 4-2)
1	B1	3-volt battery (2 penlite cells)
1	C1	365-pf polyethylene-type miniature variable capacitor (Allied Radio 19 L 091 or equiv.)
1	C2	10-mfd 6WVDC electrolytic capacitor
1	L1	Ferrite-rod antenna (J W. Miller 2004, or equiv.)
1	R1	100,000-ohm, 1/2-watt resistor
1	T1	Transformer, 200,000-ohm primary to 1000-ohm secondary, miniature (Argonne AR-100, or equiv.)
2	X1, X2	Pnp transistors, 26404 or equiv.
1	—	3000-ohm earpiece (Lafayette 99 G 2540 or equiv.)
1	—	Plastic box
1	—	Battery holder for 2 penlite cells

Fig. 4-5. The completed two-transistor portable.

Position the board, battery holder, and capacitor C1 in the plastic box you intend to use and mark hole locations for mounting. The box used in the original (Fig. 4-5) is somewhat oversize; the next size smaller, which is generally available over the country, however, is a bit cramped for comfortable working.

Drill the mounting holes in the plastic with a hand drill and light pressure. Too much pressure will crack the plastic, and an electric drill will create so much heat at the drill point that the plastic will dissolve into a gummy mess. Install all the components and complete the connections according to the schematic diagram (Fig. 4-4). The parts layout for the board appears in Fig. 4-6.

Fig. 4-6. Parts layout for two-transistor portable.

Operation is simplicity itself. Tune in the desired station and listen. No switch is included since the current drain of the detector transistor is almost zero in the absence of a signal, and current flow for the audio transistor is interrupted by unplugging the earpiece. If desired, however, a spst switch can be added in series with a battery lead.

Short-Wave Converter

Many would-be short-wave listeners (SWL'ers) are stymied by the lack of a suitable receiver. While inexpensive short-wave sets are available, many of them leave much to be desired in the way of tuning ease, stability, and selectivity—and with the crowded conditions of today's short-wave bands, these three characteristics are essential to success.

Our third receiver project, therefore, is a crystal-controlled converter for SWL (Fig. 4-7), which connects between the antenna and any broadcast-band receiver. It covers a single s-w band, but the band can be any one between 5 mc and 15 mc by proper choice of crystal frequency and tuning coils. As described here, it covers the 31-meter band (9 to 10 mc).

Fig. 4-7. Short-wave converter schematic.

A converter of this type acts primarily as a frequency changer, translating the short-wave signal down to a frequency in the standard broadcast band where it can be picked up on an ordinary receiver. The receiver to be used with it should be of a type which requires an outside antenna; otherwise strong broadcast signals may come through and interfere with the desired short-wave stations.
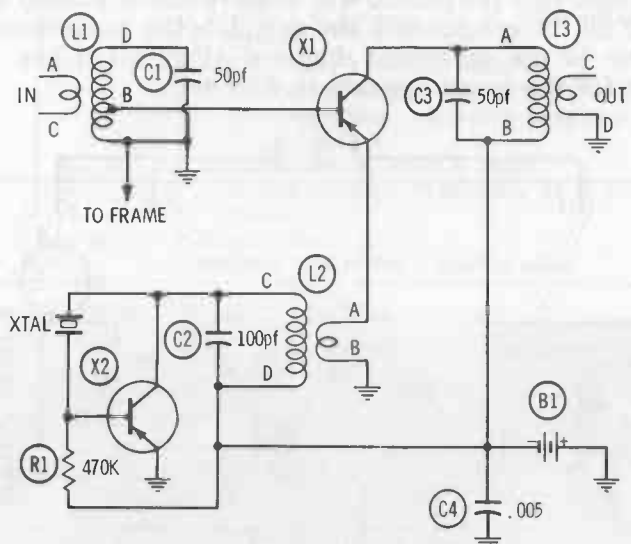
To build this project, first etch the board (using Negative 4-3) and drill lead holes with a No. 60 drill. Drill the mounting holes in the circuit board corners with a 9/64-inch bit, and the holes for the three coil forms with a 13/64-inch bit. The holes for the crystal socket are 1/16 inch.

Next wind the coils. This is not difficult if one end of the wire is soldered to a terminal ring and the other end of the wire tied to a doorknob to provide tension. When you are winding the link coils (two on L1, one each on L2 and L3), the end of the wire can be secured by temporarily wrapping

several twists *around* the cold-end terminal ring and then twisting the leads together. The links for L1 and L2 are 6 turns each, while that for L3 is 15 turns.

If you prefer, J. W. Miller prewound coils can be substituted. For these, drill mounting holes 11/64 inch in diameter. Use Type 4311 coils for L1 and L2, and a Type 4315 for L3. Add 30 turns of No. 30 wire to the cold end of L3, and make the link windings on L1 and L2 10 turns each with No. 30 wire. The link on L3 is then 40 turns. In addition, capacitors C1 and C2 should be changed to 20 pf each, and C3 becomes 100 pf.

To cover other short-wave bands, select a crystal frequency that is 550 kilocycles *lower* than the lowest end of the 1-mc segment you want to receive. Then change the values of C1, C2, L1, and L2 to suit. C2 and L2 should be resonant at the frequency of the crystal. C1 and L1 must resonate at the desired input frequencies. In both cases, resonance should be achieved with the tuning slug almost all the way into the coil. A grid-dip oscillator is virtually a necessity when making such changes; check the resonant frequencies by tacking C1 across L1, away from the circuit board, and similarly for C2 and L2. In the circuit, no dip can be found due to loading by the transistors.

With the coils completed, mount them in place on the board and install the other components as shown in Fig. 4-8. Drill the metal chassis box (Fig. 4-9) for mounting
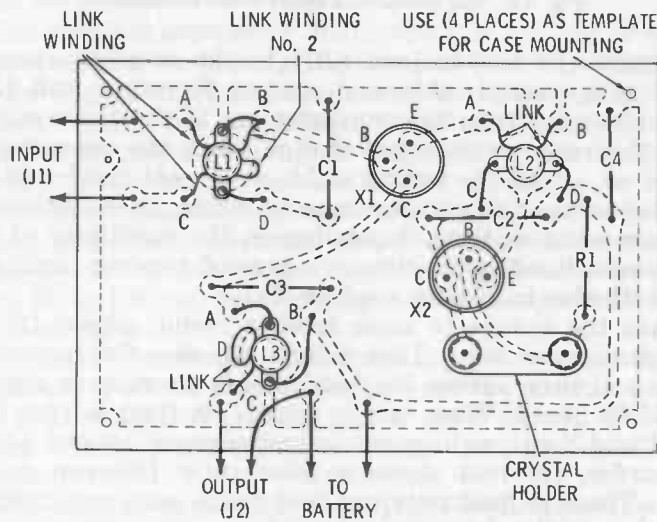

Fig. 4-8. Parts layout for short-wave converter.

holes, and install the switch, battery holder, and jacks J1 and J2. Use 6-32 × 1-1/2 inch machine screws to mount the board in place (Fig. 4-9). Connect the board to the other components, following the schematic (Fig. 4-7) and you're ready to test and tune up.
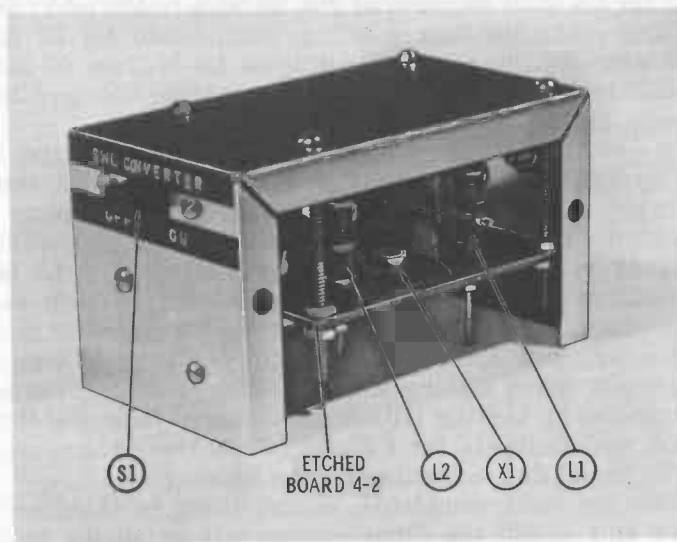

Fig. 4-9. The completed short-wave converter.

Connect the output jack (J2) to the receiver antenna input using coaxial cable, and connect the input jack (J1) to an antenna. Turn the converter on. If the noise output from the receiver does not change when the converter is turned on, adjust the tuning of L2 until a noticeable change in noise occurs (this change may be either an increase or a decrease of noise level, depending on the conditions of the short-wave band at the time, the type of receiver used, and the particular transistor used at X1).

When the change in noise level is found, adjust L3 for maximum noise level. Then adjust L1, also for maximum noise, and tune across the band. Some short-wave signals should be heard. When one is found, readjust L3 for best signal and then touch up the adjustments of L2 and L1, in that order, for best signal-to-noise ratio (clearest reception). These adjustments are best made on a weak signal near the middle of the desired band.

Table 4-3. Parts List for Short-Wave Converter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 4-3)
1	B1	4-1/2-volt battery (3 penlite cells)
2	C1, C3	50-pf npo ceramic tubular capacitors (Centralab TCZ-50 or equiv.)
1	C2	100-pf disc-ceramic capacitor
1	C4	.005-mfd disc-ceramic capacitor
2	J1, J2	Phono connectors
3	L1, L2, L3	Tuning coils (see text)
1	R1	470,000-ohm, 1/2-watt transistor
2	X1, X2	Pnp h-f transistors such as 2N247, 2N2084, OC171, or equiv. (Layout is for 2N2084; other types may require longer leads to reach proper hole positions.)
1	XTAL	Quartz crystal; see text for frequency selection
1	—	Chassis box
1	—	Battery holder for B1
1	—	Crystal socket, 1/2-inch spacing, for XTAL

VHF Converter

Hams and SWL'ers often want to receive signals in frequency ranges higher than those normally covered by communications receivers (which traditionally go up only to 30 mc or so).

The simplest answer to this problem is the use of a converter, similar in basic principles to the s-w converter of our prior project. However, in the vhf region, a few differences in design are necessary. Not all transistors function properly at frequencies higher than 30 mc, nor do conventional crystal circuits operate in this region.

The two-transistor converter circuit in Fig. 4-10 is designed specifically to cover the 50-54-mc "6-Meter" ham band. It can be moved to other frequencies in the range from 30 to 100 mc, by changing coils and capacitors in the tuned circuits.

At these frequencies, the stray capacitance becomes an important part of circuit design—often, 'strays' provide the total tuning capacitance in a tank circuit. Thus the etched circuit construction technique assures reproducible results.

While our board is laid out for TO-33 transistor lead configurations, the circuit works well with some types of

transistors having different layouts. Best results are obtained from the 2N1177/2N1178 pair, with the 2N1177 used as a mixer and the 2N1178 as oscillator. Another substitute, at slightly greater cost, is the 2N2084 "universal" r-f transistor.

To build the unit, etch the board (using Negative 4-4) as described in Chapter 1 and drill lead holes with a No. 60 drill. The mounting holes are 9/64 inch, and coil-form holes are 11/64 inch.
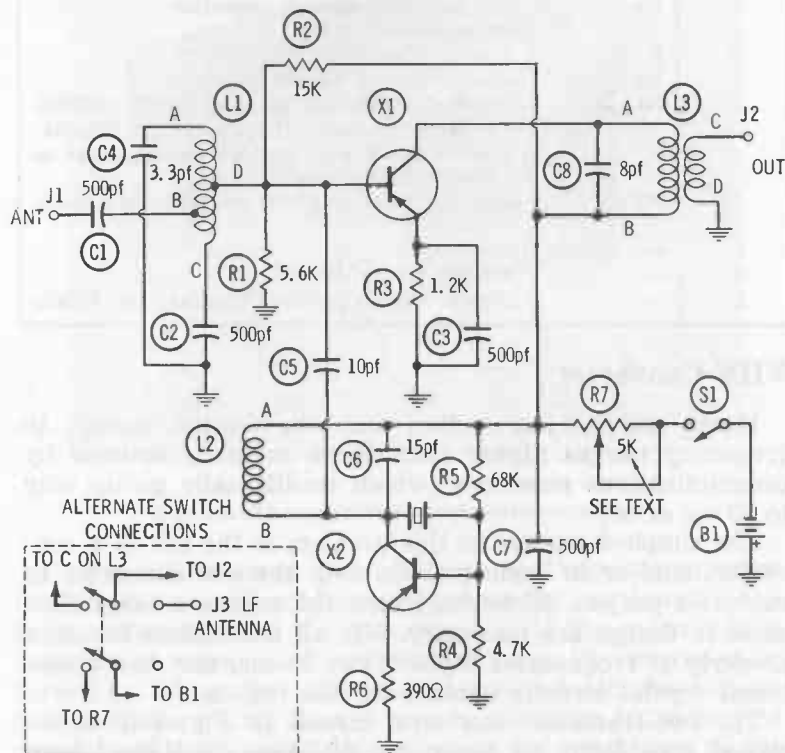

Fig. 4-10. Vhf converter schematic.

The coils are wound on J. W. Miller Type 4300 forms, with No. 26 Formvar-enameled wire. If a different wire size is used, the number of turns may have to be changed.

The taps on L1 are located at 1/2 the total number of turns and 1/4 the total, counting from the ground end of the coil. With specified sizes of form and wire, L1 totals 12 turns and L2 is 13 turns. L3 is 80 turns of No. 30 enamel, scramble-wound; it must tune to the desired output fre-

Table 4-4. Parts List for VHF Converter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 4-4)
1	B1	9-volt battery
1	C1	500-pf, disc-ceramic capacitor
3	C2, C3, C7	.01-mfd, disc-ceramic capacitors
1	C4	3.3-pf npo tubular-ceramic capacitor (Centralab TCZ-3R3 or equiv.)
1	C5	10-pf npo tubular-ceramic capacitor (Centralab TCZ-10 or equiv.)
1	C6	15-pf npo tubular-ceramic capacitor (Centralab TCZ-15 or equiv.)
1	C8	8-pf npo ceramic capacitor
2	J1, J2	Phono connectors
3	L1, L3	Variable inductors; wound on J. W. Miller Type 4300 coil forms (see text for details).
1	R1	5600-ohm, 1/2-watt resistor
1	R2	15,000-ohm, 1/2-watt resistor
1	R3	1200-ohm, 1/2-watt resistor
1	R4	4700-ohm, 1/2-watt resistor
1	R5	68,000-ohm, 1/2-watt resistor
1	R6	390-ohm, 1/2-watt resistor
1	R7	5000-ohm, linear-taper potentiometer (see text)
1	S1	SPST slide switch (see text)
2	X1, X2	Vhf pnp transistors (Board laid out for 2N2084. 2N1177 can be used as X1 and 2N1178 as X2 with good results. 2N384 can be used at X1 and 2N247 at X2 with slightly lower sensitivity)
1	—	Chassis box
1	XTAL	3rd-overtone quartz crystal; see text for frequency selection
1	—	Crystal socket for XTAL; 1/2-inch spacing (may be omitted by soldering XTAL directly onto board)
1	—	Battery clip for B1

quency (7 mc in the prototype) and should do so with the core almost all the way into the winding. The link winding on L3 has 12 turns. The value of the tuning capacitor across this coil may be varied as necessary to achieve this result. R7 can be a potentiometer as specified in Table 4-4, or a fixed resistor. If a fixed value is used, select one which will give 7 volts on the converter side of the resistor. If potentiometer is used adjust for the 7-volt reading.

Mount all components (Table 4-4) on the board as shown in the layout drawing (Fig. 4-11) and connect the battery and input and output jacks as shown in Fig. 4-10. The metal
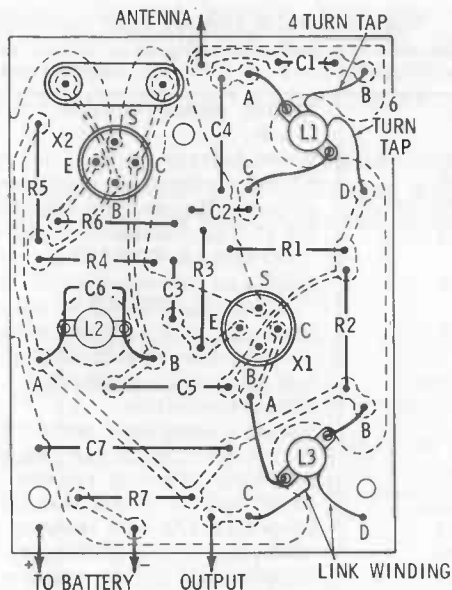
Fig. 4-11. Parts layout for vhf converter.

Fig. 4-12. The completed vhf converter.

box is a necessity to avoid i-f pickup, and for the same reason input and output jacks are located on opposite ends of the box. If single-switch control is desired, a dpdt switch can be substituted for S1 and another jack added to the chassis as shown in the alternate circuit in Fig. 4-10. This permits switching the l-f antenna directly to the receiver when the converter is not in use. This arrangement is particularly suitable for mobile use by hams.

Apply power and adjust L2 until oscillation at the crystal frequency is obtained. This is best detected by listening at the crystal frequency with a communications receiver; a grid-dip oscillator or indicating wavemeter can be used as a substitute, and as a last resort an r-f probe on a vtvm will work. If the r-f probe is used, monitor the frequencies around 1/3 and 1/5 of the marked crystal frequency to be sure that the crystal is oscillating on its desired overtone, rather than on the fundamental frequency. Adjust L2 for maximum oscillator output consistent with reliable starting; at maximum output, the oscillator may fail to start every time.

Then connect the converter to a receiver and provide a signal source at 50.3 mc. Tune the receiver to 7.3 mc and locate the signal, then adjust L3 and L1 (in that order) for

maximum strength. Finally, connect an antenna and find a weak on-the-air signal near 50.2 mc. Touch up the adjustment of L1 for best reception.

The final adjustment of all coils should be made with the metal box back portion slipped into place, to take into account the reduction of inductance caused by the box wall. If wide-band coverage is desired, L3 may be peaked near 51 mc and L1 near 50 mc. Most activity, however, is in the lower 500 kc of the band; for this reason, the recommended procedure is to peak for this region.

The performance of this unit compares favorably with the tube-type converters. It is far superior to superregenerative receivers such as those found in small vhf transceivers.

Superhet Broadcast Tuner

For maximum performance, the superhet circuit has established itself over the years. However, such circuits are often a bit complex for all but the most dedicated experimenters.

This project (Fig. 4-13) makes use of a relatively new circuit component, which, in conjunction with the etched-circuit construction, makes a high-performance superhet actually simpler to build than most beginners' projects.

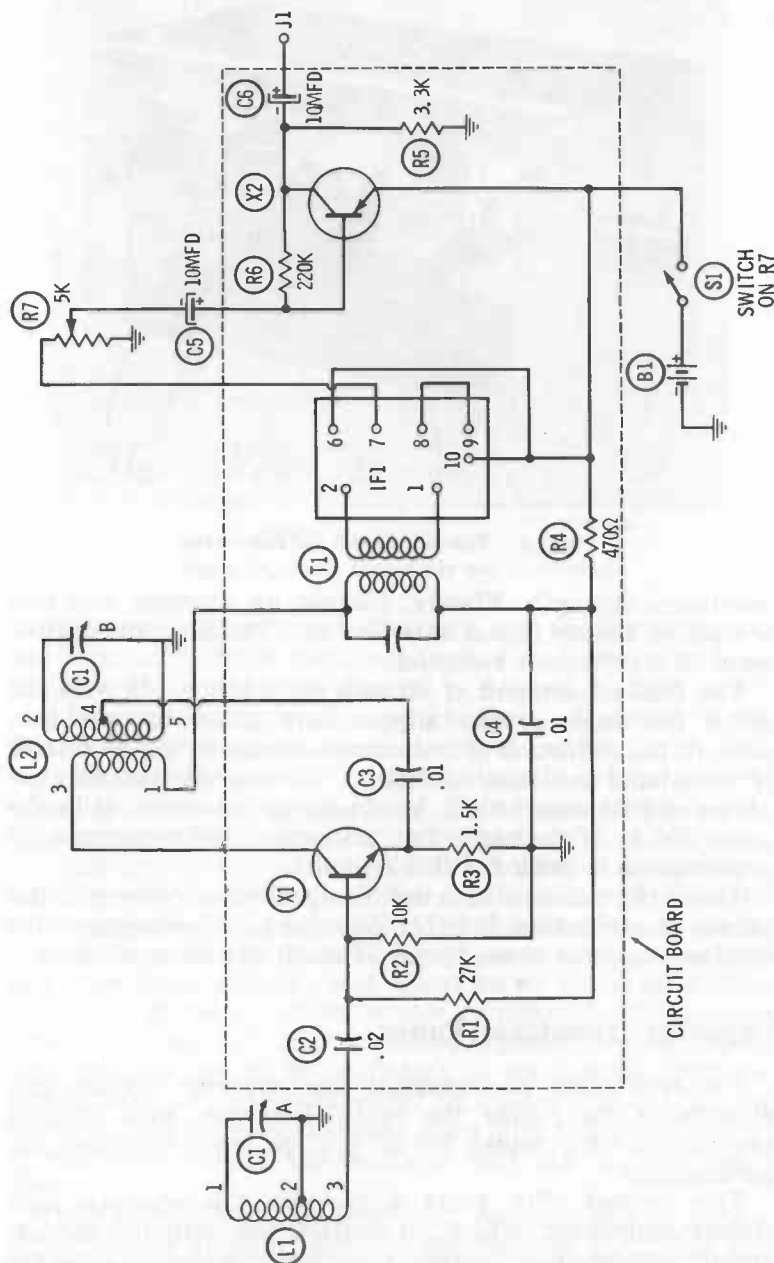**Fig. 4-13. Superhet tuner schematic.**

To take full advantage of the simplicity, the board has been laid out in such a manner that you can use any type of oscillator and r-f coil you desire; with a h-f transistor in the X1 position rather than the GE-6 broadcast-band unit specified in Table 4-5, and with suitable coils, short-wave reception is as easy as that in the broadcast band.

