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Winter 1996

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# POPTRONIX™

Hobbyists Handbook

## 1996

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## Editorial

**POPtronix**—that's an old name. I first heard it spoken back in 1959 when I was the Managing Editor of *Popular Electronics* magazine, which was then published by Ziff-Davis Publications, Inc. A reader kept mentioning "POPtronix" in reference to the magazine. Other people, readers and staff members alike, independently referred to the magazine by that name. Who was the first to do so? We'll never know!

Nevertheless, through the years, the term "POPtronix" was used to refer to *Popular Electronics* magazine, even after it came home to Gernsback Publications, Inc. a few years ago. (Gernsback first used the name "Popular Electronics" in 1938, and it was transferred to Ziff-Davis about 1954.)

Gernsback Publications has published various one-shot, annual, and semi-annual publications on construction projects and other topics, all of which are related to the hobby-electronics field. The editorial material was gleaned from previous issues of *Popular Electronics* and its sister publication *Electronics Now*, plus a few new items were added to the stew.

When the editorial meeting discussions began earlier this year on a new handbook, our publisher, Larry Steckler, suggested the title *POPtronix Hobbyists Handbook*. In an atmosphere that is usually contrariwise to suggestions from anyone, the title was universally accepted and applauded by the editors.

Now, in this issue, you have the fruit of our labor. We went from an idea to the printed page which is in your hands. How'd we do? We believe that we did a good job. Let us know what you think, and your suggestions for future issues are always welcome. Happy reading and happy building.

Julian Martin  
Editor

1996 EDITION

# POPTRONIX<sup>TM</sup>

## Hobbyists Handbook

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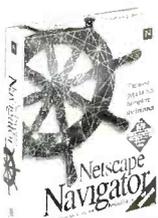
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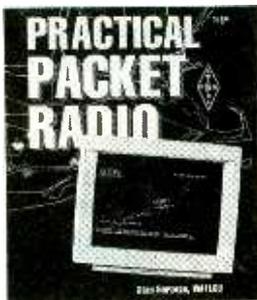
# LITERATURE LIBRARY

## Practical Packet Radio

by Stan Horzepa, W1LOU  
The American Radio Relay League,  
225 Main Street, Newington, CT  
06111-1494, Phone: 203-666-1541,  
Fax: 203-665-7531

**\$15.95**

Packet radio has come a long way since the early days. Such developments as low-cost PCs, a new generation of terminal-node controllers (TNCs), and 9600-plus baud rates have created a world of new opportunities for packet enthusiasts. This



book brings readers up to date on the very latest developments in the field, and provides all the practical information needed to select, install, and operate a packet station. It also includes tables and lists of symbols and commands that serve as handy references. The installation section of the book deals with practicalities. It describes the necessary hardware—including TNCs, modems, computers, terminals, radios—and software. It then shows readers how to tie all those pieces together, with information on such topics as setting the switches and picking baud rates.

The applications section lays a foundation with a thorough examination of the basics, and really takes off from there. Topics include networking, HF communications, bulletin boards, DX packet clusters, gateways, and packet in outer space.

CIRCLE 30 ON FREE INFORMATION CARD

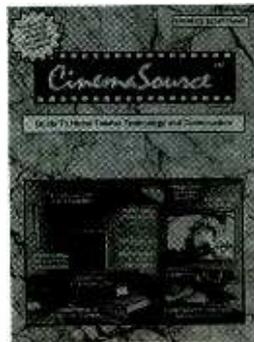
## Guide to Home Theater Technology and Construction

The Cinema Source, 2 Redmond Street,  
Burlington, MA 01803-2924, Phone:

1-800-483-9778

**\$9.95 (\$12.95 in Canada)**

This 100-page book is much more than a catalog. Aimed at home-theater enthusiasts and do-it-yourselfers, it provides a wealth of practical information about home theater. It describes all the necessary components—large-screen picture, multi-



channel audio, speakers, etc.—and what roles they play in the hometheater system. The book explains how line-doublers and THX and Dolby Pro Logic surround sound work. It explains how curved and flat screens differ, what tactile sound is, and what AC-3 digital sound is. Readers are shown how to mount a video projector, project video on different aspect ratio screens, set up a surround-sound system, and what types of cables and interconnects to use. A customer profile details one family's custom home-theater setup.

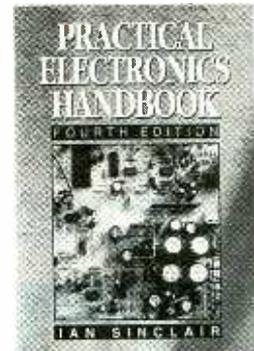
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## Practical Electronics Handbook Fourth Edition

by Ian Sinclair  
Butterworth-Heinemann, 225  
Wildwood Avenue, Unit B, P. O. Box  
4500, Woburn, MA 01801, Phone:  
617-928-2500

**\$32.95**

This book provides a practical collection of circuits, rules of thumb, and design data for professional engineers, students, and electronic hobbyists. Enough background is included to make the book accessible to beginners and to allow the understanding and development of a range



of basic circuits. For those with more electronics experience, the book can serve as a compact compendium of everyday information and a convenient reminder of electronic principles and circuits.