Table 4-5. Parts List for Superhet Broadcast Tuner

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 4-5)
1	B1	4 penlite cells
1	C1	Dual variable capacitor, special cut for superhet. R-f section: 130-pf max; osc. section: 78-pf max (J. W. Miller Type 2110 or equiv.)
1	C2	.02-mfd, disc-ceramic capacitor
2	C3, C4	.01-mfd, disc-ceramic capacitors
2	C5, C6	10-mfd 6WVDC electrolytic capacitors
1	IF1	Special i-f assembly (J. W. Miller Type 8902)
1	J1	Phono connector (output)
1	L1	Ferrite rod antenna (J. W. Miller Type 2005 or equiv.)
1	L2	Oscillator coil (J. W. Miller Type 2022 or equiv.)
1	R1	27,000-ohm, 1/2-watt resistor
1	R2	10,000-ohm, 1/2-watt resistor
1	R3	1500-ohm, 1/2-watt resistor
1	R4	470-ohm, 1/2-watt resistor
1	R5	3300-ohm, 1/2-watt resistor
1	R6	220,000-ohm, 1/2-watt resistor
1	R7	5000-ohm, audio-taper volume control with SPST switch
1	S1	SPST switch (part of R7)
1	T1	455-kc i-f transformer for use with IF1, J. W. Miller Type 8901 (both IF1 and T1 are packed together under Miller part number 8903)
1	X1	Npn mixer transistor, 2N1087 or GE-6
1	X2	Pnp a-f transistor, 2N404 or GE-2
1	—	Chassis box 3×4×5 inches (Bud CU-3005-A or equiv.)
1	—	Battery holder for B1 (Lafayette 34 G 5009 or equiv.)

The component which makes all this so simple is an integrated i-f strip produced by the J. W. Miller Co.; it includes a three-transistor i-f amplifier and detector in a tiny can no larger than most i-f transformers. All we must

add to it are a converter stage at the front, and a single stage of audio at the back, to have a complete tuner.

For the converter stage, an npn unit is used, while the audio in this board is a pnp. This mixing of types is not difficult to do, and offers highest performance in this application. However, it is not possible to use a pnp type to replace X1, nor an npn for X2.

To build it, etch the board (using Negative 4-5) and drill parts holes. Mount all components as shown in Fig. 4-14, and solder. Be quick when soldering in the i-f assembly; the insulating base softens with prolonged heat.
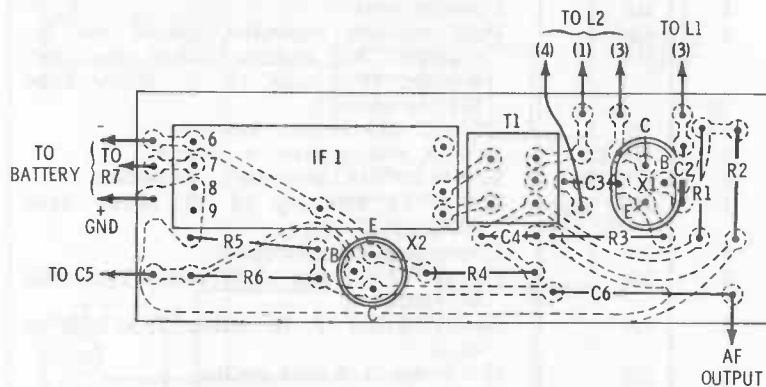

Fig. 4-14. Parts layout for superhet tuner.

Arrange the assembled board, the tuning capacitor, coils, volume control, and the batteries in the case you intend to use and decide upon a mounting arrangement. As shown in Fig. 4-15, an excess of room is available in the $3 \times 4 \times 5$ box used for the prototype, but the next smaller size available produced too much crowding of the tuned circuits. Note also that the oscillator coil specified must be mounted on a small bracket bent from sheet aluminum.

When all parts are mounted in the box, interconnect them following the schematic (Fig. 4-13). Connect to an audio amplifier and apply power. If you have a strong local station, it should be heard at some setting of the tuning capacitor.

Alignment follows conventional superhet practice, except that only one adjustment is made in the i-f region, and this may not be necessary (it wasn't in the original). Provide a modulated signal at 600 kc, set the tuning capacitor to the 600-kc position, and adjust the core of the oscillator coil
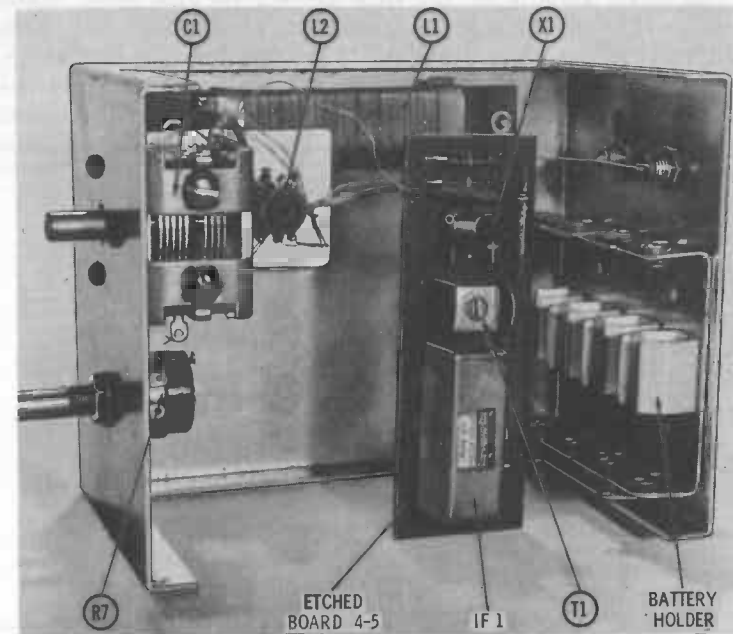

Fig. 4-15. The completed superhet tuner.

until the signal comes in with maximum strength. Move the signal to 1400 kc, tune to 1400 on the dial, and adjust the trimmer associated with the oscillator section of the tuning capacitor until the signal appears at maximum. Adjust the other trimmer also for best signal. Repeat the process several times until no more interaction is found.

Finally, touch up adjustments to the coupling transformer between the converter and the i-f assembly for maximum signal strength. This adjustment can be made on any weak signal. If wide readjustment is made, repeat the oscillator alignment to be sure of maximum sensitivity.

Tunable Short-Wave Converter

While the crystal-controlled converter described earlier in this chapter offers the maximum of reliability so far as receiving a given short-wave station is concerned, it's often nice to be able to scan over a wide region—greater than provided by the 1-megacycle range of the crystal unit.

In such cases, the tunable converter described here comes in handy. It covers nearly a 2-to-1 frequency range and can be built for any band from 5 to 15 mc.

The basic circuit of the unit shown in Fig. 4-16 is the same as that of the crystal converter, except that the oscillator circuit has been modified to permit tunable operation. To change frequency coverage to something other than the 10-18-mc range of the prototype, the same procedure used to change coverage of the crystal converter earlier in this chapter, applies.
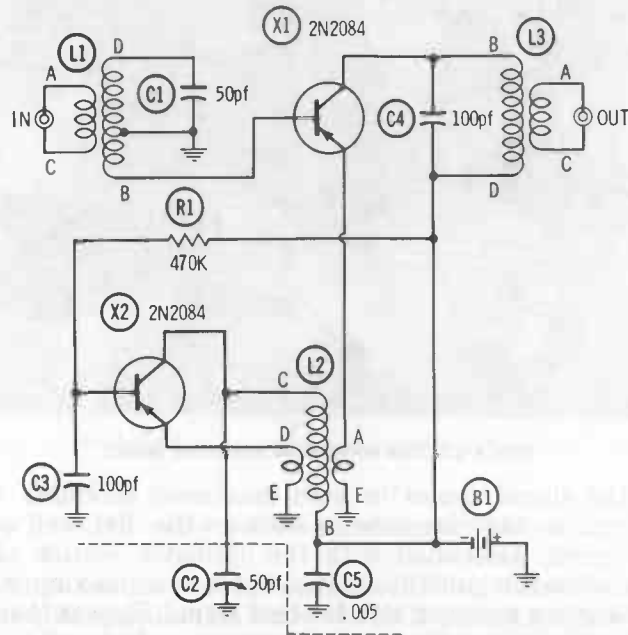

Fig. 4-16. Tunable s-w converter schematic.

If the value of C1 is changed for other coverage, the maximum-capacitance value of C2 should be changed to the same value. If "bandspread" tuning is desired, C2 can be changed to a smaller-valued unit, and the difference between the value of the unit used and that specified for C2 can be made up by a fixed ceramic npo or silver-mica capacitor wired in parallel with C2. Virtually any desired degree of bandspread may be obtained in this manner.

To build the unit, etch the board (using Negative 4-6) as described in Chapter 1 and wind the coils in the same manner as described for the crystal converter. L1 and L2 are 25 turns of No. 30 wire on a J. W. Miller Type 20A000-RBI form. Two 10-turn links are wound on each coil.

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Mount the components (Table 4-6) on the board (except C2) as shown in Fig. 4-17. If the 2N2084 transistors specified in Table 4-6 are used, clip the shield lead from the

Table 4-6. Parts List for Tunable SWL Converter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 4-6)
1	B1	3 penlite cells
1	C1	50-pf npo ceramic tubular capacitor
1	C2	50-pf miniature air variable capacitor (Hammerlund APC-50B or equiv.)
1	C3, C4	100-pf ceramic disc capacitor
1	C5	.005-mfd ceramic disc capacitor
2	J1, J2	Phono connectors
2	L1, L2	Tuning coils, (see text)
1	L3	Output coil, J. W. Miller Type 4315 (60-turn link added.)
1		
1	R1	470,000-ohm, 1/2-watt resistor
2	X1, X2	Pnp h-f transistors such as 2N2084
1	—	Chassis box
1	—	Battery holder for B1
	—	Knob for C2

transistors. If transistors using a TO-5 case are employed, they can be used without modification. Drill the box for board mounting screws, C2 shaft and mounting, and the two jacks: Install all parts in the box and connect as shown in Fig. 4-16. Fig. 4-18 shows the completed unit.
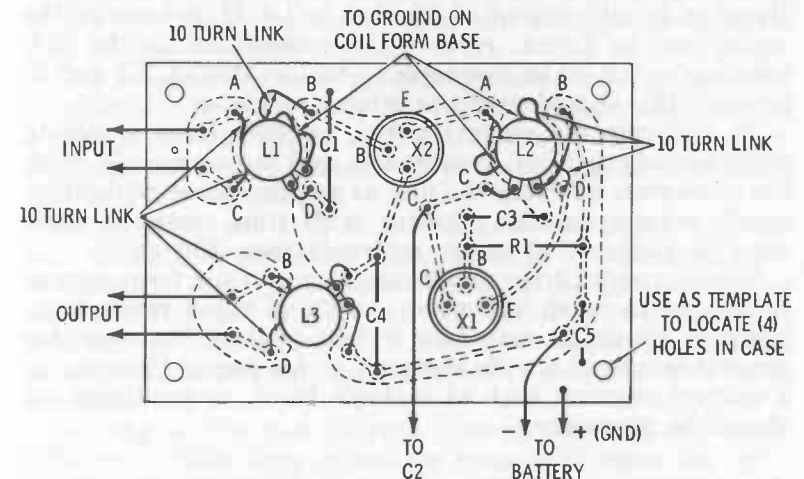

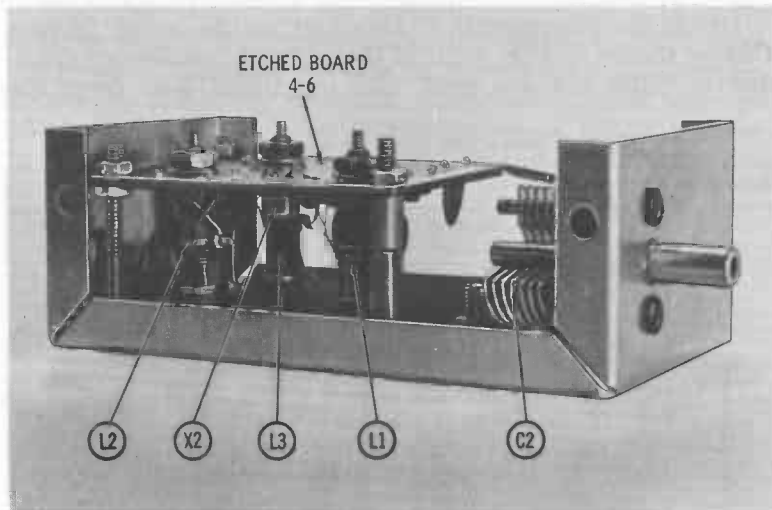Fig. 4-17. Parts layout for tunable s-w converter.

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Fig. 4-18. The completed tunable s-w converter.

Tune-up is simplified if a grid-dip oscillator or other signal source is available. Connect the converter to a receiver and tune the receiver to an unused channel near the upper end of the broadcast band. Set the signal source to this frequency and feed its output into the converter. Peak L3 for maximum output.

Then tune to the low-frequency end of the desired tuning range and adjust C2 to maximum capacitance. Bring the signal in by adjustment of the slug on L2. If no trace of the signal can be found, reverse the connections to the link winding on L2 which connects to the emitter of X2 and to ground; this should result in strong reception.

To calibrate the converter dial, set the signal source to progressively greater frequencies and tune them in with the converter, marking the dial as you go. Since calibration won't remain exactly constant with time, there is little need to calibrate at closer intervals than 500 kc.

Finally, peak L1 for maximum output at the frequency in which you're most interested. As C2 is tuned through its complete range, L1 may have to be repeaked. However, for general search of a wide segment, or for casual listening in a narrow segment such as a single band, no readjustment should be necessary.

Chapter 5

Just Gadgets

Almost everyone having any connection at all with electronics, whether as vocation or avocation, has an interest in "just gadgets." This, of course, is the category into which many useful items fall. The projects included in this chapter offer a wide range of gadgets, from those which are useful on the lab bench to those which help in other hobbies.

Constant-Current Generator

Though it's not a widely known device, the constant-current generator is a useful item in many areas. It can be used to protect experimental projects (since it performs many of the functions of a fuse), or it can be made an integral part of more complex gadgets.

The constant current generator shown in Fig. 5-1 and diagrammed in Fig. 5-2 is intended for general use, but if a fixed resistor is placed on the pads provided for the rheostat-connected potentiometer, it is readily adapted to inclusion in other equipment.

Silicon diode D1 acts as a reference element to hold the base of X1 approximately 0.6 volt negative with respect to the positive supply terminal. R1 is a bleeder resistor to maintain the current through D1 relatively constant. The load current flows from the source, through rheostat R2, through the transistor from emitter to collector, and on to the load.

As long as the load current through R2 does not cause sufficient voltage drop across the resistor to make the emitter more than half a volt negative with respect to the posi-
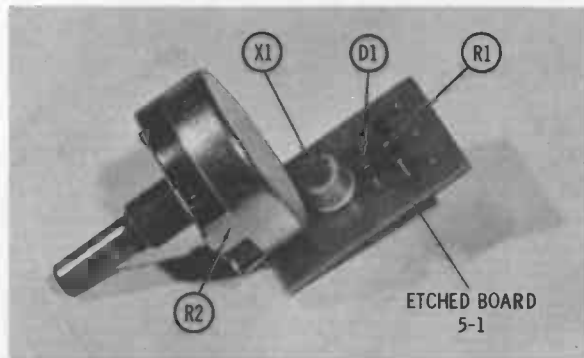
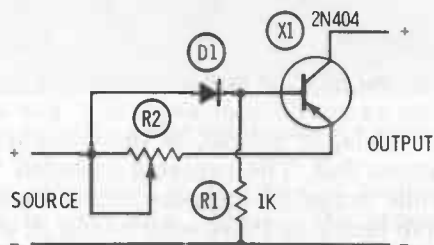Fig. 5-1. The completed constant-current generator.

Fig. 5-2. Constant-current generator schematic.

tive source terminal, the transistor is saturated and represents a very small resistance in series with the load. The total impedance of the generator is then approximately that of R2 alone.

When, however, the load current through R2 drops the emitter voltage to 0.5 volt, X1 begins to come out of saturation, and its series resistance rises sharply. Should the current drop the emitter voltage more negative than the base voltage (clamped by the drop across D1), the transistor will cut off and be a virtual infinite impedance. If this were to happen, however, current could not flow. The practical effect of the circuit is to clamp the load current at a value determined by the resistance of R2.

With the 100-ohm value of R2 specified in Table 5-1, the minimum load current that can be regulated is 6 ma. Increasing the value of R2 will reduce the load current and vice versa; the practical limit is reached when transistor leakage currents are as large as the load current.

A zener diode could be used for D1 and slightly better regulation would be obtained, but, it would both cost more

Table 5-1. Parts List for Constant-Current Generator

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 5-1)
1	D1	1N456 silicon diode (1N457, 1N458, or 1N459 can be substituted)
1	R1	1000-ohm, 1/2-watt resistor
1	R2	100-ohm potentiometer, (For other current values, resistance equals 500/current in ma.)
1	X1	Pnp transistor with moderate to high beta, adequate current rating). (2N404 is excellent; 2N1303 also fine.)

and require larger values of R2 for the same current. The 1N456 silicon diode works nicely; do not, however, use a germanium diode such as a 1N34A.

To build the device, etch the board (using Negative 5-1), and mount the parts as shown in Fig. 5-3. The board mounts

Fig. 5-3. Parts layout for constant-current generator.

on the potentiometer terminals by bending the terminals over and soldering to the broad pads. If stranded wire (no heavier than No. 20) is used for the input, output, and ground connections, no other support is necessary.

While the unit pictured in Fig. 5-1 uses a 2N414 transistor, any type that will handle the desired current and is capable of safely dissipating the full supply voltage at the desired regulation current (to survive short circuits) can be substituted.

In addition to the obvious uses of a constant-current source, some not-so-obvious ones are to establish a reference voltage by passing the regulated current through a resistor of known value, and to establish a known time delay by charging a capacitor with the regulated current. Delay time is linear, in this case, rather than exponential as in the ordinary r-c timing circuit. The voltage on the capacitor at the end of 1 second will be 0.1 volt per milli-

ampere with a 100-mfd capacitor; with 1000 mfd, it is 1 volt per milliampere. Other times and voltages can be calculated from these ratios.

Shutter-Saving Flash Unit

Synchronizing contacts inside camera shutters take more of a beating than most camera enthusiasts realize. The ordinary flashbulb requires nearly a full amp before it will fire, and this entire current must pass through the contacts when using conventional flash circuitry.

Eventually the heavy current flow through the tiny contacts results in pitting, corrosion, and erratic flash action. When this happens, the usual cure is a trip to the repair shop.

The flash unit pictured in Fig. 5-4 was built to enable continued operation with a pitted set of contacts as an

Fig. 5-4. The completed shutter-saver flash unit.

alternative to the repair-shop trip. Since its design, the original damaged camera has been replaced—and the shutter-saving action of the flash unit has prevented any damage at all to the new shutter.

As shown in the schematic diagram (Fig. 5-5), this unit uses a transistor switch to handle the heavy current flow
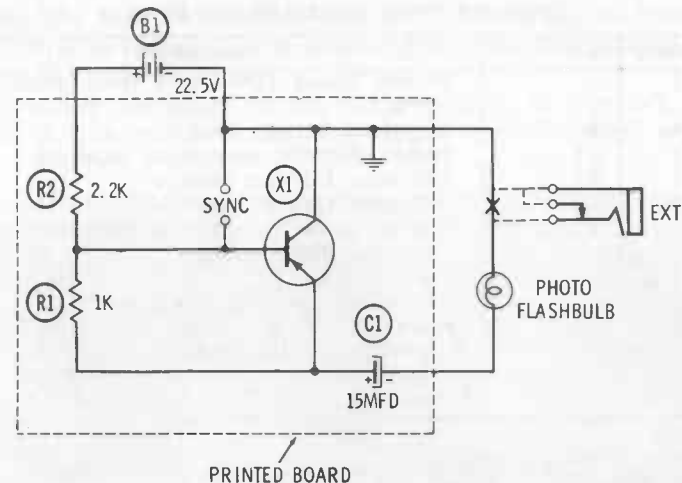
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Fig. 5-5. Schematic for the shutter saver.

required by the flashbulb. The only current flow through the shutter contacts is that needed by the transistor base; it is under 1/10 ampere for bad conditions and is usually about 10 ma for normal situations.

The two resistors (R1 and R2) tend to bias the transistor firmly "off" except when flashing, allowing the capacitor to reach full charge. The battery, as a result, lasts for its full shelf life. One battery has been in service in the author's unit for more than 3-1/2 years, and it still operates perfectly.

Building this unit is more of a mechanical challenge than an electronic one. While any type of flashgun can be salvaged to obtain the reflector, socket, and shutter cord, if you must purchase one, it is recommended that the unit specified in Table 5-2 be obtained, since the following description applies only to this particular unit.

Etch the board (using Negative 5-2), and drill component holes with a No. 60 bit. The holes for the base and emitter pins of X1 are 1/16 inch in diameter while those for the collector bolts are 5/32 inch in diameter. Mount the transistor with 6-32 machine screws, using a 1/4-inch long screw on the "inside" hole and a 3/8-inch long one on the hole near the corner of the board. Install the other components as indicated in Fig. 5-6, and solder.

Next, disassemble the flashgun by removing the small screw in the center of the reflector. This exposes two more

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Table 5-2. Parts List for Shutter Saver

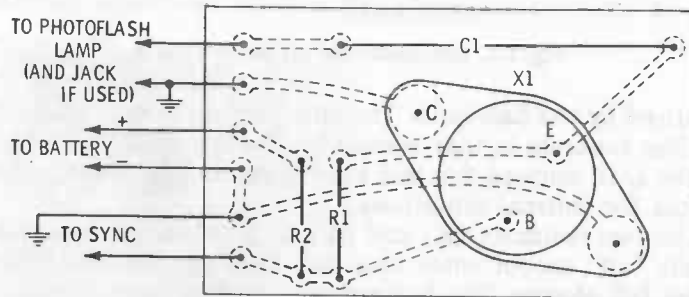| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 5-2)
1	B1	22-1/2-volt battery
1	C1	50-mfd 25WVDC electrolytic capacitor
1	R1	1000-ohm, 1/2-watt resistor
1	R2	2200-ohm, 1/2-watt resistor
1	X1	Pnp a-f power transistor in TO-3 case (2N255, 2N301A, etc.)
1	—	Battery holder for B1
1	—	Camera sync cord to fit shutter
1	—	Flashbulb reflector/socket assembly (Lafayette 15 G 4901, modified as decribed in text)
1	—	Chassis box

Fig. 5-6. Parts layout for the shutter saver.

small screws which must also be removed. Next, the socket assembly is separated from the plastic case by judicious tugging and juggling.

A pair of small side-cutting pliers is an excellent tool for cutting off the back part of the socket assembly which contains a resistor, capacitor, and neon test lamp. Keep the socket, ejector, and flat rear plate intact. Unsolder the red and blue wires from the socket.

Drill two holes in what will be the top of the metal chassis box, using a 1/8-inch bit. Then align the plastic housing of the flashgun in position, and mark through these holes to assure proper location of the holes in the housing. The plastic can be drilled with an electric drill, but use caution—it cuts through rapidly.

Drill a third hole through the plastic, and mark its location on the box after temporarily clamping the housing in place with a pair of 4-36 by 1/4-inch screws. Drill the

matching hole in the box with a 3/16-inch bit, to prevent any burr at the edge from touching the two wires which will pass through this hole.

Position the board in the box as shown in Fig. 5-7, and drill a 1/8-inch hole for the single angle bracket which

Fig. 5-7. The completed shutter saver.

holds it in place. The bracket is held to the board by the 3/8-inch-long transistor mounting bolt; this also puts the entire box at transistor-collector potential.

The 1/8-inch holes for the battery holder mounting can also be drilled at this time, and another 1/8-inch or 3/16-inch hole can be drilled in the bottom of the box for the shutter cord.

Remove the mounting foot from the flashgun case (if you haven't already had to do so to mark the holes), and locate it on the box side at the position best suited to your own camera. Drill two 1/8-inch holes for its mounting bolts, and install it in place.

Temporarily install the board and battery holder in the box, and measure the lengths of the connecting wires. Cut and strip all wires; then disassemble the unit as necessary to make the connections.

Take special care to be certain that the shutter contact, which is grounded to the frame of the shutter, comes to the board on the pad connected to the collector of the transistor. This will prevent accidental firing of bulbs by shorting the camera to the metal box.

If desired, an extension-flash socket may be added by mounting a closed-circuit phone jack in the bottom of the box and wiring its switched terminal to the lead from the

bulb socket, which otherwise would return to the transistor collector. This connection is shown in dotted lines in Fig. 5-5, but it was not included in the unit pictured. When so wired, the unit will operate normally with either flash-on-camera or camera bulb plus extension; it will not, however, fire the extension only. A bulb must be in the camera unit before firing is possible.

With all connections soldered, the only things left to do are to put in a 22-1/2-volt hearing-aid battery, assemble the two halves of the box, and secure them in place with the sheet-metal screws furnished with the box. Then mount the unit on the camera, plug the unit into the shutter, and fire away with the assurance that the bulb will fire on every shot.

Windicator

How hard is the wind blowing? To pilots, boating enthusiasts, and ham operators who have tall antenna towers the question is an essential one. It's of interest to many other folks as well. The "Windicator" will give you the answer without even having to go to the window.

Basically, this unit is a wind-driven generator combined with a transistorized meter. The harder the wind, the faster the generator turns, and the more current there is indicated on the meter. The meter face is calibrated in miles per hour; you could just as easily calibrate in knots if you prefer.
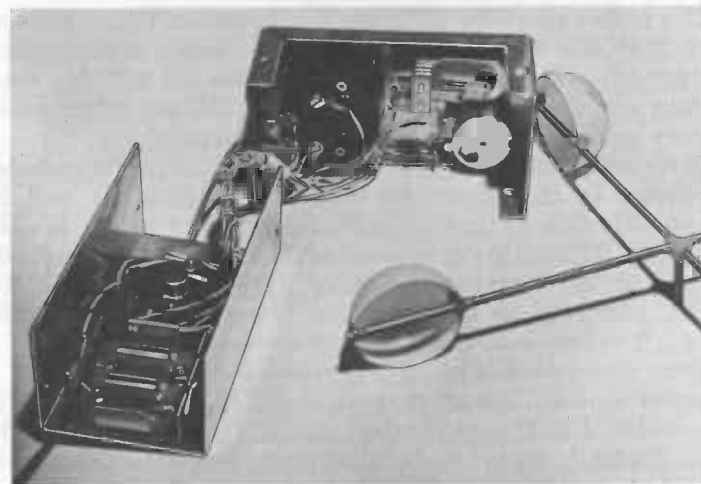
Construction of the Windicator, like the "shutter saver" described in the preceding section, is more of a mechanical job than an electronic one. The major part of the work is the construction of the wind-driven generator.

This generator (Fig. 5-8) is made from two ping-pong balls and two 1-foot lengths of 1/8-inch (od) brass or copper tubing. Both the ping-pong balls and the tubing may be obtained at toy stores and hobby shops. Avoid aluminum tubing since it's difficult to solder.

Cut the two lengths of tubing to lengths of 9 inches each, and file a square-cornered notch halfway through each length at its exact midpoint, as shown in the detail view (Fig. 5-9). Cut another piece from one of the 3-inch scraps, about 1-1/2 inches long, and file one end of this length square and the other end to a scalloped cross-section, also shown in Fig. 5-9. Then assemble the three lengths of tubing as shown, and solder them together.

(A) Assembled.

(B) Chassis opened.

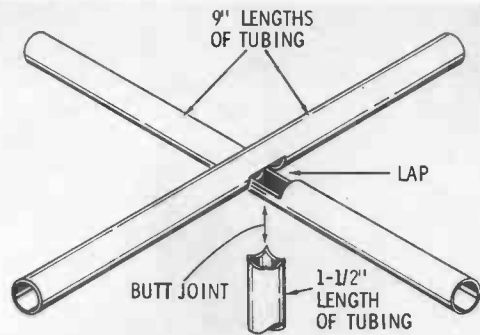**Fig. 5-8. The completed Windicator.**

Fig. 5-9. Generator assembly details.

Bisect each of the ping-pong balls, using a saw-edge table knife or a fine-pitch coping saw blade, to obtain four hemispherical sections. Cut notches on the rim of each section to fit (approximately) around the tubing, and cement them in place, as shown in Fig. 5-8. Position each with its open side toward the closed side of the preceding one, and with the open sides facing in such a direction that final rotation will be in a clockwise direction as viewed from the top.

If the hobby motor specified in Table 5-3 is used for the generator, the 1/8-inch tubing will be a loose fit on its shaft. Crimp the tubing extremely gently with pliers for a better fit; only about 0.002 inch of compression is necessary.

The motor specified in Table 5-3, however, is not the only type that can be used. Virtually any small motor, either a-c or d-c, will work nicely. One source of suitable small motors is a discarded electric clock; clocks use synchronous motors which are excellent for the purpose.

If an a-c motor is employed, diode D1 should be included, as shown in the schematic diagram (Fig. 5-10) and the layout drawing (Fig. 5-11). If the specified motor is used, however, D1 should be omitted and the red motor lead connected to the terminal provided for the cathode of D1, which connects to the transistor base (shown in dotted lines). The blue lead connects to the negative side of C1.

Etch the board (using Negative 5-3) as described in Chapter 1, drill the holes, and mount the components. Do not solder R3, the calibration resistor, into place at this time. Instead, "tack" it into position, since it may require changing during the calibration.

The value of R3 will determine the sensitivity of the instrument, and will fix the full-scale reading in miles per

Table 5-3. Parts List for Windicator

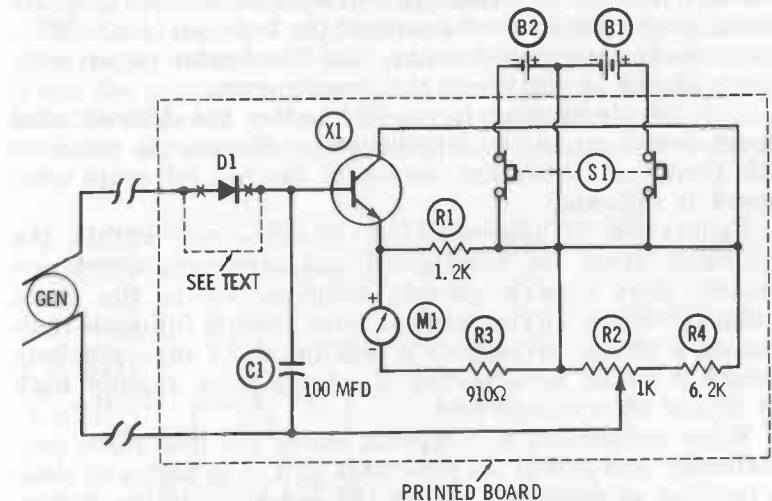| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 5-3)
1	B1	2 flashlight cells
1	B2	1 flashlight cell
1	C1	100-mfd 6WVDC electrolytic capacitor
1	D1	1N34A diode, or equiv.
1	G1	Small motor (Lafayette 99 G 9002 can be used, or motor can be salvaged from discarded electric clock)
1	M1	0-1 milliammeter, moving-coil type (Lafayette 99 G5052 or equiv.)
1	R1	1200-ohm, 1/2-watt resistor
1	R2	910-ohm, 1/2-watt resistor (see text concerning value)
1	R3	1000-ohm linear-taper potentiometer
1	R4	6200-ohm, 1/2-watt resistor
1	S1	Switch, dpst push-button, normally open
1	X1	2N169 or 2N233 npn transistor
1	—	Chassis box
1	—	2-cell battery holder for B1
1	—	1-cell battery holder for B2
1	—	2-terminal barrier strip
2	—	Ping-pong balls (for wind cups)
2	—	1-foot lengths of 1/8-inch (od) brass tubing

Fig. 5-10. Schematic for the Windicator.

hour. It should not be less than 50 ohms for best results, although the prototype (which used a low-gain transistor in its initial version) required a 47-ohm value. With this low
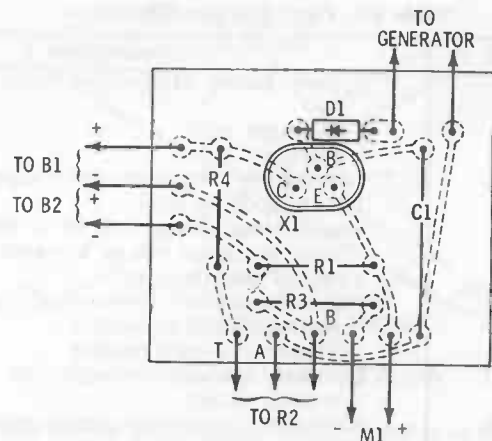
Fig. 5-11. Parts layout for the Windicator.

value of R3, zero stability is poor. With higher values, the zero setting remains unchanged for several days at a time.

When mechanical and electrical work is finished, it's time to calibrate. Choose a nonwindy day, and clamp the generator unit to a window of an automobile in such a manner that the generator is well clear of the car body (to avoid errors due to air currents at the body surface.) Drive at a steady speed and compare the Windicator meter reading with the indication of the speedometer.

If full-scale reading is reached before the desired wind speed comes up on the speedometer, increase the value of R3. Continue calibration tests until desired full-scale wind speed is indicated.

Calibration is approximately linear — well within the allowable error for wind-speed measurements, which are seldom more than 5 percent accurate due to the gusty nature of winds. In the original, with 50-mph full-scale indication, a 10-mph wind gave a reading of 0.1 ma—precisely where it would be expected. Readings were slightly high at 20 and 30 mph, however.

When calibration is complete, solder R3 into place permanently, and install the generator unit in as high and clear a position as possible. Connect the generator to the indicator with two-wire cable; miniature speaker wire sold for hi-fi use is excellent and unobtrusive.

To use the unit, temporarily short out the generator with a clip lead or metal object, and zero the meter (if R3 is greater than 50 ohms or so, this step may not be necessary

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except at 7- to 10-day intervals). Then remove the short, and press the "read" button. The reading will be wind speed.

Tiny Tachometer

Sports-car buffs and Sunday drivers alike find uses for a tachometer that gives direct and instant reading of engine speed—but many commercial tachometer designs require more room than is available on many crowded auto dashboards.

This tiny tach, designed around the popular 1-1/2-inch diameter Japanese-built meters imported by a number of firms, is self-contained on the circuit board—which is exactly the same diameter as the meter barrel.

As a result, only one 1-1/2-inch hole need be cut in the dash for a custom mounting. Alternatively, a strap may be bent from sheet aluminum to mount on the steering column; the small meter won't interfere with the view of other instruments.

The circuit is universal—it works with 6-volt or 12-volt autos and is as accurate for 4-cylinder midgets as for 12-cylinder behemoths. Only one resistor need be to changed to adapt to the various types of engines.

This tach registers engine speed by counting the number of times per second that the ignition breaker points operate. When the points are open, X1 (Fig. 5-12) is turned "on" and the collector voltage drops to zero. When the points close, X1 turns "off" and the collector rises to the voltage
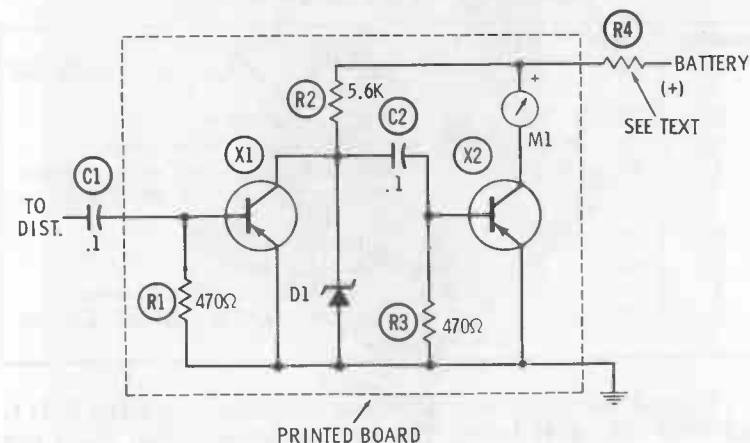

Fig. 5-12. Tachometer schematic.

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level set by zener diode D1. This produces a train of rectangular waves at the collector of X1, with a pulse-repetition rate determined directly by the number of operations of the breaker points per second.

This pulse train is differentiated into a series of spikes by C2. Positive-going spikes turn X2 "on" and allow a pulse of current to flow through the meter; the absence of spikes, or the presence of negative-going spikes, leaves X2 turned "off" and no current can flow in the meter circuit.

Thus, every time the breaker points operate, a pulse of current attempts to push the needle of M1 upward, but at the end of the spike the needle tends to fall back. The mechanical inertia of the needle, together with the spring force of the meter movement, integrate the pulses into an averaged current reading which is dependent on the frequency of the pulses. The closer together the pulses (the faster the engine turns), the higher the meter reading will be.

The calibration resistor (R4) sets the full-scale meter reading at the desired value. To choose the value for this resistor, connect a tach of known accuracy to the completed instrument, and rev the engine up to the desired full-scale number of rpm's. Vary the calibrating resistor until the meter indicates exactly full scale. With a 12-volt 8-cylinder automobile, the value of this resistor is 2700 ohms for 5000 rpm. Six-volt vehicles will require less resistance, as do engines with fewer cylinders.

Table 5-4. Parts List for Tachometer

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 5-4)
2	C1, C2	.1-mfd 75WVDC ceramic capacitors
1	D1	1N751, 5.1-volt, 400-mw zener diode
1	M1	0-1 milliammeter, 1-9/16-inch square, moving-coil variety (Lafayette 99 G 5052 or equiv.)
2	R1, R3	470-ohm, 1/2-watt resistors
1	R2	5600-ohm, 1/2-watt resistor
1	R4	Calibrating resistor (see text for value)
2	X1, X2	Npn switching transistors, 2N1302, 2N1304, or 2N1306

To build the unit, etch the board (using Negative 5-4)), and drill the parts holes. The two meter-terminal holes are 1/8 inch in diameter. To round the board, use a coarse file.