Topics covered include passive components, active discrete components, discrete component circuits, linear ICs, digital ICs, microprocessors and microprocessor systems, transferring digital data, digital-to-analog conversions, computer aids in electronics, and hardware components. The fourth edition has been updated with new chapters and sections covering topics such as sensing components, connectors, and soldering.

CIRCLE 32 ON FREE INFORMATION CARD

## Modern CMOS Circuits Manual

by R. M. Marston  
Newnes, an imprint of Butterworth-  
Heinemann, 225 Wildwood Avenue,  
Unit B, P. O. Box 4500, Woburn, MA  
01801, Phone: 617-928-2500

**\$28.95**

The first in a new series of circuits manuals from **Electronics Now** contributor Ray Marston, this book examines operating principles and practical applications of modern medium-speed and fast CMOS digital ICs. The informative, "how-to" text is accompanied by 470 carefully selected circuits, diagrams, graphs, and tables. Detailed descriptions of more than 120 modern CMOS ICs and their practical applications are included. Aimed at practical design engineers and technicians, the book's clear layout and easy-to-understand

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- ST-5 - Screw Driver Slotted 3/16"
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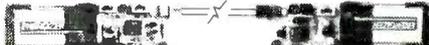
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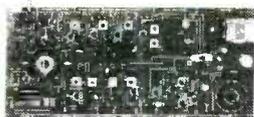


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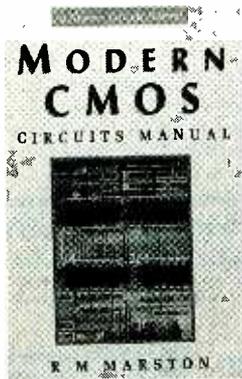
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explanations also make it a good starting point for students and hobbyists.

The first chapter describes and explains digital IC basics, CMOS and TTL principles, the various CMOS sub-families, and the basic rules of CMOS usage. Chapter 2 gives a practical introduction to CMOS fundamentals via the 4007UB IC, which can be used in



both digital and linear applications. Subsequent chapters modern logic circuitry, CMOS bilateral switches and data selectors, waveform generator circuitry, clocked flip-flop and counter circuits, ICs, special counter/dividers, data latches, registers, comparators, code converters, and specialized ICs such as multiplexers and decoders. The final chapter presents a miscellaneous collection of CMOS circuits.

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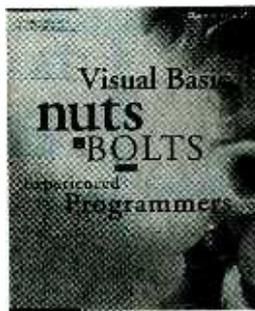
## Visual Basic 4 Nuts & Bolts for Experienced Programmers

by Gary Cornell and Troy Strain  
Osborne/McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710, Phone: 1-800-822-8158, Fax: 614-759-3644

**\$24.95**

If you already know the basics of programming and would like to add Visual Basic 4 to your tool chest, this book skips the remedial information and guides you swiftly along the road to mastering the latest version of Microsoft's best-selling rapid-application development tool.

The book teaches the concepts and



structures of Visual Basic 4 in a simple, straightforward format that allows you to learn what you need to know and then quickly move on to the next topic. It covers all of the essentials, including the fundamentals of Visual Basic's language, designing a form, handling errors, debugging, objects, advanced program features, and OLE.

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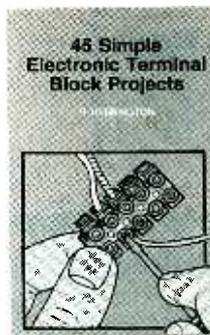
## 45 Simple Electronic Terminal Block Projects

by R. Bebbington  
Electronics Technology Today Inc., P.O. Box 240, Massapequa Park, NY 11762-0240

**\$6.25 plus \$3 S&H**

When soldering is off-limits—for absolute young beginners in electronics—simple terminal block projects offer a safe introduction to the hobby. The 45 projects presented in this book not only do not require soldering, but also are powered by nothing more jeopardous than a small battery.

The projects are constructed on terminal blocks using only a screwdriver and other simple hand tools. By



following the layout diagrams, most of the projects can be finished in a matter of minutes. The parts can be unscrewed to make new circuits using the same parts. A circuit diagram is included with each project to help broaden the hobbyist's experience and knowledge.