Mount the components (Table 5-4) as shown in the layout drawing (Fig. 5-13). Then install the board on the back of
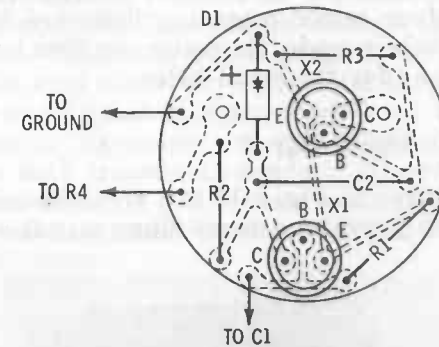

Fig. 5-13. Parts layout for the tachometer.

the meter, with the etched side facing the meter, as shown in Fig. 5-14. Connect the power leads, and the signal input lead to the ungrounded side of the breaker points at the distributor.
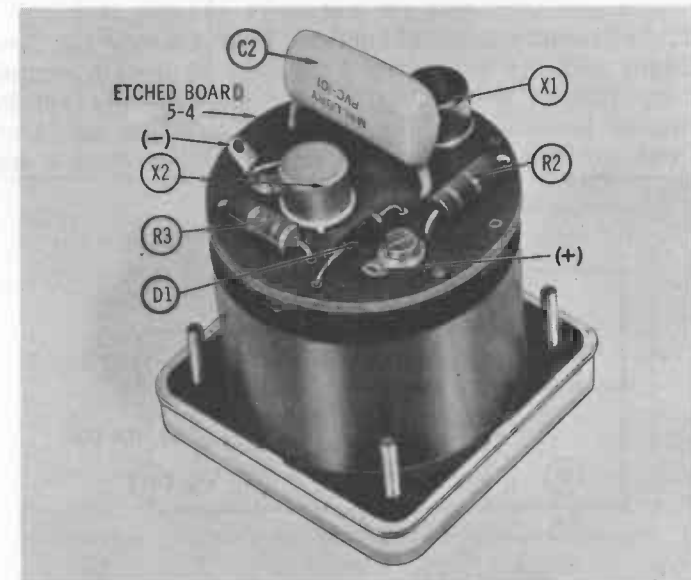

Fig. 5-14. The completed tachometer.

No installation details can be provided, since each auto poses its own problem. Mounting of the meter is easiest if the main hole is made with a 1-1/2-inch chassis punch, but a hole saw or fly-cutter can be used if desired. The 1/8-inch holes for the four meter mounting bolts are best drilled after the main hole is made; the meter can then be positioned to mark locations for the small holes.

Code-Practice Oscillator

The unit pictured in Fig. 5-15 is a versatile code-practice oscillator, which provides a room-filling signal with only a
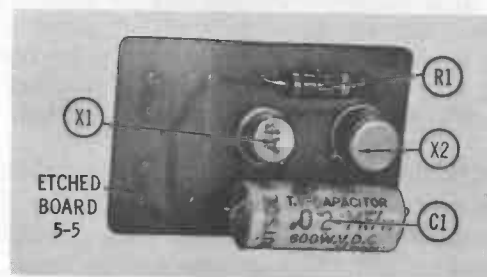

Fig. 5-15. The code-practice oscillator board.

handful of components and operates from a single 1-1/2-volt flashlight cell. As shown in Fig. 5-16, it uses a complementary astable multivibrator circuit, with the speaker serving as the load. Unlike many code-practice oscillators, this one provides a pulse-type signal rather than a sine
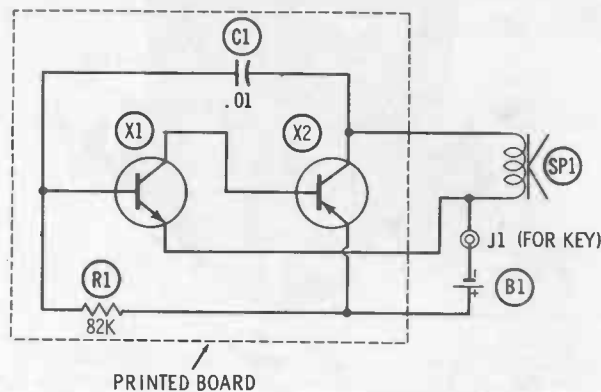

Fig. 5-16. Schematic for the code-practice oscillator.

wave. The "richness" added by the harmonics makes the sound easier to listen to during extended practice sessions.

The complementary multivibrator circuit is unusual in that both transistors conduct at the same time, and both are cut off together. This feature extends battery life to a great degree. When the key is pressed, neither transistor can conduct until capacitor C1 charges through R1. When the charge on C1 reaches approximately 0.1 volt, X1 can go into conduction. Its collector current passes into the base of X2, so that both transistors conduct. However, this shorts out C1, discharging it and turning both off again. C1 then begins to recharge, and the process repeats itself so long as the key is down.

Every time X2 conducts, a pulse of current passes through the speaker voice coil. With the values of R1 and C1 specified in Table 5-5, these pulses occur at an audio rate and produce a tone output. For a higher pitch, the value of C1

Table 5-5. Parts List for Code-Practice Oscillator

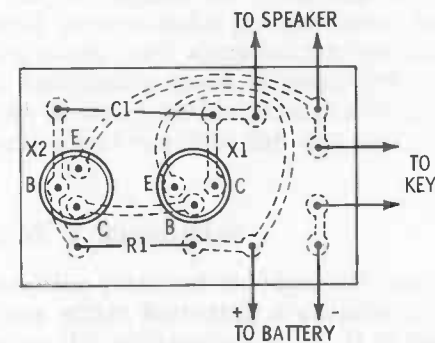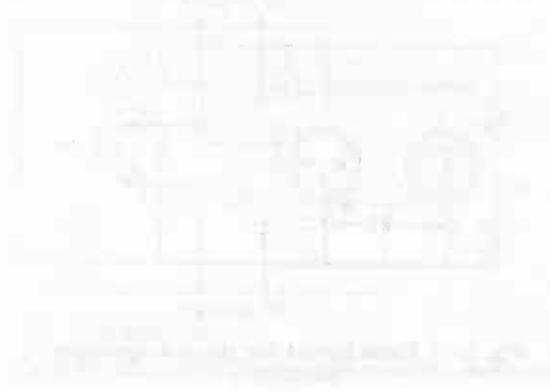| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 5-5)
1	B1	1-1/2-volt flashlight cell
1	C1	.01-mfd, 100WVDC paper capacitor
1	J1	Phone jack (for key)
1	R1	82,000-ohm, 1/2-watt resistor
1	SP1	3-4-ohm pm speaker, any size
1	X1	Npn transistor, 2N233, 2N1302, etc.
1	X2	Pnp transistor, 2N404, 2N1303, etc.
1	—	Speaker case
1	—	Battery holder for B1

Fig. 5-17. Parts layout for the code-practice oscillator.

can be reduced; for a lower tone it should be increased in value. The value of R1 should not be decreased, but it can be increased if desired to achieve extra-low tones.

By using a silicon transistor for X1, increasing the value of C1 into the tens of microfarads range, and substituting a pilot light for the speaker voice coil, a stable light flasher can be built. In this modification, X2 must be capable of passing the full current required by the bulb.

To build the oscillator, etch the board (using Negative 5-5) and mount the parts. Take special care to get the npn and pnp transistors in their proper positions, as shown in Fig. 5-17. Also be sure that battery polarity is correct when making the final hookup to battery, key, and speaker.

Once the components are soldered and the external parts connected, the unit is complete. Simply key, and listen. Should difficulty be encountered, check X1 for leakage; a leaky transistor can stall the oscillation.

Transmitter Projects

Although transistorized receivers that operate up into the vhf regions and above have been in existence for several years, transistorized transmitters and transmitter accessories are still something of a novelty to most electronics buffs.

Silicon transistors capable of operating up to the uhf regions at quite appreciable power levels, are available for less than $1 through many industrial-electronics suppliers. These inexpensive transistors are now making transistorized transmitting equipment both feasible and economical. The two projects here are a 0.1-watt, 80-meter ham transmitter with vfo built in, and a stable vfo for 50-mc ham use, including provisions for narrowband frequency modulation. Both are for practical use.

The first project makes an excellent vfo for use with higher-powered vacuum-tube transmitters, and it can give a fine showing when used alone in conjunction with a good antenna and reasonably good propagation conditions. The second project is more stable than most comparable vacuum-tube devices and requires far less space on the operating desk.

80-Meter C-W Transmitter

This transmitter pictured in Figs. 6-1 and 6-2 is an 80-meter–band c-w affair featuring a variable frequency oscillator and giving 100 milliwatts output. It is designed around a pair of the recently released "economy line" epoxy-encapsulated npn silicon transistors and offers a high degree of

Fig. 6-1. The completed 80-meter c-w transmitter.

Table 6-1. Parts List for 80-Meter C-W Transmitter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 6-1)
1	B1	12-volt lantern battery
2	C1, C10	.001-mfd disc-ceramic capacitors
1	C2	500-pf npo tubular-ceramic capacitor
1	C3	1000-pf npo tubular-ceramic capacitor
1	C4	15-pf air variable capacitor (Hammarlund HF-15-X, or equiv.)
1	C5	50-pf miniature air variable capacitor, screwdriver adjust, (Hammarlund APC-50, or equiv.)
1	C6	100-pf disc-ceramic capacitor
2	C7, C8	.01-mfd disc-ceramic capacitors
1	C9	75-pf miniature air variable capacitor (Hammarlund APC-75B or equiv.)
1	J1	Phono connector or uhf coax socket
2	L1, L3	2-1/2 millihenry rf chokes (National R-50 or equiv.)
2	L2, L4	Tuning coils (cut from 1 length B&W Type 3016 or Airdux Type 832 stock; L2 is 57 turns and L4 is 35 turns)
1	M1	0-15 d-c milliammeter
1	R1	120,000-ohm, 1/2-watt resistor
1	R2	100,000-ohm, 1/2-watt resistor
2	R3, R4	2200-ohm, 1/2-watt resistors
2	X1, X2	2N2711 transistors (do not substitute)
1	—	Chassis box
1	—	Vernier dial for C4
1	—	Knob for C9
1	—	2-terminal barrier strip

performance per dollar. No substitutions should be made for the 2N2711's specified in Table 6-1, but have no fears about cost, because you should get change from a $2 bill after buying the two transistors.

The circuit (Fig. 6-3) is self-protecting. Transistor X1 is a Clapp-type oscillator, and the emitter resistor and base-bias network is kept below 25 volts. Transistor X2 operates as a class-C amplifier and cannot draw collector current in the absence of excitation.

Keying is accomplished by breaking the negative power lead; both the oscillator and amplifier are keyed, but this has not resulted in chirp or clicks, apparently because of the extremely low power levels involved and the high degree of stability of the transistor oscillator.

To build the unit, etch the board (using Negative 6-1) and drill all parts holes. Note that even a No. 60 drill leaves a very small rim of copper around the hole; the small pads are necessary because of the tiny size of the transistors.

Plate coils L2 and L4 are made from a single length of air-wound inductor stock. Count off 58 turns from one end,

and cut the wire; then unwind a half-turn in each direction from the cut. Use a heated single-edge razor blade to cut through the plastic supports and separate the coil into two pieces; next unwind as many turns as are necessary to obtain 57 full turns on L2 and 35 turns on L4. Leave the unwound wire on the coil through the assembly steps; it will be used to make leads to the tuning capacitors.

Position the tuning capacitors inside the metal chassis box as shown in Fig. 6-2, and mark the hole locations. Then drill the holes and mount the capacitors.

Install the components on the board as shown in Fig. 6-4, being especially careful to get the transistor leads into their proper holes and to keep them from shorting to each other. When the transistors are properly oriented, their flat surfaces will be pointing in the directions shown in Fig. 6-4. Then solder all connections, and clip all excess leads except those from L2 and L4.
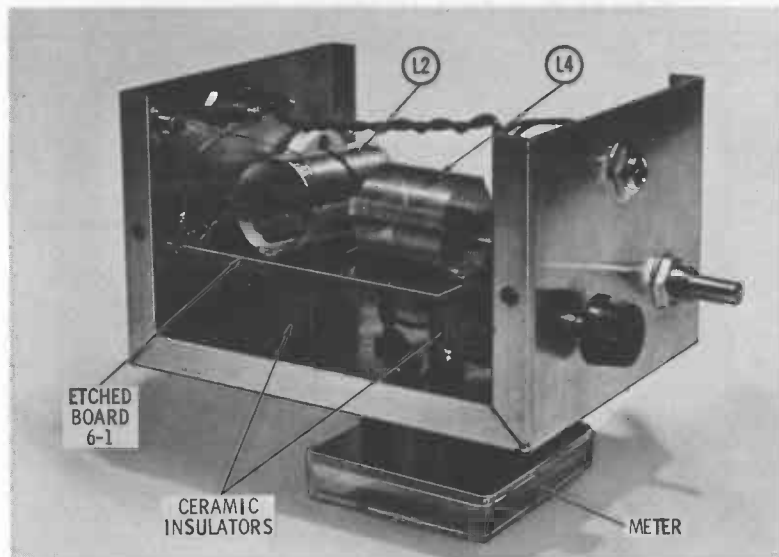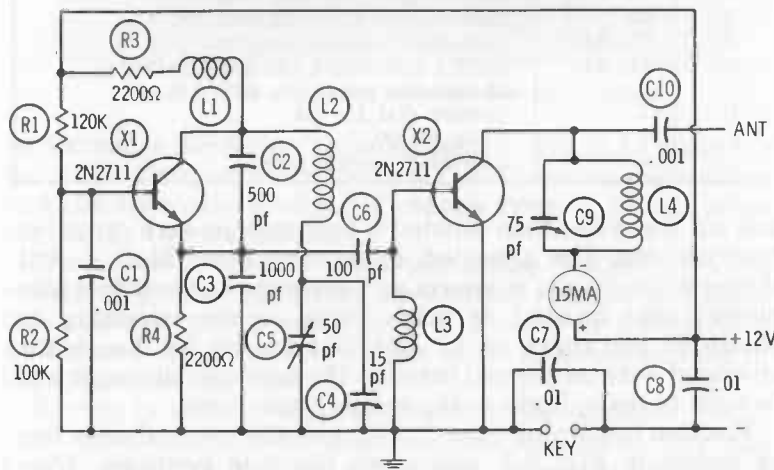
Fig. 6-2. Transmitter with cover removed.

Fig. 6-3. Schematic of the 80-meter transmitter.

Drill the box for two 1-inch-long ceramic insulators (Fig. 6-2) and mount the insulators on the box with 6-32 screws. Connect 6-inch lengths of hookup wire to the various terminal pads of the board, and then secure the board to the ceramic insulators with epoxy cement. Allow the cement to set for 24 hours before proceeding.
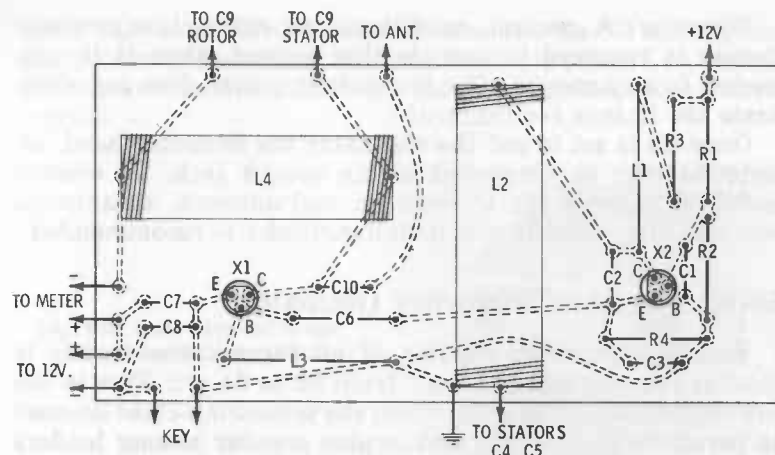
Fig. 6-4. Parts layout for 80-meter transmitter.

Next, connect the leads from L2 to bandset capacitor C5 (on rear panel) and those from L4 to final-tuning capacitor C9. Be sure that the shaft and rotor of C9 do not short out to the metal panel, since they are at 12-volt potential to the box. Connect the stator of C5 to that of bandspread capacitor C4 with a length of stiff wire, and make the power, output, and keying connections to the proper connectors.

The meter may either be mounted on top of the box as shown in the photos, or separately. If mounted on the box, it should be installed prior to the installation of the board, since it is difficult to reach the mounting nuts later.

When all connections are complete, hook up a 12-volt power source. Leave the antenna disconnected, and close the key. Quickly tune C9 for a dip in the meter reading; this should not be more than 5 ma in the dip, although the meter needle will probably be pinned when off resonance.

Tune a communications receiver to 3500 kc and set bandspread capacitor C4 to maximum capacitance. Close the key again, and adjust bandset capacitor C5 until the transmitter signal appears at 3500 kc. Retune C9 as necessary to keep collector current dipped.

To calibrate C4, use the receiver. Set the receiver to successively higher frequencies, and mark their locations on the dial of C4. However, in practice, calibration is not necessary, since the receiver will be used to find a clear spot on the band, and C4 tuned to put the transmitter at that spot.

Warning: A general, conditional, or extra-class amateur license is required to operate this project when it is connected to an antenna. The low output power does not eliminate the license requirement.

Once C5 is set to put the rig inside the 80-meter band, an antenna may be connected to the output jack. To control coupling between the transmitter and antenna, an antenna coupler (described in any ham handbook) is recommended.

50-Mc Variable-Frequency Oscillator

Possibly the most popular of all the amateur bands is that known as "Six Meters," from 50 to 54 mc. This is the lowest-frequency band on which the technician-class licensee is permitted to operate, and is also popular among holders of other classes of license.

Until recently crystal control of transmitter frequency was the normal approach to vhf operation. However, the influx of operators to the 50-mc band has resulted in increased need for vfo capabilities to avoid interference. The problem lies in the operating frequency. Traditionally, stable oscillators must operate at low frequency, and the high order of multiplication necessary to reach 50 mc also multiplies all the faults of the vfo.

The transistorized unit pictured in Figs. 6-5 and 6-6 operates at 25 mc and is more stable than most vacuum-tube oscillators previously used on this band. In fact, the
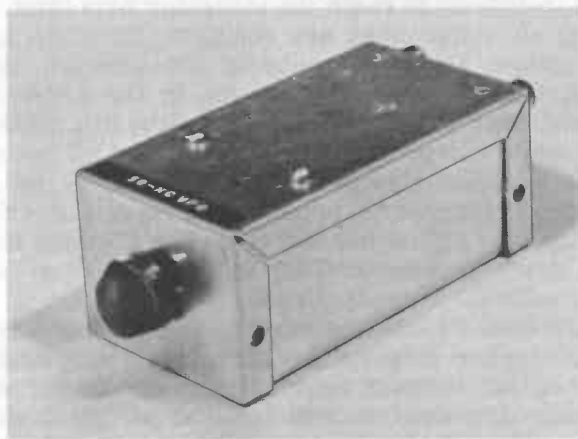
Fig. 6-5. Front view of 50-mc vfo.

drift rate is so low that other stations find it almost impossible to differentiate this vfo from a crystal. The etched-circuit construction technique assures repeatability of these results.

Fig. 6-6. Rear view of 50-mc vfo, showing connections.

An added bonus from the transistor circuit (Fig. 6-7) is the capability of using frequency modulation by simply applying a low-level audio to the base of the oscillator transistor. The output signal of a standard crystal, ceramic, or dynamic mike will usually result in about 3-kc swing, adequate for nbfm. A preamp can be used to increase the swing for wbfm operators.

When frequency modulation is not desired, removing the mike plug from the vfo disables it. Fig. 6-6 shows the mike and output plugs, on the rear of the vfo cases. The power leads are also brought out at the rear to simplify interconnection with other station equipment.

To build this vfo, etch the board (using Negative 6-2) and drill all parts holes. Wind the coils, following Table 6-2. If different coil forms or wire sizes are used, the coils may be trimmed to proper inductance value by use of a grid-dip meter, but they should definitely resonate with the specified values of capacitance with the slugs nearly all the way into the forms. This permits repeaking after the coils are installed into the circuit to allow for input and output capacitances of the transistors.

With the board etched and drilled, and all three coils complete, install the parts (Table 6-3) as shown in Fig. 6-8. Note the polarity on diode D1, and be sure it is correct; incorrect polarity will destroy the diode. If your most convenient source of dc power for the unit is higher than 12 volts, adjust the value of R7 accordingly. R7 must carry no more
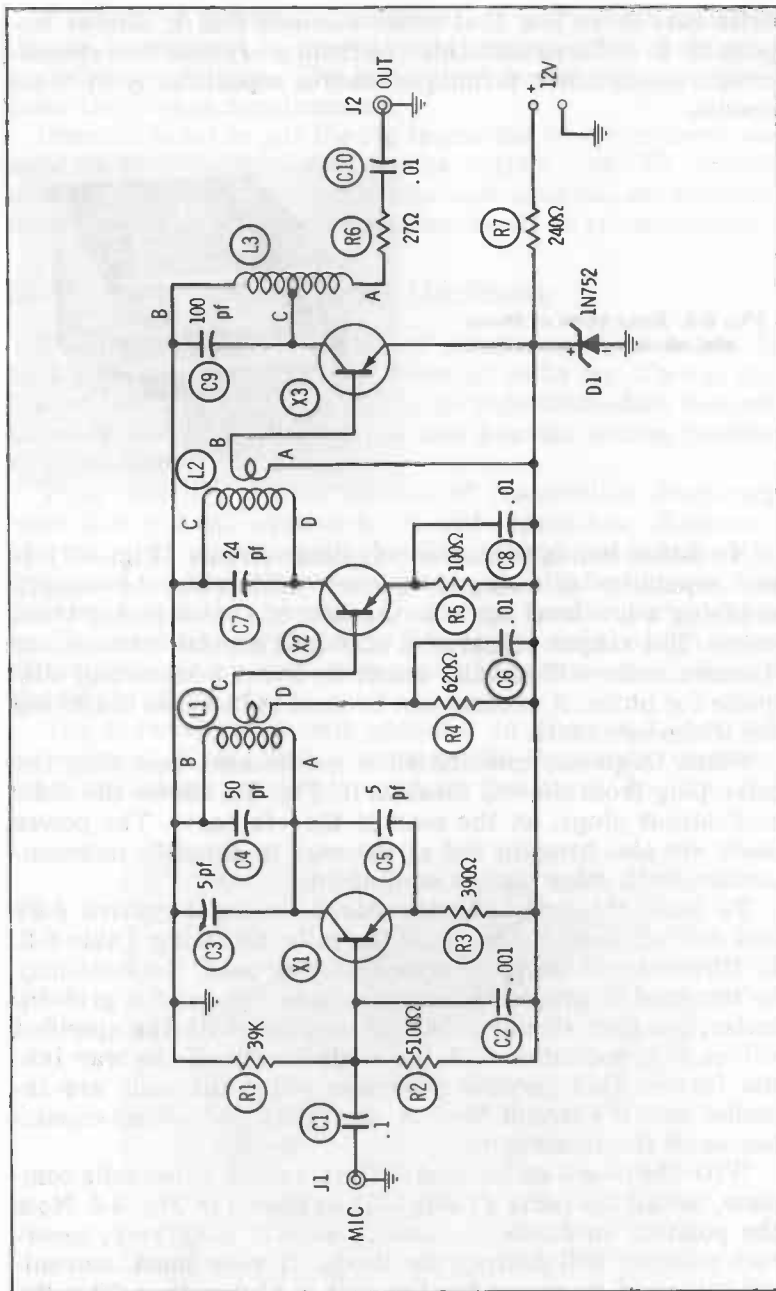
Fig. 6-7. Schematic of 50-mc vfo.

Table 6-2. Coil Data for VFO

Coil	Number of Turns & Wire Size
L1	11 turns No. 30 enamel, closewound, 4-turn link
L2	12 turns No. 30 enamel, closewound, 3-turn link
L3	15 turns No. 30 enamel, tap at 5 turns from bottom

All coils wound on Miller Type 4500 forms

Table 6-3. Parts List for 50-MC VFO

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 6-2)
1	C1	.1-mfd 100WVDC paper capacitor
1	C2	.001-mfd disc-ceramic capacitor
1	C3	5-pf miniature air variable capacitor (E. F. Johnson Type 160-102 or equiv.)
1	C4	50-pf npo tubular-ceramic capacitor (Centralab TCZ-50 or equiv.)
1	C5	5-pf npo tubular-ceramic capacitor (Centralab TCZ-5 or equiv.)
4	C6, C8, C10	.01-mfd disc-ceramic capacitors
1	C7	24-pf npo tubular-ceramic capacitor (Centralab TCZ-20 or equiv.)
1	C9	100-pf disc-ceramic capacitor
1	D1	1N752 6-volt zener diode
2	J1, J2	Phono connectors
3	L1, L2, L3	Tuning coils, wound on J. W. Miller Type 4500 forms (see Table 6-2 for winding data)
1	R1	39,000-ohm, 1/2-watt resistor
1	R2	5100-ohm, 1/2-watt resistor
1	R3	390-ohm, 1/2-watt resistor
1	R4	620-ohm, 1/2-watt resistor
1	R5	100-ohm, 1/2-watt resistor
1	R6	27-ohm, 1/2-watt resistor
1	R7	240-ohm, 1/2-watt resistor (see text)
3	X1, X2, X3	Vhf pnp transistors, 2N2084 or equiv.
1	—	Chassis box
1	—	Knob for C3
1	—	2-terminal barrier strip

than 25 milliamperes of current; diode D1 limits voltage at the circuit end of R7 to 6.2 volts, so that the proper value for R7 is found by subtracting 6.2 from your source voltage, dividing the result by 0.025, and rounding off the quotient to the next *higher* standard resistance value. The value specified in Table 6-3 is for a 12-volt supply.

Drill the box for the four board-mounting bolts, using a 5/32-inch bit. Also drill the mounting holes for tuning capacitor C3 on the front of the box and for the output and
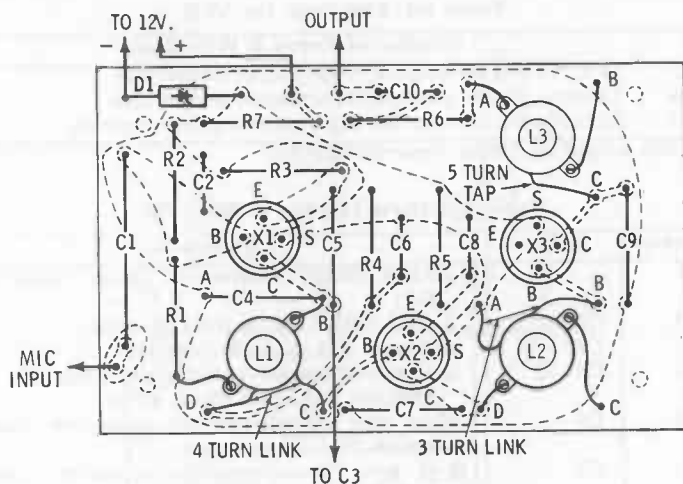
Fig. 6-8. Parts layout for 50-mc vfo.

mike jacks (J1 and J2) on the rear. Also at the rear, cut a notch to clear the terminal strip for power connections.

Mount C3, the two jacks, and the terminal strip before installing the board. The board is held by two angle brackets at the rear, and 1-1/2-inch 6-32 bolts and spacers at the front. In lieu of spacers, you can use multiple nuts to hold the board in position. Finally, connect the jacks, power terminals, and C3 to the board, and the vfo is ready for alignment.

Rough alignment is performed with the cover removed from the box. For final frequency calibration, the cover should be fitted into the side of the box nearest L1 and L2 so that the reduction in inductance of L1 caused by the presence of the metal will be taken into account.

Alignment is easiest if a communications receiver equipped with an S-meter and capable of tuning to 25 mc is employed. The regular 6-meter receiver can also be used, by listening on the output frequency.

Begin by setting C3 to its fully-meshed position and tuning the receiver exactly to either 25 or 50 mc. Adjust the slug on L1 until the output signal is heard; then slowly adjust L1 for maximum indicated signal strength.

Set the receiver to 25.3 or 50.6 mc next, and adjust C3 until the signal is heard. Precise location of the frequency during this step is not essential, but it should be within 50 kc of the 50.6 final output. Adjust L2 for maximum signal

strength. If the frequency shifts as L2 is adjusted, retune the receiver as necessary. (Some frequency shift during this step is normal due to varying load on X1.)

Reset both the receiver and C3 to 25 or 50 mc, and adjust L3 for maximum signal. No change in frequency should be noted as L3 is adjusted.

Finally, insert the box cover (reversed) in position next to L1 and L2, set the receiver to exactly 25 or 50 mc. and C3 to full mesh. Then adjust L1 carefully for maximum signal strength. Secure the box cover in place; the frequency should remain essentially unchanged, though some "warble" and shifting will be noted if you listen while replacing the cover.

To calibrate C3, set the receiver to frequencies which are 100 kc apart in the 50-mc region; that is, if you're calibrating at 25 mc, set first to 25.00, then to 25.05, 25.10, 25.15, etc. Adjust C3 until you have a maximum signal at each position, and mark the dial accordingly.

The dial calibration of any vfo should not be trusted as having absolute precision. When you are working near the edges of the band, compare the frequency to a known-accurate frequency marker. Elsewhere, follow receiver calibration. The dial markings of the vfo are primarily for getting a general idea of the portion of the band in which you are working or for presetting it to a general area.

To check the frequency swing of the f-m provisions, listen to the signal at the output frequency (50-mc region) while talking into the microphone. If swing is not excessive for nbfm, the signal will sound very much like an a-m signal and will have no distortion. If audio appears to be weak, additional swing can be used—either add a pre-amp or use a higher-output mike. If distortion is evident, the swing is too great, so the audio level should be reduced.

Nbfm, with swing not exceeding 3 kc on each side of the carrier frequency, can be used in all ham phone bands. Wbfm, with swing exceeding 3 kc, cannot be used at frequencies lower than 51.5 mc. This vfo can be used for either nbfm or wbfm, by varying the audio level applied to the mike jack.

Test Equipment Projects

One of the most useful areas of application for the transistor is in test equipment; the low power requirements and small size of transistorized test equipment add the advantage of portability.

For this reason, almost one-fourth of all the projects in this volume are based on test equipment. The test equipment described here ranges from the simple to the exotic, but it's all handy for general use. A number of the projects are devices not normally found in experimenter's labs—but they should be.

Square-Waver

For testing both audio amplifiers and instrument preamplifiers, square-wave signals offer a number of advantages over the more common sine waves. By viewing the signal with an oscilloscope, a single mid-frequency square wave can show you both high-frequency and low-frequency response at the same time.

Many a-f signal generators include provisions for square-wave output, but this handy square-waver (Fig. 7-1) is a little larger than a couple of packs of cigarettes and can readily be carried into locations where the bulk of a standard a-f signal generator is too great. What's more, its output signal is of better quality than that of many more expensive a-f generators. The rise time of the waveform is well under one microsecond—few service-quality instruments match this.
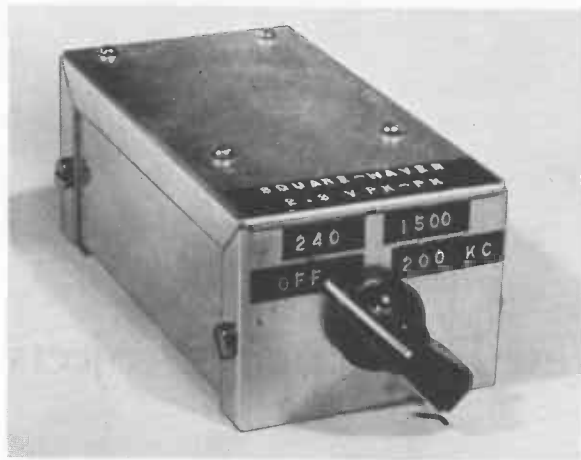
Fig. 7-1. The completed square-waver.

The circuit is a two-transistor multivibrator. The frequency of oscillation is determined by a single capacitor. Switch S1 (Fig. 7-2) selects one of three values for this capacitor to offer a choice of frequencies. A fourth position of the switch turns the unit off.
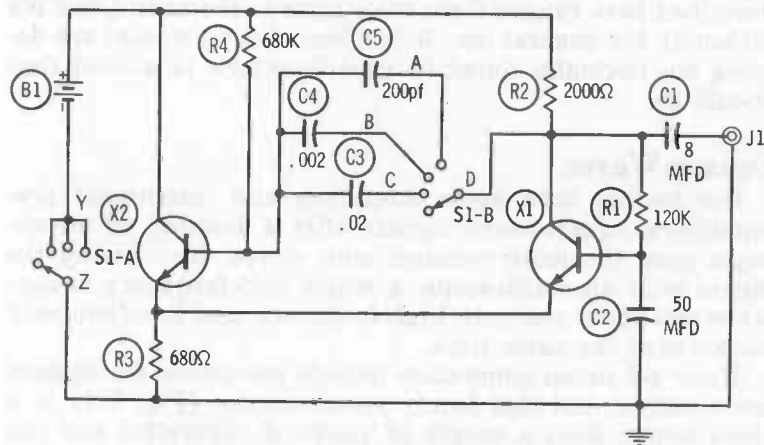

Fig. 7-2. Schematic of the square-waver.

The output is 2.3 volts, peak-to-peak. With the capacitors specified in Table 7-1 and used in the original unit the operating frequencies were 240 cps, 1500 cps, and 200 kc respectively. Smaller values give higher frequencies.

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Table 7-1. Parts List for Square-Waver

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-1)
1	B1	1-1/2-volt penlite cell
1	C1	8-mfd 6WVDC electrolytic capacitor
1	C2	50-mfd 6WVDC electrolytic capacitor
1	C3	.02-mfd tubular paper capacitor
1	C4	.002-mfd tubular paper capacitor
1	C5	200-pf tubular paper or ceramic capacitor
1	J1	Phono connector
1	R1	120,000-ohm, 1/2-watt resistor
1	R2	2,000-ohm, 1/2-watt resistor
1	R3	680-ohm, 1/2-watt resistor
1	R4	680,000-ohm, 1/2-watt resistor
1	S1	2-pole 4-position rotary switch (Mallory 3134J with one pole unused, or equiv.)
2	X1, X2	Npn a-f transistors such as 2N1302, 2N1304, 2N1306, etc.
1	—	Chassis box, 2 1/4 × 2 1/4 × 4 (Bud CU-3003A, LMB TF-715, or equiv.)
1	—	Battery holder for B1
1	—	Knob for S1

In the 240-cps position, a slight amount of top tilt on the waveform is visible. If lower-frequency operation is desired, the output coupling capacitor should be increased in value. In the 200-kc position, a slight rounding of the leading edge can be seen, so higher-frequency operation is not recommended. Few service-type oscilloscopes are able to reproduce even the 200-kc waveform accurately; a 20-kc frequency would be better.

To build the unit, etch the board (using Negative 7-1) and mount all components as shown in the parts layout (Fig. 7-3). Solder lengths of hookup wire into place for the six switch connections and for the battery and output. Drill the box for the mounting holes, output jack, and switch, and install the switch. Then fit the board into place, with 1/4-inch spacers and 4-36 by 1/2-inch machine screws, and secure it. Finally, install the output jack. Then connect the leads as shown in Fig. 7-3.

The battery holder mounts in the other half of the box, with leads long enough to allow the box to be disassembled for battery replacement (Fig. 7-4). Its location is not critical.

When all connections are made, install the batteries and switch the unit on. There is an approximately one-second delay between switching on and the appearance of the output,
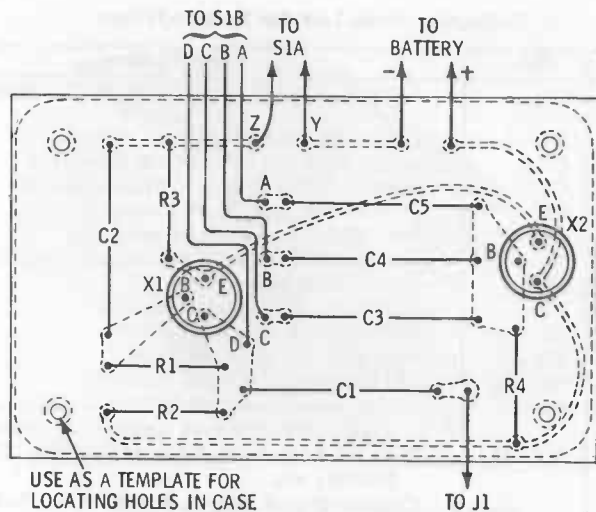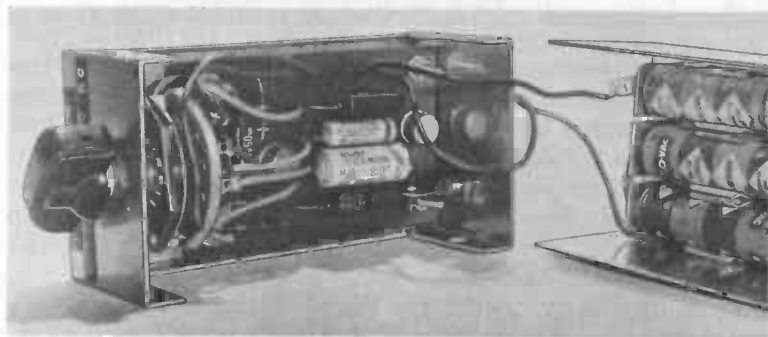
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Fig. 7-3. Parts layout for the square-waver.

Fig. 7-4. The square-waver chassis.

due to the time required to charge the base-bypass capacitor connected to X1. When the output appears, it will remain constant.

Check all three positions to make sure that oscillation occurs at each. To check the highest-frequency position, use an a-c vtvm or scope connected to the output; the frequency will be too high to be heard.

Peak-to-Peak Probe

The r-f probe described in Chapter 2, being a half-wave affair, sometimes fails to give accurate readings of modu-

lated signals or other waveforms in which peak-to-peak values are not related to sine-wave values. This peak-to-peak probe overcomes this disadvantage.

With sine-wave input signals, the d-c voltage at the output of the probe will be 2.83 times the rms value of the a-c voltage. With nonsinusoidal signals, the d-c output will equal the peak-to-peak voltage swing.

Calibration resistor R1 can be selected, in conjunction with the input resistance of the meter or scope with which the probe is to be used, to make the meter read rms equivalent, or to get peak-to-peak readings.

For instance, if the probe is to be used with an 11-megohm vtvm (which has 10-megohm input resistance and 1 megohm in the d-c probe), R1 would be 18 megohms for rms readings, and any value less than 100,000 ohms for peak-to-peak readings.

The probe will give accurate readings at frequencies up to about 200 mc, but it should not be subjected to more than 20 volts rms or 55 volts peak-to-peak.

To build it, etch the board (using Negative 7-2) and mount the components (Table 7-2) shown in the parts layout (Fig. 7-5). The schematic of the unit is given in Fig. 7-6. Assemble the coaxial cable and the probe tip as described for the simple half-wave probe of Chapter 2; shielding can also be added in the same manner. Fig. 7-7 shows probe prior to assembly into the housing.
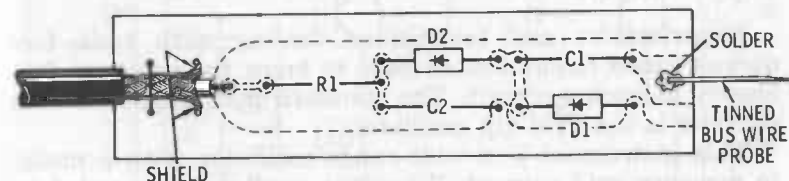

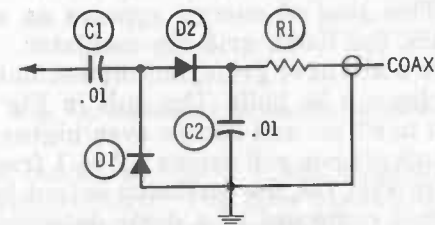Fig. 7-5. Parts layout for the peak-to-peak probe.

Fig. 7-6. Schematic for the peak-to-peak probe.

Table 7-2. Parts List for Peak-to-Peak Probe

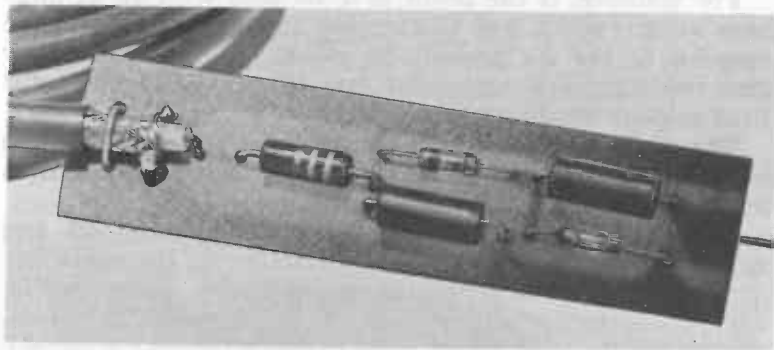| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-2)
2	D1, D2	1N34A crystal diodes
2	C1, C2	.01-mfd 200WVDC microminiature tubular capacitors
1	R1	1/2-watt resistor (see text for determination of value)
3 ft.	—	RG-58A/U coaxial cable
1	—	Shielding tube, make from brass shim stock 3 × 3 by .005 inches

Fig. 7-7. The peak-to-peak probe, less housing.