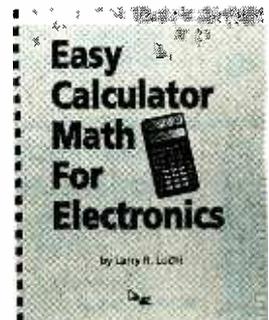
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## Easy Calculator Math for Electronics

by Larry R. Luchi  
Limelight Books, Division of Tiare Publications, P. O. Box 493, Lake Geneva, WI 53147, Phone: 414-248-4845

**\$17.95 plus \$3 S&H**

This study guide helps readers make quick work of math problems involving electronics. It takes the reader through each required step in more than 30 formulas used in electronics—from Ohm's Law to phase angles, component values for reso-



nance, and transistor characteristics. Each formula is carefully explained, with one or more step-by-step examples presented in an easyview, easy-to-follow format. Explanations of terminology and theory are also included, along with diagrams to help readers understand the material.

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## The No B.S. Guide to Windows 95

by Scott Spanbauer  
No Starch Books, 401 China Basin Street at Pier 50, Suite 108, San Francisco, CA 94107-2192, Phone: 1-800-420-7240, Fax: 415-284-9944, E-mail: info@nostarch.com

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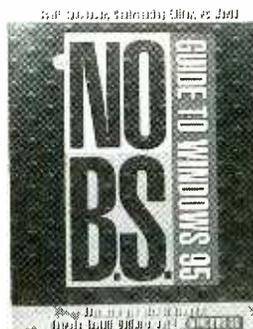
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(Continued from page 6)  
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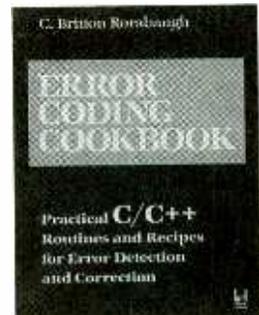
## Error Coding Cookbook: Practical C/C++ Routines and Recipes for Error Detection and Correction

by C. Britton Rorabaugh  
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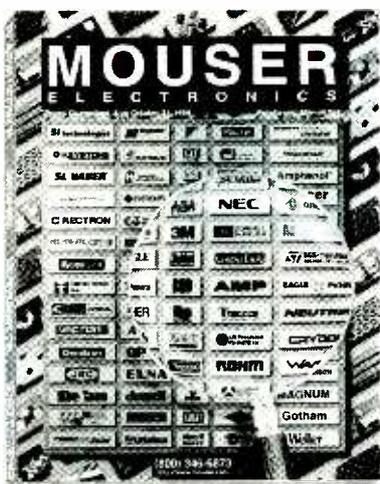
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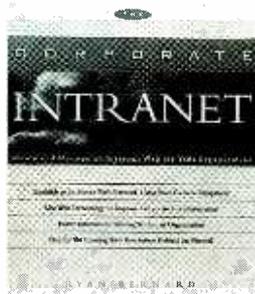


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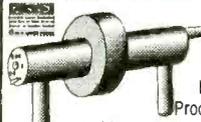
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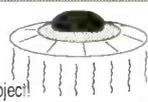


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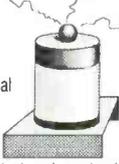
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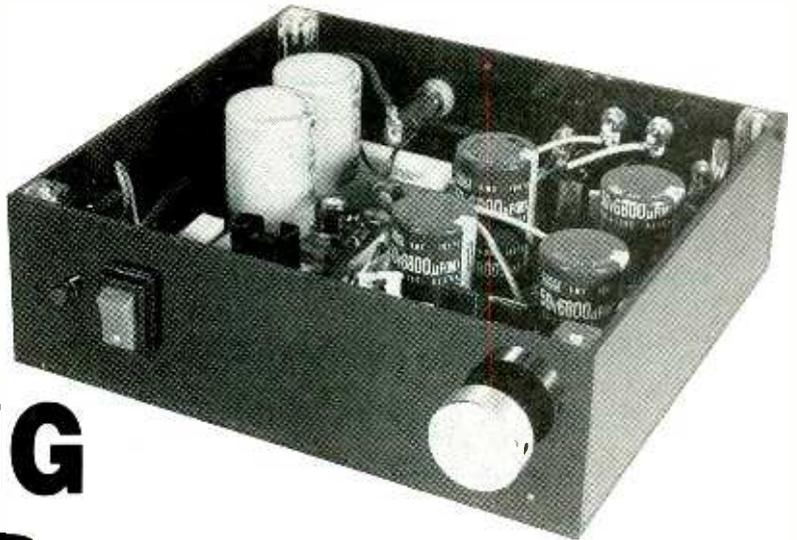
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**Switching Amps.** Class-A and Class-B linear amplifiers (as well as their derivatives) are routinely used to amplify audio signals in most common applications. However, it is also possible to amplify audio signals with a nonlinear amplifier. Such nonlinear amplifiers are also known as "switching" or Class-D amplifiers, because the output transistors used in the units switch on and off.

In a switching amplifier, almost all power is delivered to a load when the amplifier circuit is fully switched on. The largest amount of power is dissipated during the turn-on and turn-off transitions; the faster the transition, the smaller the amount of power dissipated in the output transistors.

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The Switching Amplifier (and many other units of its type) uses a pulse-width modulator to obtain the required switching action. Audio signals are converted into a series of pulses, each of which is directly proportional to the original audio-signal frequency and amplitude when compared to a fixed-frequency, fixed-amplitude, triangular reference waveform.

Therefore, for a given input frequency, the signal's amplitude varies the output's pulse width (duty cycle). Those deviations are amplified and directed to a single full-range, 8-ohm speaker, which in turn demodulate the pulses producing an amplified audio output.

**Circuit Description.** The schematic for the Switching Amplifier is shown in Fig. 1. A separate 51-volt-DC source is required to power the Amplifier circuit (we'll deal with that power-supply circuit later on). The 51-volt-DC source is fed to a pair of Zener diodes, D5 and D6, and is filtered by capacitors C11 and C12 to provide a 12-volt-DC source for part of the circuit. Also, part of the 51-volt-DC source bypasses the Zeners to power the sections of the circuit that require such a high voltage.

The right and left signals are input to the Amplifier through jacks J1 and J2, respectively. Two sections of a TL074 op-amp, IC1-c and IC1-d, generate a 4-volt peak-to-peak, 50-kHz triangular reference waveform. The generated waveform is then fed to potentiometer R19, which provides an adjustable reference for the voltage comparators. That enables the amplifier to use input signals with amplitudes ranging from 1 volt p-p to 4 volts p-p. The other two op-amp sections, IC1-a and IC1-b, function as comparators to produce the pulse-width-modulating output for the left and right channels of the Amplifier.

In the right channel of the Amplifier, the output of the voltage comparator is coupled to the bipolar translating circuit through a current-limiting resistor, R5. The translating circuit has a positive and negative "leg"; Q1, D1, and R1 make up the positive leg, and Q3, D3, and R11 make up the negative leg. Both legs are tied to ground through the emitters of Q1 and Q3, providing a reference point for the translator.

The translator arrangement results in 17 volts being present across Q1, Q3, and Zener-diodes D1 and D3. Sufficient current is then present to overcome the power MOSFET gate capacitance; that rapidly switches on and off the power MOSFET complementary push-pull output stage, composed of Q5 and Q7.