Dip Oscillator

Experimeters and technicians dealing with radio-frequency tuned circuits often need to know the resonant frequency of such a circuit. The standard instrument for this purpose is the grid-dip oscillator.

This instrument is a wide-range oscillator with a meter to measure grid current. When the oscillator is coupled to a tuned circuit and tuned through its range, energy will be extracted at the resonant frequency of the tuned circuit under test. This loss of energy appears as a dip in grid current; hence, the name grid-dip oscillator.

Transistors don't have grids, but dip oscillators using the same principles can be built. The unit in Fig 7-8 covers a range from 3 to 52 mc and can go even higher in frequency if desired. Each plug-in coil covers a 2-to-1 frequency range.

As shown in Fig. 7-9, the oscillator output is coupled to a metering circuit composed of a diode detector and a single d-c amplifier. This circuit has been arranged so that the
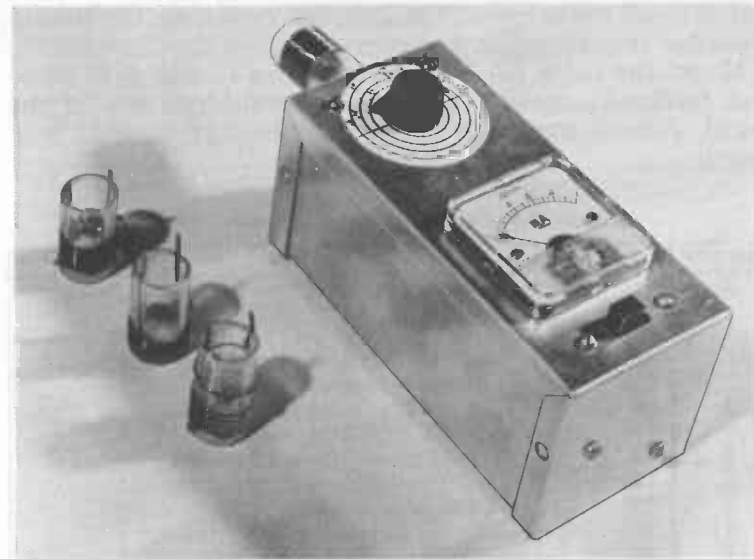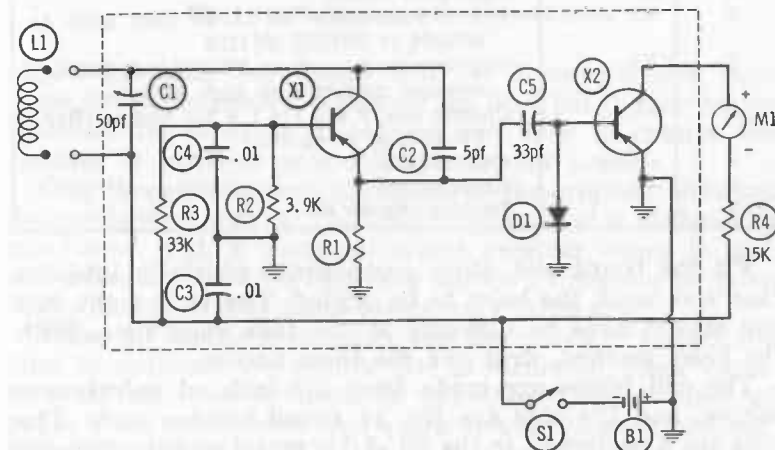

Fig. 7-8. The completed dip oscillator.

Fig. 7-9. Schematic for the dip oscillator.

meter needle cannot go above 1 ma, eliminating the need for a sensitivity control. The only operating controls are the on-off switch and the tuning knob.

To build the unit, etch the board (using Negative 7-3), and drill all parts holes. The hole for mounting the tuning capacitor is 3/8 inch in diameter.

Mount the parts (Table 7-3) as shown in Fig. 7-10; note that feedback capacitor C2 mounts on the foil side of the board, rather than on the top, for shortest possible lead length.

Table 7-3. Parts List for Dip Oscillator

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-3)
1	B1	15-volt battery
1	C1	50-pf air variable capacitor (Hammarlund HF-50 or equiv.)
1	C2	5-pf NPO tubular-ceramic capacitor (Centralab TCZ-5 or equiv.)
2	C3, C4	.01-mfd disc-ceramic capacitors
1	C5	33-pf tubular-ceramic capacitor
1	D1	1N34A crystal diode
1	M1	0-1 d-c milliammeter (any type)
1	R1	3300-ohm, 1/2-watt resistor
1	R2	3900-ohm, 1/2-watt resistor
1	R3	33,000-ohm, 1/2-watt resistor
1	R4	15,000-ohm, 1/2-watt resistor
1	S1	Dpdt slide switch
1	X1	Pnp h-f transistor in TO-33 case, such as 2N1224 or 2N1225, 2N1178
1	X2	Pnp transistor such as 2N404; pick for low leakage, moderate to high beta
1	—	Chassis box, 5 X 2 1/4 X 2 1/4 inches (Bud CU-3004-A, or equiv.)
1	—	Dial for C1
1	—	Knob for C1
1	—	Battery clip for B1

Fit the board and other components carefully into the case and mark the holes to be drilled. The fit is tight, but you should have no difficulty if you take your time. With the holes marked, drill and file them to size.

The coil forms are made from 5/8-inch od polystyrene tubing, and the pins are No. 18 round bus-bar wire. The pins are a perfect fit in the HC-6/U crystal socket; they are attached to the form by heating the wire with a soldering iron until the plastic just softens and then pressing the wire in with long-nose pliers and holding it in place until cool.

Table 7-4 gives particulars of the coils used in the prototype. Small variations are not important; these were de-

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Table 7-4. Dip Oscillator Coil Data

Band	Coil Details
4.5-8.5 mc	26-1/2 turns No. 30 enamel, closewound
7.5-15 mc	22-1/2 turns No. 24 enamel, closewound
15-30 mc	9-1/2 turns No. 24 enamel, closewound
25-52 mc	6-1/2 turns No. 24 enamel, spaced 1/8-inch; adjusting for proper coverage

All coils wound on 5/8-inch od polystyrene tubing; dope after winding and adjusting to inductance.
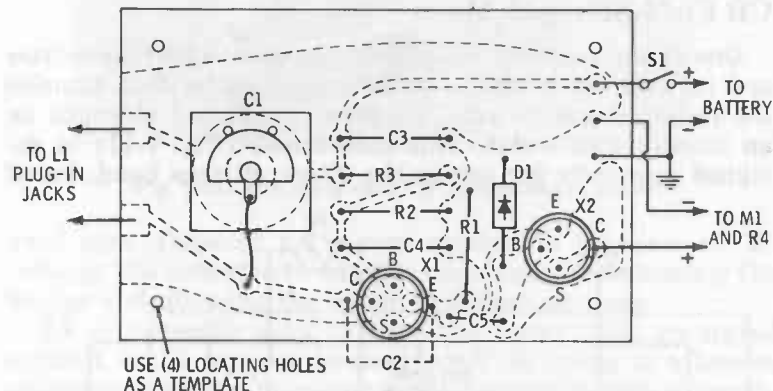

Fig. 7-10. Parts layout for dip oscillator.

signed to make ham bands and the 27-mc Citizens band come out in convenient places on the dial, but if your major interests lie in other directions, feel free to change the number of turns in each coil to suit your needs.

Only three bands were calibrated on the original, although four coils were wound. The low-frequency coil is continually monitored with a communications receiver when in use, so calibration was omitted. The author's interests lie from 7.5 to 52 mc, so only these bands were calibrated.

When all wiring is complete and the coils are wound, it's time to calibrate. No sample dial is furnished, since variations in coils would make it unusable. Tape a piece of paper to the instrument, and warm up a short-wave receiver. Plug in your first coil and turn on the unit. Find its frequency, then set the receiver to the nearest even megacycle and tune the oscillator to this frequency. Mark the spot on the paper, then tune to the next higher even megacycle and repeat the process.

On the lower bands, you can use 100-kc or 200-kc intervals. Above 40 mc, it's easier to calibrate only every fifth

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megacycle. In-between spots can be found by interpolation or by monitoring with the receiver during use.

With the rough dial marked, make a final version from lightweight cardboard (file-card stock) using pen and ink. For a professional appearance, make it two or three times actual size and have a reduced photocopy made at a blueprint house. Glue it in place on the box, and correct any misalignment by slipping the pointer knob.

CB Field-Strength Meter

One of the quickest ways to check out a radio transmitter and its antenna is with a field-strength meter that samples the radiated energy and indicates its relative strength on an uncalibrated meter. This instrument (Fig. 7-11) is designed especially for use on the 27-mc citizens band, but it
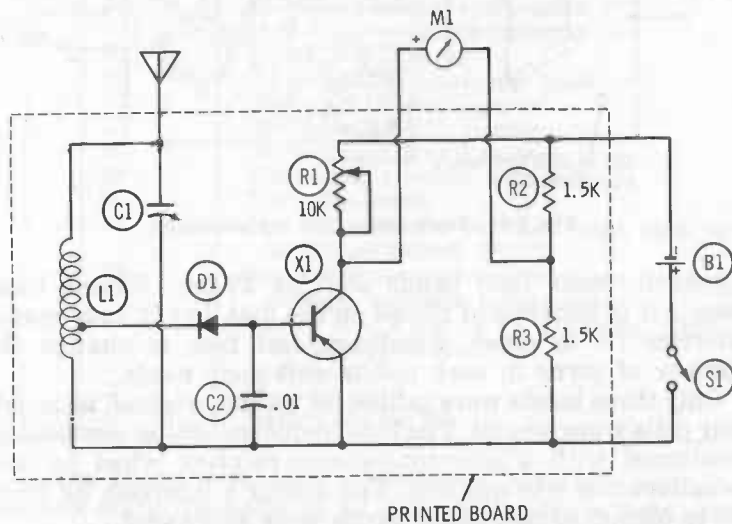

Fig. 7-11. Schematic for CB field-strength meter.

can be tuned to cover any frequency between 26 and 50 mc by adjustment of the trimmer capacitor (C1). It includes a transistor d-c amplifier to boost sensitivity, and it will give a full-scale indication with only 200 millivolts of signal.

The d-c amplifier is a bridge-type arrangement in which resistors R2 and R3 form one arm of the bridge and zero-set potentiometer R1 and the transistor form the other arm. When R1 is set so that its resistance is equal to the collector-to-emitter resistance of the transistor, the meter will
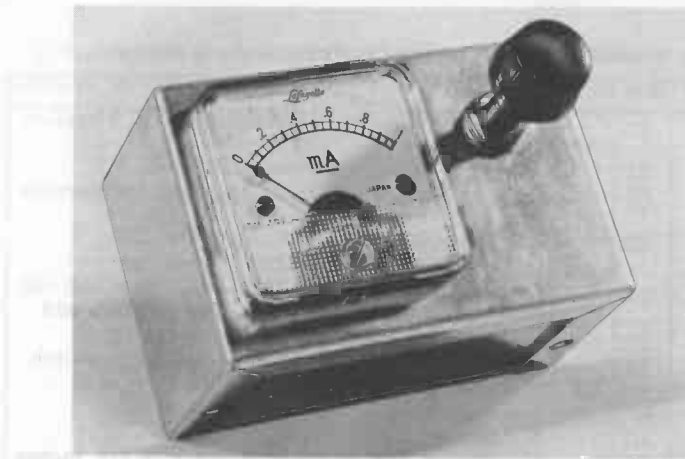
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Fig. 7-12. The completed CB field-strength meter.

read zero. Detected r-f energy applied to the base of X1 reduces the collector-to-emitter resistance, unbalancing the bridge and allowing the meter to deflect up-scale.

R1 is normally used to zero the meter with no signal applied, but it can also be used to set the meter to a known reference point for detecting small changes in field strength. For instance, the meter needle can be brought to half-scale with R1 while normal field strength is present. Then a decrease or increase in strength will readily show up. This is especially helpful in adjusting a transmitter; the effect of any adjustments to the transmitter or antenna system can be instantly seen.

To build the unit (Fig. 7-12), etch the board (using Negative 7-4) and drill the lead holes. Cut the meter hole in the front of the box, and a 5/8-inch diameter hole in the back to clear trimmer capacitor C1. Also drill holes in the box back for the battery holder mounting screws, input jack J1, and the board-mounting screws. Drill a hole in the front for R1.

Mount all components (Table 7-5) on the board as shown in Fig. 7-13; then install the board and other components in the box. After interconnections are complete, check the meter circuit by turning the unit on and determining whether R1 controls the meter needle position.

Affix a short length of stiff wire to a banana plug and insert it into J1. Set a test oscillator to 27 mc, or fire up a CB transmitter, and adjust C1 with an insulated alignment tool or screwdriver until an upscale reading is obtained.

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Table 7-5. Parts List for CB Field-Strength Meter

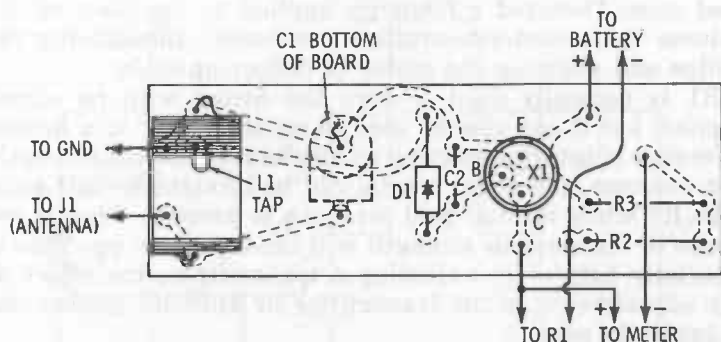| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-5)
1	B1	1-1/2-volt penlite cell
1	C1	7-pf ceramic trimmer capacitor (Centralab 827-A or equiv.)
1	C2	.01-mfd disc-ceramic capacitor
1	J1	Banana-plug jack
1	L1	12 turns B&W No. 3015 or Airdux 816 coil stock, tapped 3 turns from ground end
1	M1	0-1 d-c milliammeter, miniature type
1	R1	10,000-ohm potentiometer with spst switch
2	R2, R3	1500-ohm, 1/2-watt resistors
1	S1	Part of R1
1	X1	2N404 or similar pnp transistor
1	—	Chassis box, 3 1/4 × 2 1/8 × 1 1/8 inches (Bud CU-3017-A, LMB TF-772, or equiv.)
1	—	Battery holder for B1

Fig. 7-13. Parts layout for CB field-strength meter.

If C1 is set for maximum reading on Channel 13, the instrument should perform adequately on all 23 channels. Otherwise, C1 may need to be readjusted for channels at one end of the band or the other. Naturally, C1 must be readjusted when making wide changes in frequency.

If the sensitivity is too great, use a shorter pick-up wire; if it is not great enough, use a longer wire. The average length of the wire will be from 6 to 12 inches.

Universal Oscillator

Frequently in test work or general experimenting, the need arises for a quick and simple oscillator. If you have this circuit put together, you already have one.

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You can view this project (Fig. 7-14) in any one of a number of ways. It can be considered as a "box of negative
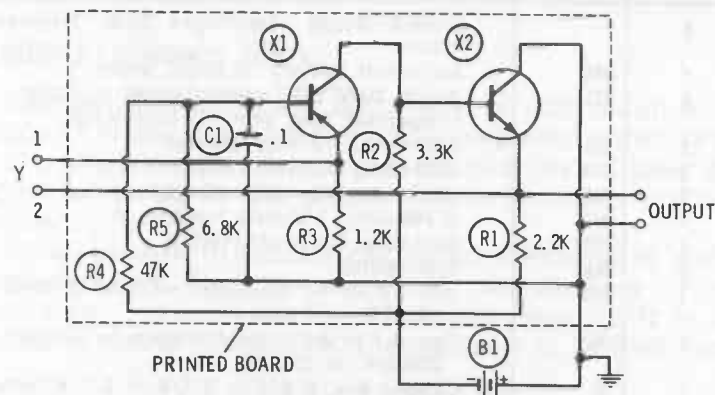

Fig. 7-14. Schematic for universal oscillator.

resistance," or from the more conventional view as a feedback amplifier with its loop open. Regardless of your viewpoint, the application remains the same. Connect a resonator (tank circuit or quartz crystal) across the "Y" terminals, and it will oscillate at the resonator frequency. It operates up into the broadcast band and down to the lowest audio frequencies.

In addition, a signal fed in across the Y1 terminal and ground will be amplified by the unit and appear at the output. By adding an r-f probe in this hookup, the unit is turned into a signal tracer. Connecting a capacitor across the Y terminals instead of a resonator produces a sawtooth oscillation. All in all, this is a versatile device, especially since only a few components (Table 7-6) are needed for its construction.
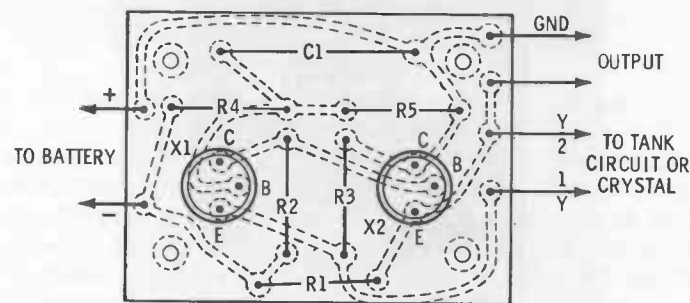

Fig. 7-15. Parts layout for universal oscillator.

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Table 7-6. Parts List for Universal Oscillator

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-5)
1	B1	4-1/2-volt battery (3 size-C cells)
1	C1	.1-mfd 200WVDC tubular-paper or mylar capacitor (not over 7/8-inch long)
1	R1	2200-ohm, 1/2-watt resistor
1	R2	3300-ohm, 1/2-watt resistor
1	R3	1200-ohm, 1/2-watt resistor
1	R4	47,000-ohm, 1/2-watt resistor
1	R5	6800-ohm, 1/2-watt resittor
1	S1	Spst switch
1	X1	Pnp a-f or r-f transistor such as 2N1303, 2N1305, or 2N414
1	X2	Npn a-f or r-f transistor such as 2N1302, 2N1304, or 2N1306
1	Y	Chassis box, 2 3/4 × 2 1/8 × 2 3/4 inches (LMB TF-771 or equiv.)
1	—	Resonator (see text)
1	—	Battery holder for B1 (Keystone No. 187 or equiv.)
2	—	Binding posts
1	—	Crystal socket (or binding posts)

To build it, etch the board (using Negative 7-5), and mount the parts as shown in Fig. 7-15. With all parts on the board, bring out terminals Y1 and Y2 to either a crystal socket or to the binding posts, as you prefer, and the output terminals to the binding posts.

The finished board (Fig. 7-16) can be mounted in a metal box, or in any other manner you like. The original simply sits on the author's bench, as an idle board, until it's needed. Then test clips are used to hook up to any available battery
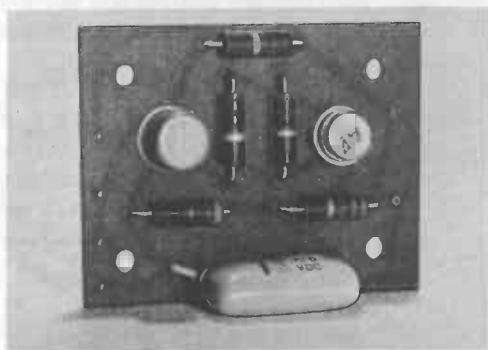

Fig. 7-16. The universal oscillator circuit board.

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and the desired resonator; the "universal oscillator" is then in business.

Audio-Frequency Meter

One useful device that's not nearly as well known as it might be is the direct-reading audio-frequency meter (Fig. 7-17). When connected to a line carrying an a-f tone, the calibrated meter in this gadget directly indicates the frequency of the tone.

It can be used to monitor the output frequency of audio oscillators, but its real value is in the checking of r-f oscillators. For instance, it will rapidly reveal drift in an oscillator circuit. To do this, the oscillator to be tested and

Fig. 7-17. The completed audio-frequency meter.

a known stable crystal oscillator are both connected to a mixer, and the oscillator under test is tuned to produce an audio-frequency beat note. This beat note signal is then applied to the audio-frequency meter, and the test is ready to proceed. Any change in frequency of the r-f oscillator will produce an equal change in the beat-note frequency. This change in frequency will, in turn, change the reading

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of the audio-frequency meter. Drift rates as little as 10 cycles per second per hour are readily detected by this test.