Resistor R3 keeps the output swing

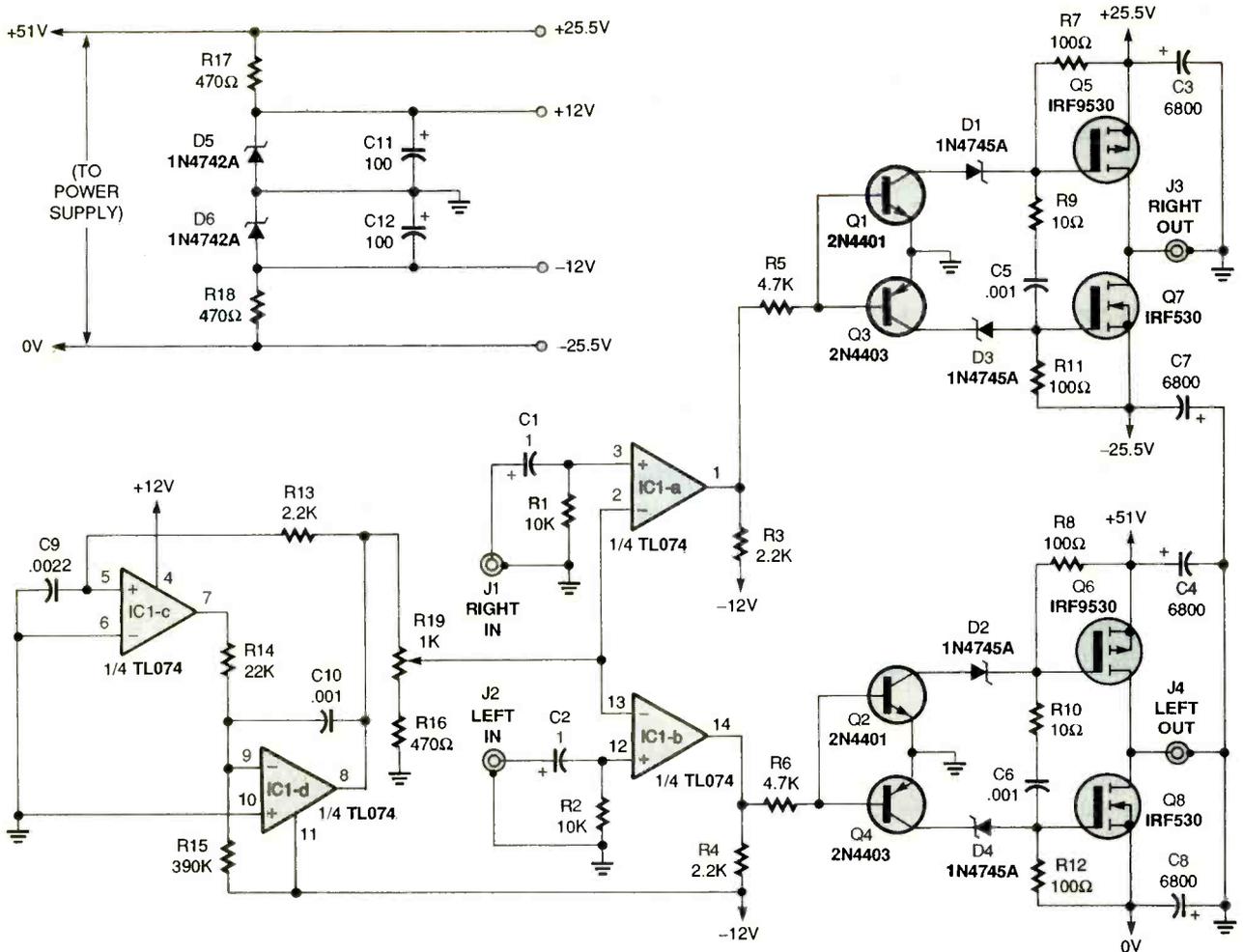


Fig. 1. Here's the schematic for the Switching Amplifier. A separate power-supply circuit is necessary to provide a 51-volt DC source. Two Zeners, D5 and D6, drop some of that voltage to also provide a 12-volt DC supply for the circuit. The power supply is not AC-line isolated. The speaker leads may become AC hot. If speakers and amplifier are in a sealed cabinet, place a warning on the back of the cabinet.

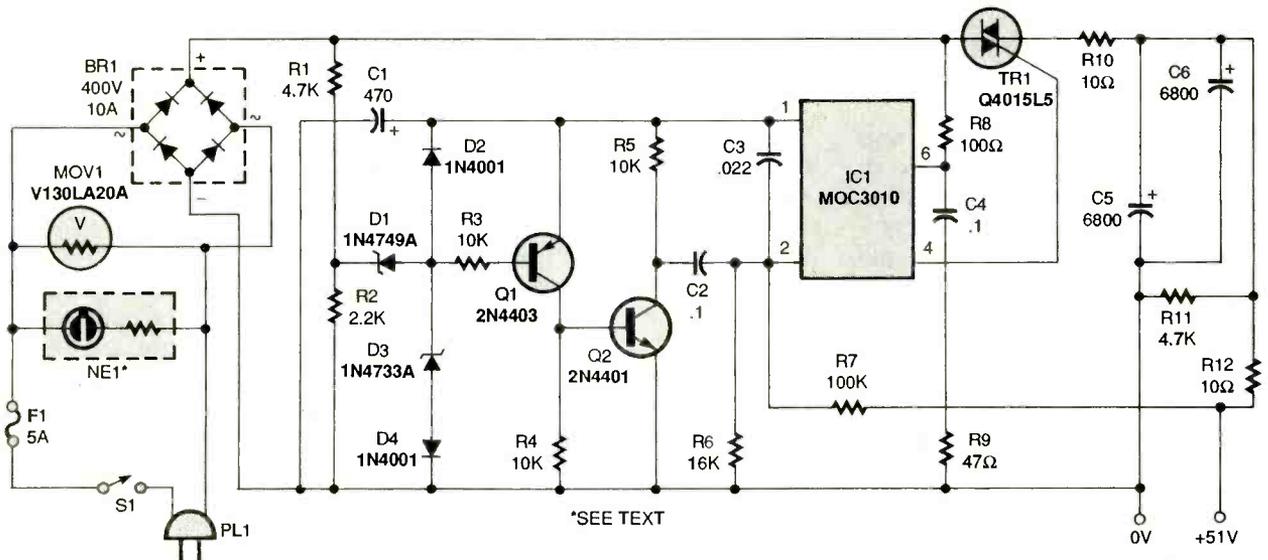


Fig. 2. This power supply rectifies 117-volts AC and use a triac circuit to produce a 51-volt DC source for the amplifier. The power supply is not AC-line isolated. It is recommended that a line-isolation transformer of 6-KVA rating be placed between the bridge circuit BR1 and the 5-A fuse.

centered at the midpoint of the supply voltage. Without R3 the square-wave output drifts down towards the

negative rail. The RC network composed of R9 and C5, which connects to both N- and P-channel gates, mini-

mizes switching noise and sharpens the squarewave output.

There's no need to go into how the

## PARTS LIST FOR THE SWITCHING AMPLIFIER (Fig. 1)

### SEMICONDUCTORS

IC1—TL074N quad JFET op-amp, integrated circuit  
 Q1, Q2—2N4401 small-signal NPN transistor  
 Q3, Q4—2N4403 small-signal PNP transistor  
 Q5, Q6—IRF9530 P-channel, 100-volt power MOSFET (see text)  
 Q7, Q8—IRF530 N-channel, 100-volt power MOSFET (see text)  
 D1-D4—1N4745A 16-volt, 1-watt Zener diode  
 D5, D6—1N4742A 12-volt, 1-watt Zener diode

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units, except where otherwise noted.)

R1, R2—10,000-ohm  
 R3, R4, R13—2200-ohm  
 R5, R6—4700-ohm  
 R7, R8, R11, R12—100-ohm, 2-watt  
 R9, R10—10-ohm  
 R14—22,000-ohm  
 R15—390,000-ohm

R16—470-ohm  
 R17, R18—470-ohm, 2-watt  
 R19—1000-ohm potentiometer

### CAPACITORS

C1, C2—1- $\mu$ F, 16-WVDC, electrolytic  
 C3, C4, C7, C8—6800- $\mu$ F, 50-WVDC, electrolytic  
 C5, C6, C10—0.001- $\mu$ F, polyester  
 C9—0.0022- $\mu$ F, polyester  
 C11, C12—100- $\mu$ F, 16-WVDC, electrolytic

### ADDITIONAL PARTS AND MATERIALS

J1-J4—RCA jack  
 Printed-circuit materials, project enclosure (see text), 5-watt heatsinks (clip-on type) for Q5-Q8, 2 tin-can bottoms, 14-pin IC socket, two-connection wire connector (should match the one used in the power-supply board), potentiometer knob, 4-40 1/2-inch machine screws, #4 washers, 4-40 hex nuts, wire, solder, hardware, etc.

left channel operates. If you examine Fig. 1, you'll notice that the left channel is identical to the right one we just dealt with. They both operate in the same way. Also note that both channels contain power-supply elements to split the incoming, single-polarity voltage in half. Capacitors C3, C4, C7,

and C8 make up a series-parallel circuit that converts the 51-volt-DC supply to 25.5-volts DC.

The right and left outputs of the Amplifier are jacks J3 and J4, respectively. The output can feed full-range 60-watt RMS speakers, which demodulate the signal and produce an ampli-

fied audio output. (At peak output power, the current draw for an 8-ohm dynamic load is approximately 1.2 amperes at 51-volts DC.)

Let's now turn our attention to the power supply. Figure 2 is the schematic diagram for that circuit. The AC voltage taken from PL1 feeds into bridge-rectifier BR1, which delivers a fullwave output of approximately 165-volts DC.

The network composed of R1, R2, D1, D3, and D4 generates a series of 5-volt pulses that provide two important functions: First the pulses are used as a 5-volt power source for the pulse shaping and monostable network through D2 and C1. Second, the pulses trigger optoisolator IC1 and power-triac TR1 via the pulse-shaping network composed of Q1, Q2, and R3-R5, and the monostable circuit made of C2 and R6. Resistor R2 sets the maximum pulse width and therefore the maximum output voltage.

Without feedback the unfiltered peak voltage is approximately 90 volts. To obtain the required 51-volt output, the feedback network composed of R6, R7, and C3 reverse biases the optoisolator whenever the output voltage exceeds 51 volts. That then forces TR1 to turn off as the unfiltered voltage goes to zero volts. The RC feedback network therefore regulates the output voltage by actively modifying IC1's conducting state.