One reason audio-frequency meters haven't been widely used is that most of the circuits for them have been complex. This one, however, is not. It can be built for well under $10, and the etched board eliminates all chance of wiring errors.

The circuit, diagrammed in Fig. 7-18, uses two transistors in the switching mode. In the absence of any signal, both
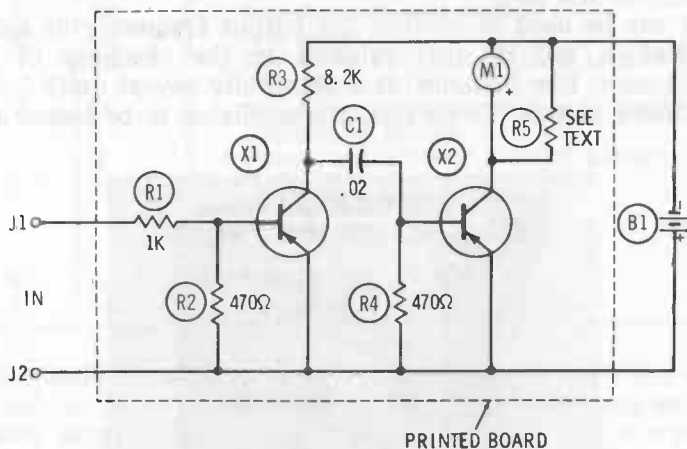

Fig. 7-18. Schematic for the audio-frequency meter.

transistors are "off," and no current flows through the meter (incidentally, because of this property, no switch is necessary). When an audio signal is applied, X1 switches into conduction on the negative-going halves of each cycle.

When X1 conducts, its collector voltage goes from −9 volts to zero; when conduction ceases, the collector returns to −9 volts. These changes in level are differentiated by C1; the negative-going spikes when the collector returns to −9 volts turn X2 on briefly, allowing a pulse of current to flow through the meter on each cycle of input signal. Between pulses, the meter needle attempts to return to zero. When the pulses recur at an audio rate, however, the needle cannot get back to zero before the next pulse arrives; as a result, the needle remains steady at some upscale reading.

The more frequent the pulses, the higher the needle is held. With the parts values specified, the meter indication is linear with a frequency from less than 20 cps (lower limit of oscillator used for checking) up to 1 kc; for higher

upper frequency limits, the value of C1 can be reduced. Increasing C1 will lower the upper-frequency limit, but this simple circuit does not offer good results at frequencies below 20 cps, because the flicker of the needle becomes evident to the eye.

To build the meter, etch the board (using Negative 7-6) and drill all holes. The two meter-terminal holes are 1/8 inch in diameter, while all others are No. 60. Then mount the components (Table 7-7) as shown in Fig. 7-19 and solder.

Mount the meter in the box, and also the two input connectors. Solder short lengths of hookup wire (the clipped leads of C1 were used in the original) to the input connec-

Table 7-7. Parts List for Audio-Frequency Meter

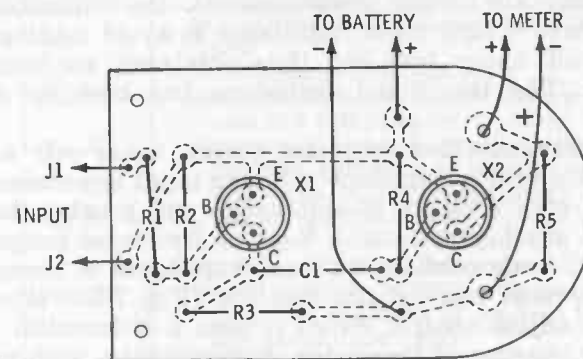| Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-7)
1	B1	9-volt transistor battery, tubular-type
1	C1	.02-mfd tubular-paper capacitor (see text)
2	J1, J2	Bind posts for test leads
1	M1	0-1 d-c milliammeter, miniature type (Lafayette 99 G 5052 or equiv.)
1	R1	1000-ohm, 1/2-watt resistor
2	R2, R4	470-ohm, 1/2-watt resistors
1	R3	8200-ohm, 1/2-watt resistor
1	R5	100-ohm, 1/2-watt resistor (see text)
2	X1, X2	Pnp switching transistors such as 2N404, 2N414, 2N1303, etc.
1	—	Chassis box, 2 3/4 × 2 1/8 × 1 5/8 inches (Bud CU-3000-A, LMB TF-770, or equiv.)
1	—	Battery clip for B1

Fig. 7-19. Component parts layout for the audio-frequency meter.

tors, then fasten the board in place with the meter-terminal screws and solder the input leads to the board.

Space requirements rule out a conventional 9-volt battery, if the box specified in Table 7-7 is used. However, the smaller double-ended battery fits nicely. Connectors for this battery are made by cutting apart a standard 9-volt clip. The battery wedges into place and is held by friction.

To calibrate the meter, connect it to an audio oscillator and set the oscillator output to maximum. If square-wave output is available, use it. Adjust the oscillator to the frequency which gives full-scale reading; this should be higher than 1000 cps. Temporarily connect a 1000-ohm potentiometer to the R5 terminals and adjust its resistance until full-scale reading is obtained with a 1000-cycle input.

Next measure the resistance of the pot, and use this value for R5. If the value cannot be obtained with standard resistors, use the next larger value. This will result in a slightly low reading (full-scale with slightly higher than 1000-cycle input), but since readings tend to be a few percent high with sine-wave input as compared to square-wave input, the two errors will tend to cancel each other out.

This meter is power-operated, and it requires a signal of at least 2 volts to give accurate indications. If smaller signals are to be measured, a preamplifier should be used. However, the preamplifier must be capable of passing the frequency of the signal (see Chapter 3 for suitable designs).

Transistorized Voltmeter

In many electronics measurements, the voltmeter used should have a high input impedance to avoid loading down the circuit under test and thus obtaining an inaccurate reading. The traditional technique has been to employ a vtvm.

This transistorized voltmeter (tvm), using only a handful of inexpensive components, has an input impedance equal to most vtvm's on its 30-volt range and greater than the vtvm on any higher ranges. Even on its lowest range, with 3-volt full-scale reading, its input impedance is 3 megohms.

Unlike most tvm circuits, this one (Fig. 7-20) eliminates the zero-adjust control. Since it uses a differential amplifier, any changes of transistor characteristics with temperature cancel out. The only thing that shows upon the meter is the signal applied to the input.
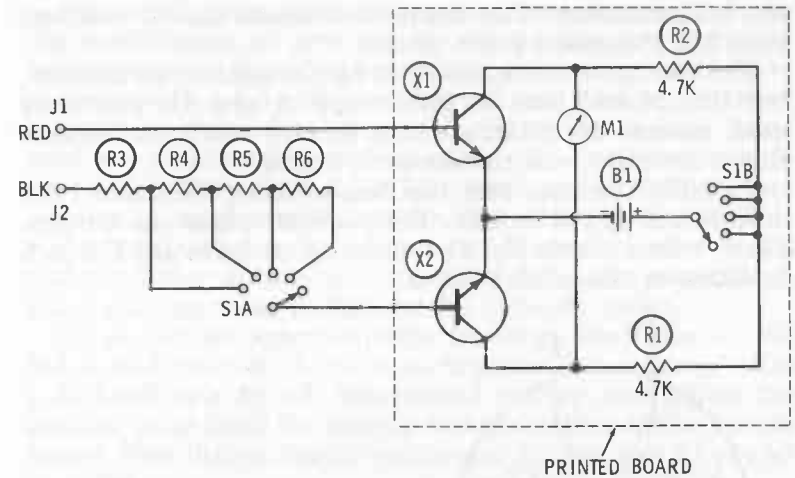
Fig. 7-20. Schematic for transistor voltmeter.

The two transistors are operated without base bias; because this eliminates shunt current paths, it contributes to the high input impedance. With the 100-microampere meter used in the original, sensitivity was 500,000-ohms-per-volt; with the 50-microampere meter specified in Table 7-8, sensitivity should be in the region of 1-megohm-per-volt.

Less sensitive meters should not be used, since the amplifier circuit is not linear over an extremely wide current range. However, the meter specified costs less than most

Table 7-8. Parts List for Transistor Voltmeter

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-8)
1	B1	3-volt battery (2 penlite cells)
1	M1	0-50 microammeter, 1-9/16″ square (Lafayette 99 G 5049 or equiv.)
2	R1, R2	4700-ohm, 1/2-watt 5 percent resistors (adjust zero indication by shunting one with high-value resistor if necessary)
4	R3, R4, R5, R6	1/2-watt multiplier resistors (see text for values)
1	S1	5-position, 2-pole rotary switch
2	X1, X2	2N1302, 2N1304, or 2N1306 transistors, npn (matched as closely as practical for leakage current and beta)
1	—	Chassis box
1	—	Knob for S1
1 pr.	—	Test lead connectors

0-1 milliammeters. The entire instrument should cost less than $12 at present parts prices.

The two transistors need not be the same type number, but they should both be either npn or pnp (if pnp's are used, reverse the polarity of the battery and input connections; the meter can remain as indicated).

To build the tvm, etch the board (using Negative 7-7), drill it, and cut it to size. The rounded edges can be produced with a coarse file. The meter-screw holes are 1/8-inch in diameter; the others No. 60.
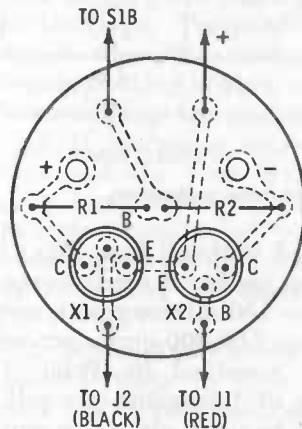

Fig. 7-21. Parts layout for transistor voltmeter.

Mount the components (Table 7-8) as shown in Fig. 7-21, with the exception of R2. In place of R2, use test-clip leads to connect a 5000-ohm pot. Then apply power.

The meter needle will probably swing off-scale in one direction or the other. Variation of the potentiometer resistance should bring it to zero, however. Once the meter is zeroed, remove power and wait 5 to 10 minutes for the transistors to cool completely. Then, without disturbing the potentiometer adjustment, reconnect power. If the zero has shifted, re-zero. This time leave power connected for 30 to 45 minutes as a check of possible zero drift. None should be detected.

Then disconnect the potentiometer, measure its resistance, and use this value for R2. If the resistance cannot be matched with standard values, use the next larger value and connect high-value resistors in parallel with it to reduce it to the zero point.

The multiplier resistors (R3 through R6) for the 3-, 10-, 30-, and 100-volt ranges must be chosen after the instrument is completed, since their values are determined in part by the amplification of your specific transistors, and by inter-base resistance. Start by connecting a 2.2-megohm resistor in series with a 1.5-volt flashlight cell and hooking the combination to the meter input leads. Vary the resistor value until you obtain a half-scale reading. The resulting value is that which you will need for R3 (3-volt scale). Add another resistor of approximately twice that value, and substitute a 9-volt battery for the 1.5-volt cell. Vary the value of the added resistor until a reading of 0.9 full scale is obtained. The resulting value is that for R4 (10-volt scale).

R5 should be approximately 10 times the value of R3, but it will probably have to be trimmed for accuracy. Use a 22.5-volt or a 30-volt hearing-aid battery, and adjust the resistor value until the battery voltage is read on the 30-volt range. Note that on the 30-volt range, R3, R4, and R5 are all in series.
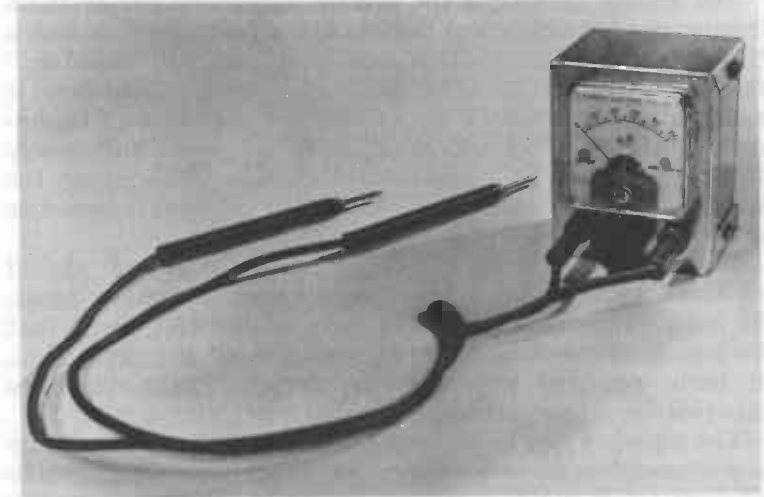

Fig. 7-22. The completed transistor voltmeter.

Finally, R6 (100-volt range) is approximately 10 times the value of R4, and it will probably be of such high value that it must be made of several lower value resistors, since resistances greater than 22 megohms are difficult to locate. Use a 30-volt (or higher) battery and adjust the value of R6 until the battery voltage is read on the 100-volt range.

In the original instrument, R3 consists of a 1-megohm and a 430,000-ohm resistor in series, R4 of a 2-megohm and

a 1-megohm in series, R5 of a pair of 7.5-megohm units, and R6 of a 8.2-megohm and a 22-megohm in series. All were trimmed into place against batteries as references.

With the multiplier resistors all trimmed to value, connect them to the range switch. Take care not to overheat the resistors while soldering, as their value can change permanently from only slight overheating. Note that the "off" position of the switch is at the far right rather than the more conventional left; this assures that when the unit is turned on, it will be on its highest range first.

Finally, install the switch, the connector jacks, and the meter in the box, and mount the board on the meter terminals. Connect the battery, and interconnect other components as shown in Fig. 7-20, and the unit is complete.

Frequency Standard

The normal technique for precise measurements of radio frequencies is to compare the unknown frequency against a "frequency standard." For this purpose, the "standard" most often used is fixed at 100 kc, since this frequency is easily adjusted to match that of National Bureau of Standards station WWV, and most receivers have sufficiently linear dials to allow interpolation between 100-kc spots for measurement of frequencies which fall between harmonics of the standard.

For maximum utility, the frequency standard should maintain its frequency for as long a period of time as possible without readjustment, and most authorities agree that it's best to allow the standard to operate all the time. This, in turn, requires a low-power circuit. Transistors are naturals for this application.

The circuit (Fig. 7-23) uses two inexpensive general-purpose transistors in a variation of the cathode-coupled multivibrator, with a 100-kc quartz crystal as the coupling element. It operates from a single flashlight cell and produces strong output throughout the high-frequency spectrum. A trimmer capacitor (C3) allows the frequency to be adjusted to an exact synchronism with WWV.

Fig. 7-24 shows the completed board for this project, less the crystal itself. The board was laid out to accommodate the widest possible variety of crystals; many inexpensive standard crystals fitted with octal-tube bases, are available on the surplus market. The board is equipped with pads which match this base.
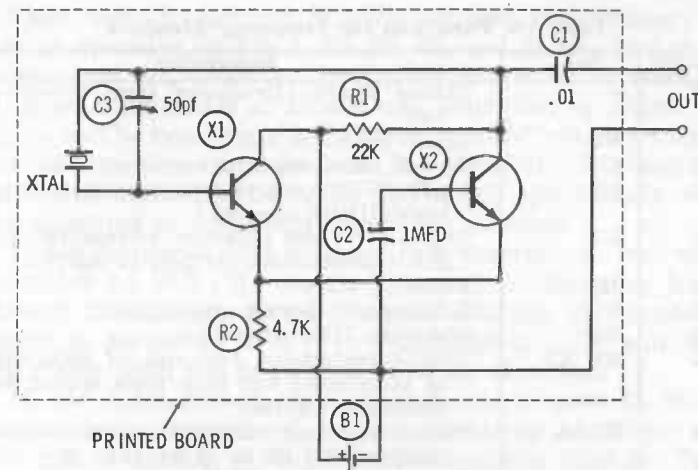
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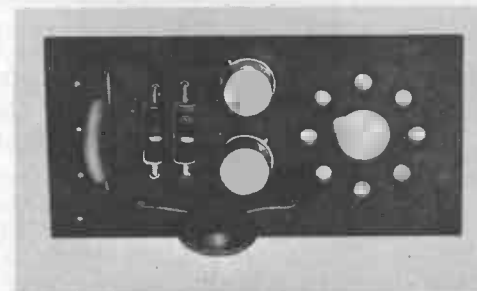Fig. 7-23. Schematic for the frequency standard.

Fig. 7-24. Circuit board for the frequency standard.

If your crystal, like the unit specified in Table 7-9, has a conventional two-pin base, you need not use the entire negative. You can omit the portion above the two octal-pin pads which connect to the rest of the circuit, and attach the crystal or crystal socket to these pads.

If your crystal does have an octal base, determine which pins connect to the crystal. Select one of these pins to connect to one of the pads which connects to the circuit, and file the keyway in the center hole accordingly. Then either prepare to run a jumper wire or cut an opening in the paper negative in order to photo-etch the jumper to connect the pad of the other pin to the other circuit pad.

The completed standard may be either mounted in a chassis box as a separate item or built into the receiver out

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Table 7-9. Parts List for Frequency Standard

Quantity	Ref.	Description
1	—	Etched Board (Developed from Negative 7-9)
1	B1	Size D flashlight cell
1	C1	.01-mfd paper capacitor
1	C2	1-mfd 3WVDC disc-ceramic capacitor (Centralab UK105 or equiv.)
1	C3	50-pf air variable capacitor, screwdriver adjust (Hammarlund APC-50 or equiv.)
2	J1, J2	Binding posts
1	R1	22,000-ohm, 1/2-watt resistor
1	R2	4700-ohm, 1/2-watt resistor
2	X1, X2	2N168A transistors. Any npn r-f units can be substituted but both units should be reasonably matched
1	XTAL	100-kc frequency standard crystal (James Knights H-93-100 kc or equiv.)
1	—	Crystal socket for XTAL
1	—	Battery holder for B1
1	—	Chassis box

of sight. For this reason, final mounting details are left to the constructor. To build the standard, first determine the details of the crystal connections, and modify the negative accordingly (if required). Then etch the board (using Negative 7-8), and drill all holes.

Mount the parts (Table 7-9) as shown in Fig. 7-25, and solder them in place. The interconnection of power and output leads, as well as of capacitor C3, are shown in Fig. 7-23.

To adjust the standard initially, apply power to it and tune the receiver to any frequency which is an even multiple of 100 kc. The output signal should be heard. If not, check all connections carefully, especially those to C3. Set C3 to minimum capacitance for this step.
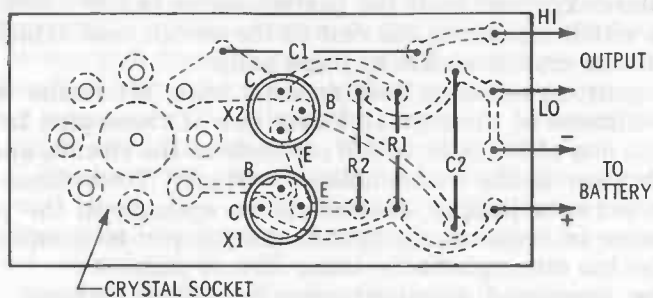

Fig. 7-25. Parts layout for the frequency standard.

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Then tune to any of WWV's several frequencies; the station operates on 2.5, 5, 10, 15, 20, and 25 mc, and it can be received anywhere in the United States on at least one of these frequencies at almost any hour, day or night. The signal can be recognized by a regular "tick" which occurs at precise one-second intervals. In addition, it frequently carries an audio tone of either 440 or 600 cps. Finally, voice identification is broadcast every five minutes.

If you hear a station meeting this description, but which identifies as WWVH, use it. You will be listening to the Hawaii installation of the National Bureau of Standards, which is slaved to WWV in Washington, D.C. and is in exact step with the primary station at all times.

If, for some reason, you are not able to tune to WWV, then tune to a standard broadcast station on either 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, or 1500 kc. These stations are required to maintain their frequencies accurate within 20 cps at all times, and most of them stay within 2 cps of their assigned frequencies as a matter of pride. While their accuracy is not quite as good as that of WWV, for most uses you'll never know the difference.

With power applied to the standard, you should hear in the receiver the station to which you are tuned, and also a loud whistling beat note. Adjust C3 for the lowest possible pitch of the beat note. After the pitch of the beat is too low to hear, you can still measure it by counting the number of swings the S-meter needle makes during each second. If possible, adjust C3 until the needle comes to a complete halt. If you can't get below 4 or 5 swings per second, it is close enough for most purposes.