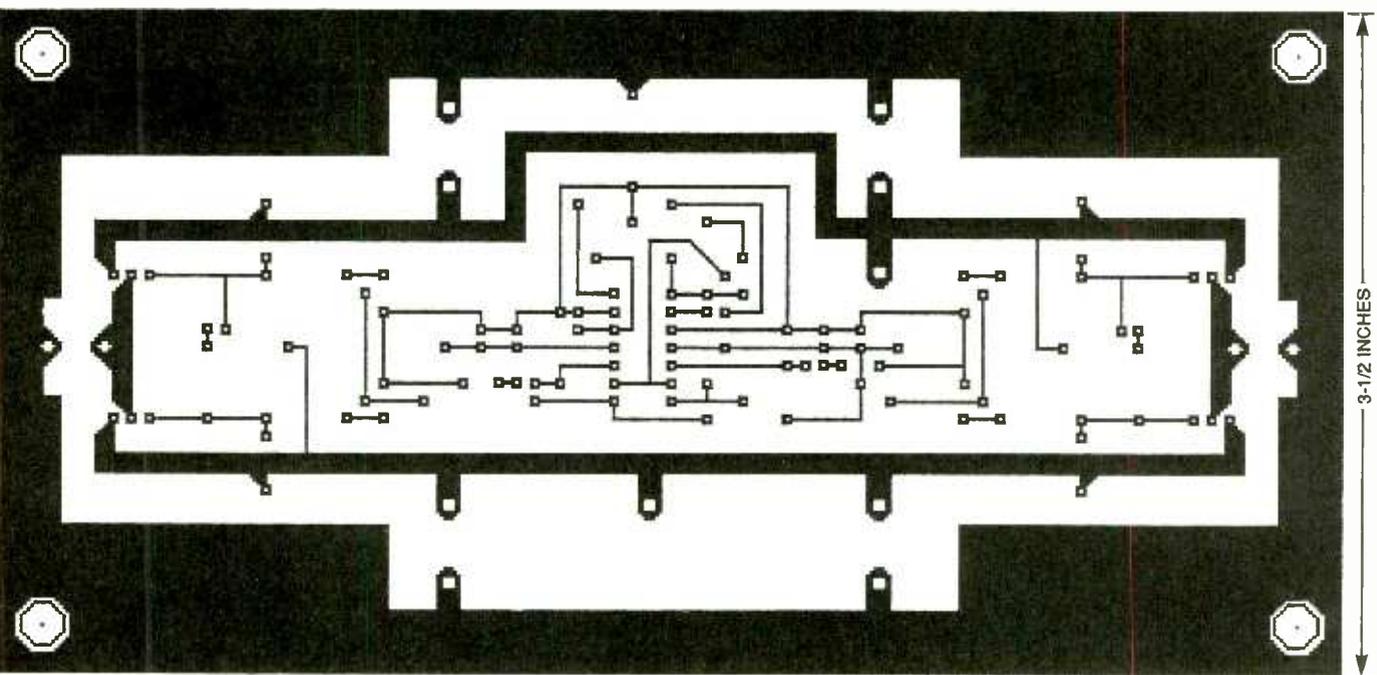


Fig. 3. Here's the full-size foil pattern for the Amplifier circuit board.

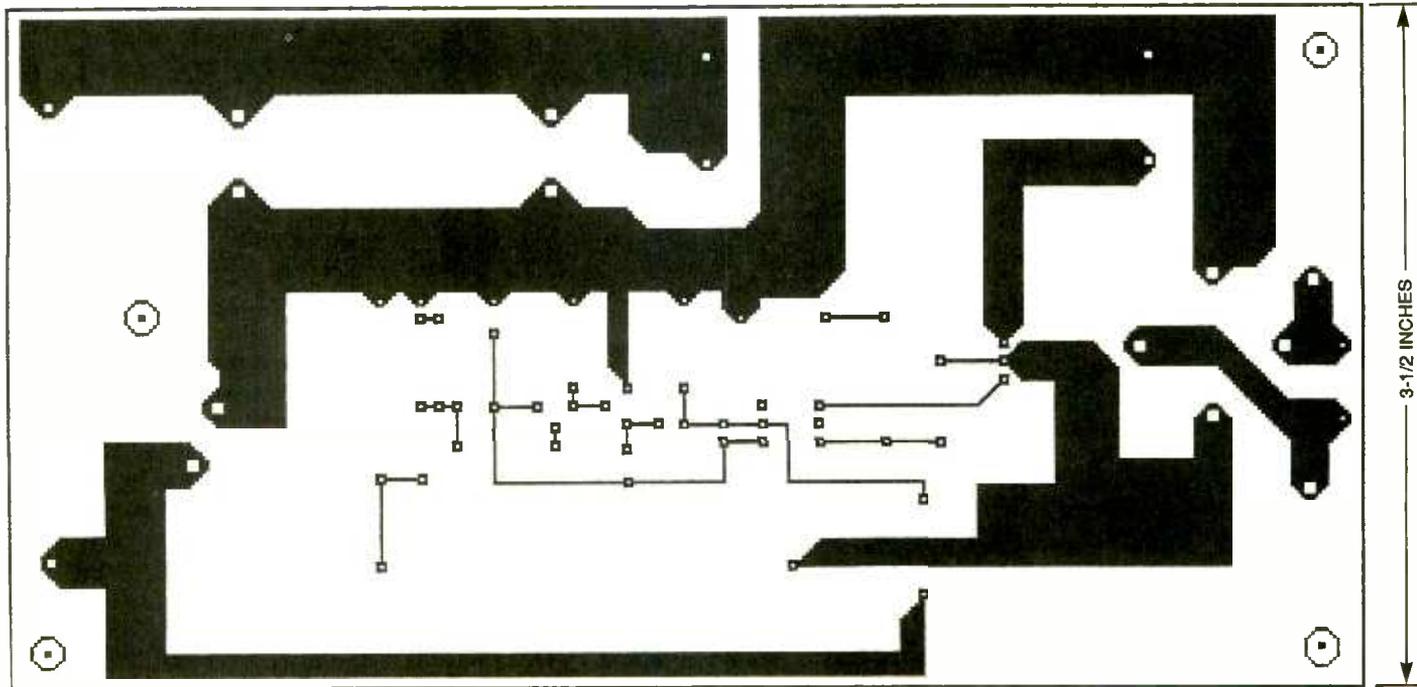


Fig. 4. This is the pattern for the power-supply board.