The final adjustment of C3 should be made when the station being used for reference is transmitting an unmodulated carrier; otherwise you may zero to a sideband of the signal rather than to the carrier itself. WWV has carrier-only periods once each five minutes which are ideal for the purpose; broadcast stations, on the other hand, attempt to avoid having "dead air" as much as possible. With them, you can adjust for the most natural-sounding speech and music after the beat note passes below audibility; this will assure that you are within a very few cycles of matching their carrier frequency.

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Chapter 8

Designing Your Own
Circuit Boards

In the preceding chapters 30 different etched-circuit projects have been presented. The negatives for duplicating them are provided in the back of this volume. While the projects have been chosen to appeal to the widest possible range of interests, obviously they cannot exhaust all the possibilities of etched-circuit projects—nor can they provide you a circuit board suitable to your own pet design.

To do this, you must design your own circuit board. This is not nearly as difficult as you may believe. The design of a circuit board, once a proven circuit has been chosen for use, falls into three broad categories—planning, parts arrangement, and mechanical production.

Planning for Etched Circuits

The "planning" we refer to at this stage covers such general topics as, "Is it a one-time circuit, or should it be arranged for easy duplication?" and "Must the board withstand temperature and humidity extremes?"

Circuit-board material is available in both one-sided and two-sided versions. All projects in this book use the one-sided boards, since duplication of two-sided boards by the photo process requires the capability of precise registration —which is beyond most experimenters' budgets.

The two-sided board is identical to the one-sided board used in this book, except that there are copper coatings on *both* faces of the board. It can be extremely useful in one-

of-a-kind designs and in professional circuit-board work where the registration capabilities are available. For instance, the jumper wires required in the all-purpose audio preamplifier of Chapter 3 could have been eliminated by use of a two-sided board; the jumper would merely have been etched on the parts side of the board.

Since the presence of copper patterns on both sides of the board allows greater freedom in placement of components, it may have quite an influence on the precise components employed. However, even in the case of boards intended for mass production, it's well to keep in mind that one-sided boards can be dip-soldered in a single operation, while two-sided boards must be hand-soldered at least on the parts side.

The number of boards to be made from the design also will influence the choice of exact components. One-of-a-kind designs may be put together around any parts on hand which have the proper electrical qualities. Production designs, however, must use components that are readily available in quantity. Differences in pad locations of only a few hundredths of an inch can make the difference between easy assembly by an unskilled person, and tedious lead-bending which is both slower and requires some skill. Fortunately, many components have been standardized in size, so that these components will fit onto circuit boards designed for them, regardless of the manufacturer of the individual component.

For high-humidity or high-temperature use, it would be wise to plan on using epoxy-base board stock rather than phenolic-base materials. The cost is higher, but the boards will be much more resistant to their environment as well.

While it's not possible to describe all the possible questions which might arise during this "planning" stage, those mentioned give an idea of what must be done. When no more questions remain to be gone into, it's time to move to the second area—parts arrangement.

Getting the Parts in Place

The process of getting the parts arranged properly on an embryo etched-circuit design is like nothing so much as the working of an intricate jigsaw puzzle. The pieces to be fitted in are the resistors, capacitors, transistors, and transformers required by the electrical circuit. Determining which can be placed where is the object of the game.

You have a number of rules to guide you in the placement of parts. Most important, of course, is the schematic diagram of the circuit itself. The parts, when finally in place on the board and interconnected by means of the etched circuit, must correspond to the schematic in order for the completed board to function.

In addition, all leads should be kept as short as possible and, insofar as possible, should run direct from one component to another without wide loops and bends.

"Wires" in an etched circuit are etched from a single sheet of copper, so it's not possible for one "wire" to cross another without making a connection. Careful layout and rigid adherence to the short-lead principle will help keep the incidence of crossovers to a minimum, but sometimes they are not avoidable.

When a crossover must be made, the simplest way of doing it is to find a component such as a resistor in one of the two "wires" which must cross, and run the crossing lead beneath this component. Examples of this approach are included in almost every project in this volume; it's the standard way of getting one lead on the "other side" of a second conductor. While it does require a departure from the direct-lead principle at times, this is the preferred method of handling the situation.

At times, however, no such simple crossover is possible, and the alternative must be used. This alternative is the use of a wire jumper, which lifts one conductor off of the etched surface so that it can cross the other. Use of jumpers should be held to an absolute minimum; they should not be employed unless excessively long leads would be required to avoid their use, as in the audio-preamp of Chapter 3.

In the earlier stages of board layout, liberal use of sketches is recommended. This helps avoid such shortcomings as the placement of two or more components in the same physical space. However, in many cases components may be stacked one atop the other, for most efficient use of board area.

The Grid Approach

For the most professional appearance of the finished board, the "grid approach" to laying out the pattern is very helpful. Professional circuit-board designers long ago standardized their designs around a 0.2-inch grid, placing all component-lead holes at intersection points on this grid.

The result is that components are arranged neatly on the board, and wiring patterns tend to have a more compact appearance.

As components become smaller, smaller grids are coming into use; however, the standard shown in Fig. 8-1 should be adequate for most applications.
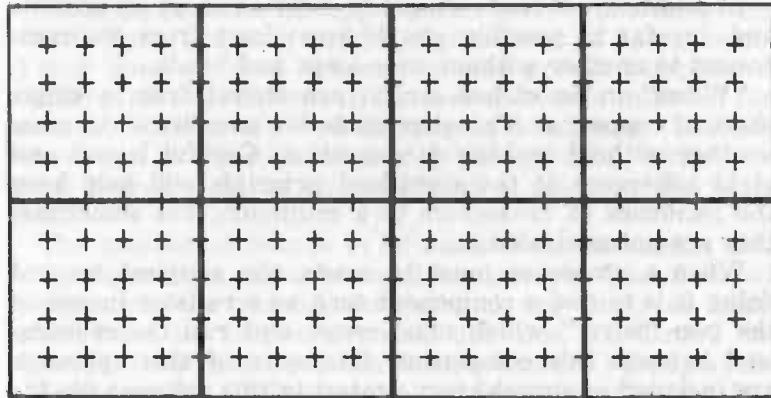

Fig. 8-1. Standard etched-circuit grids.

Those components whose sizes have been standardized for circuit-board use are standardized to either this 0.2-inch grid or to the newer 0.1-inch size. This means that their leads are even multiples of 0.2 inches apart. When using these components, a board can be designed without ever seeing the actual components if a catalog giving standard dimensions for each electrical size of component is available. To do this, simply put the pads for the component the same distance apart as the lead spacing, and allow enough space "topside" for the body of the component.
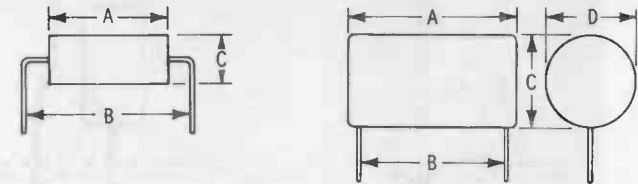
Since both the 0.1-inch and 0.2-inch grids are multiples of 1/10 inch, regular engineering graph paper or sketching pads, ruled with 10-to-the-inch squares, provides perfect grid patterns. If preliminary sketches are made on this kind of paper, the final board layout will already be made when the final preliminary sketch is completed.

For all except one-of-a-kind projects, the greatest accuracy of layout will result if the layout itself is made twice the final size and then photographically reduced to the final board size. This method entails almost no extra expense, since a negative must be made anyway. Any small errors in your layout will be reduced by 50 percent when the copy is made.

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Component Dimensions

Successful use of the grid approach requires a knowledge of component dimensions. As mentioned previously, many components have been standardized dimensionally for etched-circuit work. Many others, however, have not been formally standardized but are necessary for etched circuits. Fortunately, most of these components (resistors, some transformers, and certain r-f coils, primarily) can also be accommodated by placing pads at distances far enough apart to take care of the largest units, and bending leads to fit on smaller ones.

The sizes of the most commonly used components are given in Fig. 8-2. Components not shown in this illustration have not been standardized, or are not used frequently
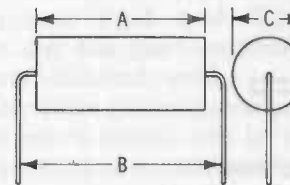

RATING	A	B	C
1/2W	3/8"	.6"	1/8"
1W	5/8"	.8"	1/4"
2W	3/4"	1"	5/16"

(A) Resistors.

VALUE	A	B	C D
TO .05	7/8"	.8"	15/32" MAX.
.1, .15	1-3/16"	1.2"	9/16" MAX.
.2 - .25	1-5/16"	1.2"	5/8" MAX.
.33 -.5	1-5/8"	1.6"	3/4" MAX.

(B) Mylar capacitors

12V RATING

VALUE	A	B	C
TO 50 μf	11/16"	8"	3/8" MAX
75, 100	13/16"	1"	3/8"
150, 200	1 1/4"	1.4"	3/8"
250	1 1/2"	1.6"	3/8"

(C) Electrolytic capacitors.

	A	B
AVERAGE	1/2"	.4"
(NO STANDARDS)		

(D) Disc-ceramic capacitors.

Fig. 8-2. Sizes of common components.

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enough to warrant inclusion. To determine the dimensions of components not shown, consult manufacturers' catalogs, or as a last resort, write to the manufacturer for a dimensional drawing of the component.

Resistors and capacitors both present the choice of "flat" mounting on the board, or "vertical" mounting. The projects of this volume employ "flat" mounting, with the body of the component flat against the board, but if board area is at a premium, the "vertical" technique can produce a savings in space. Fig. 8-3 shows how to mount axial-lead components vertically; many types of capacitors are made especially for vertical mounting as shown in Fig. 8-3C.

(A) Resistor.

(B) Axial-lead capacitor.

(C) Vertical-mounting capacitor.

Fig. 8-3. Vertical mounting of components.

Using Perforated Board

If the electrical circuit to be put onto a circuit board has not been proven in practice, the steps of "breadboarding" the electrical circuit and designing the layout of the etched circuit can be combined by using perforated phenolic or epoxy board for the prototype.

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This board is intended to be used with push-in terminal fittings, but when it is employed for prototypes of etched circuits, the fittings are not used. Instead, component leads are threaded through the board perforations and then bent back flush against the underside of the board and interconnected as necessary. Fig. 8-4 shows a typical prototype constructed in this manner.
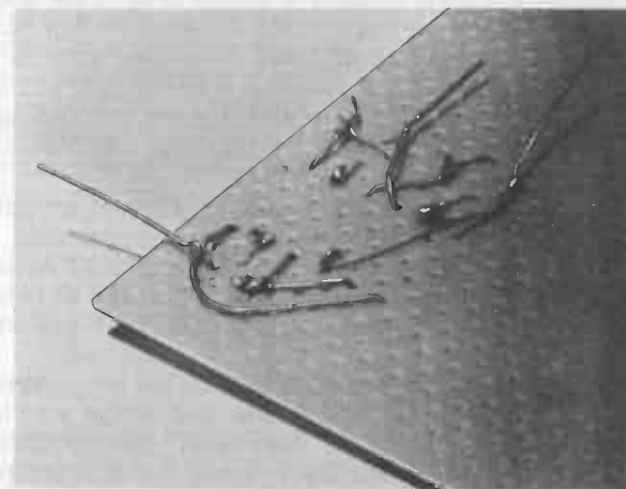

Fig. 8-4. A typical perforated-board prototype.

The boards are available with perforations arranged in a wide variety of patterns. That shown in Fig. 8-4 has been found to be most useful by the author, since the leads of standard TO-5 and TO-33 transistors are perfect fits through the perforations, which are located on a "staggered" 0.2-inch grid.

Once the prototype is performing to expectations, the circuit board layout can be made by counting perforations, or measuring along the perforation lines, to locate the pads for each component; then following the arrangement of the soldered leads, draw the conductor lines to connect the pads. Most of the projects in this volume were designed by this technique.

Obtaining the Negative

When a satisfactory board layout is achieved, the next step is to prepare a "camera-ready" drawing of it. As men-

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tioned earlier in this chapter, making this drawing double actual size will minimize the effects of minor errors.

The drawing can be prepared in any of several ways, but it must have high visual contrast so that when photographed, the only tones present will be pure black and clear white.

If you have any artistic skill at all—or even a reasonably steady hand—the least expensive means is to draw the pattern with India ink on pure white illustrator's board. The conductor lines should be at least 1/32-inch wide in final size (1/16-inch wide if the drawing is twice final size) and preferably twice that width. In addition, no two conductors should approach each other closer than the width of a conductor line.

At least 1/16-inch of metal should be allowed around the lead holes for the terminal pads. If space permits, even larger pads won't harm anything. The center of each pad should be marked by a clear white space on the drawing to provide the effect of centerpunching and make subsequent board drilling easier.

If drawing skill is not included in your list of capabilities, a number of firms offer tape circles and strips which can be used to prepare the master "drawing." Simply stick circles in place where pads are desired, and run tape strips for the conductors. The same spacing rules apply.

When the drawing is complete, it's time to have a negative made. This is a job best delegated to a professional—but don't go to a photographer. Instead, take your drawing to a printer specializing in offset lithography and tell him you want a "line negative" made from it. Emphasize that you want *only* a negative; otherwise he may misunderstand and also prepare you a printing plate, which would be a waste of several dollars. The charge for the negative is usually very small, not over $5 in most communities and often considerably less.

Equipped with your negative, you are now ready to etch boards as described in Chapter 1.

Some experimental projects may not justify the time and expense required to obtain a camera negative, yet you may want the precision results obtainable only with photo-etching. In this case, you can use what is known as a "mechanical negative."

The mechanical negative stock consists of a rather firm sheet of clear plastic, coated with a thin film of ruby red plastic which can be stripped away. This material is avail-

able from circuit-board suppliers, and is included in most circuit-board kits. In addition, it is used by printers and commercal artists for other purposes, and can be found at most art-supply houses catering to commercial trade.

To make a mechanical negative, follow the same procedure used for a photo negative up through the step of having a final sketch. Then affix the blank mechanical negative atop the sketch, with the ruby side uppermost. With a sharp, small knife such as an *X-acto* or similar model-maker's instrument, cut through the ruby layer *only* around the outlines of pads and conductor patterns, then strip away the film, leaving clear areas for all pads and conductors.

The author has found that a short length of 1/8-inch diameter tubing, filed sharp on one end (Fig. 8-5), is an effective instrument for making uniform-size pad cutouts
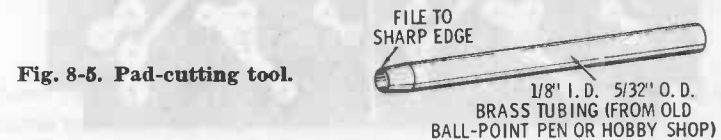

Fig. 8-5. Pad-cutting tool.

FILE TO SHARP EDGE

1/8" I. D. 5/32" O. D. BRASS TUBING (FROM OLD BALL-POINT PEN OR HOBBY SHOP)

on mechanical negatives. To make conductor strips, two *X-acto* blades can be taped together with a 1/16-inch spacer between them so that they scribe cuts a little more than 1/16-inch apart. Fig. 8-6 is a positive photoprint of a mechanical negative made with these aids.

The "center-punch" holes in the center of each pad are made by turning the negative over after all stripping is complete, and lightly punching an indentation into the plastic with a common pin. The indentation is then filled with grease pencil, and the excess rubbed away. Such center marks tend to burn out rapidly if the board is exposed a trifle too long, but even if only traces of them remain they greatly simplify the drilling of the etched board.

If a project originally laid out with mechanical negatives develops into a large-production item, requiring duplicate negatives, the duplicates can be made photographically.

Direct-Resist Techniques

All the way through this volume, the focus of attention has been on the photo-etching technique. However, for one-of-a-kind projects, direct-resist techniques are often more applicable.
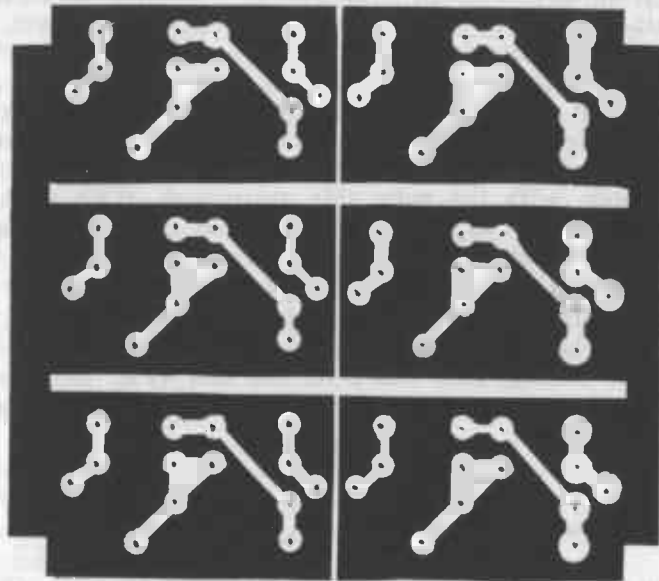
Fig. 8-6. Photoprint of a mechanical negative.

Direct resist etching differs from the photo process in that no negatives are used, nor is darkness required. The resist is applied directly to unsensitized board stock by any of several means, and the board is then etched.

This technique eliminates the advantage of reproducibility, but retains all the other advantages of etched circuits. It is particularly adaptable to hobbyist applications.

One of the newest means of applying resist to the board is by "dry transfer," as illustrated in Fig. 8-7. The resist material is obtained, preprinted on transfer sheets, from any of several manufacturers, and positioned where desired on the board. Then simply rubbing the surface of the transfer sheet releases the resist from the sheet and affixes it to the board.

To determine where on the board to apply resist, the preliminary sketch is still necessary. When a satisfactory sketch is obtained, it is transferred to the board surface by means of carbon paper, and the carbon image used as a guide to the placement of resist.

Similar to the dry transfer resist technique is the tape technique, which uses the same tape strips and circles mentioned in connection with photo drawings. This tape is a

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Courtesy Ami-tron Associates

Fig. 8-7. The dry-transfer resist technique.

good resist, and can be applied directly to the board in the same manner as the transfer material.

When using tape, take special care to see that it is burnished down onto the board at all points; frequently, it loosens just enough to allow a slight seepage of etchant under the tape, cutting through or weakening the conductors.

Another direct-resist technique is to paint the resist material directly on the board with a brush or a special applicator. However, in the author's opinion, this is the least desirable of all techniques.

While the painted-on resist has one major advantage over either dry-transfer or tape techniques, in that seepage under the resist pattern is not possible, its critical nature more than overcomes the advantage. The liquid resist is extremely rapid drying; therefore, inadvertent mistakes are exceptionally difficult to correct. In addition, many liquid resists come in bottles which seem designed to be spilled on the worktable!

The one major application for which the author endorses liquid resists is to supplement either the tape or dry transfer techniques, in masking large areas on the board. Here, the resist can be painted on with a relatively large brush, and you need not be concerned with minor detail.

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Chapter 9

Sources of Etched-Circuit Materials

While the friendly neighborhood electronic-parts house may not carry etched-circuit materials in stock, don't let this keep you from taking advantage of this construction technique. Most suppliers who cater to the rapidly-rising industrial-electronics trade have at least a small stock of the required materials—and many who cater strictly to the experimenter also have at least a few boards and some etching fluid on hand.

If not, you can obtain all the required supplies from any of the major mail-order suppliers in the country. Allied Radio, 100 N. Western, Chicago, Illinois 60680 handles a complete line of photo-etching supplies. Lafayette Radio Electronics Corporation, 111 Jericho Turnpike, Syosset, L. I., New York 11791 also stocks a complete line of these supplies.

The boards, developer, etching fluid, and mechanical negatives are packaged by Kepro Circuit Systems, Inc., Tree Court Industrial Park, St. Louis, Missouri 63122. They will be happy to supply you the name and address of their nearest distributor.

Dry transfer sheets, as well as complete kits for preparation of boards by the dry-transfer process, are available from Ami-Tron Associates, 12033 Otsego Street, North Hollywood, California, and from Vector Electronic Company, Inc., Glendale, California. Ami-Tron's kits, sold under the trade name *E-Z-Etch,* are widely distributed across the country, while Vector's materials, known as *Vectoresist,* are stocked by many industrial suppliers.

In addition to the sources listed, a number of other firms are continually entering the printed-circuit-supply field. Keep an eye on the classified-ad sections of the popular electronics magazines to find them.

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