Resistor R8 limits the current through the optoisolator, and C4 and R9 ensure that the optoisolator's operation is stable and safe. Also, R10 limits surge current through TR1 when the supply is first turned on. Capacitors C5 and C6 along with R10 form a low-pass filter stage that minimizes ripple current. Resistor R11 discharges C5 and C6 when the power supply is turned off.

**Construction.** The author's prototype for the Switching Amplifier was built on two PC boards—one for the amplifier circuit itself, and one for the power-supply circuit. If you would like to do the same, use the amplifier and power-supply board templates shown in Figs. 3 and 4, respectively.

Assemble the amplifier board first, using the parts-placement diagram shown in Fig. 5 as a guide. Begin by installing an IC socket for IC1. Then mount all the fixed resistors.

Next, install the Zener diodes. Because the 1-watt units specified for D1–D6 dissipate quite a bit of heat, they must be heatsinked. You could instead replace the Zeners with 5-watt units, but such large Zener diodes are difficult to obtain and are expensive.

To create heatsinks for the Zener diodes, cut the circular bottoms of a couple of tin cans to make four 1.4- × 1.2-inch rectangular pieces. With a file or abrasive stone, smooth all the

#### PARTS LIST FOR THE POWER SUPPLY (Fig. 2)

##### SEMICONDUCTORS

- IC1—MOC3010 triac optoisolator, integrated circuit
- TR1—Q4015L5 400-volt, 15-ampere isolated triac
- Q1—2N4403 small-signal PNP transistor
- Q2—2N4401 small-signal NPN transistor
- BR1—400-volt, 10-ampere bridge rectifier
- D1—1N4749A 24-volt, 1-watt Zener diode
- D2, D4—1N4001 silicon rectifier diode
- D3—1N4733A 5.1-volt, 1-watt Zener diode

##### RESISTORS

- (All resistors are ¼-watt, 5% units, except where otherwise noted.)
- R1—4700-ohm, 10-watt
- R2—2200-ohm, 2-watt
- R3–R5—10,000-ohm
- R6—16,000-ohm (see text)
- R7—100,000-ohm (see text)
- R8—100-ohm
- R9—47-ohm

- R10, R12—10-ohm, 10-watt
- R11—4700-ohm, 2-watt

##### CAPACITORS

- C1—470-μF, 16-WVDC, electrolytic
- C2—0.1-μF, polyester
- C3—0.022-μF, polyester
- C4—0.1-μF, polyester
- C5, C6—6800-μF, 63-WVDC, electrolytic

##### ADDITIONAL PARTS AND MATERIALS

- MOV1—V130LA20A 130-VAC, 70-joule varistor
- NE1—120-VAC neon assembly
- F1—5-ampere, 125-VAC, fast-blow fuse
- S1—SPST switch
- PL1—AC plug, two-terminal
- Printed-circuit materials, 4-40 ½-inch machine screws, #4 washers, 4-40 hex nuts, two-connection wire connector (should match the one used on the Amplifier board), IC socket, fuse holder, AC line cord, rubber grommet, 5-watt heatsinks (clip-on type) for TR1, wire, solder, hardware, etc.

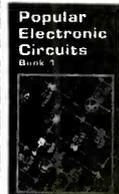
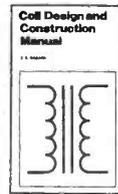
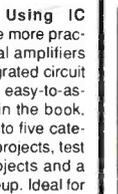
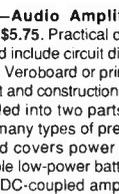
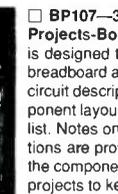
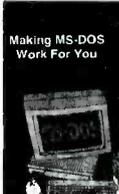
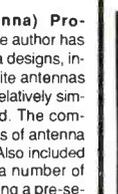
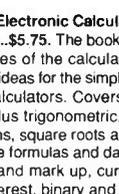
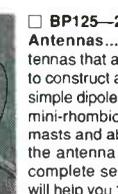
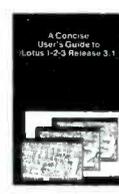
edges before proceeding to the next step.

Now fold each piece in half to form two 1.4- × 0.6-inch fins. Then, using a 7/64-inch drill bit, drill a hole at the mid-points of each heatsink where each Zener will be fitted. After fitting the diodes in place and noting their cath-

ode sides, apply epoxy to set the diodes in place. Take care to ensure that the leads are not touching the heatsink.

Once the epoxy has cured, solder each heatsink/diode combination in place on the printed-circuit board, noting polarity, and apply more ep-

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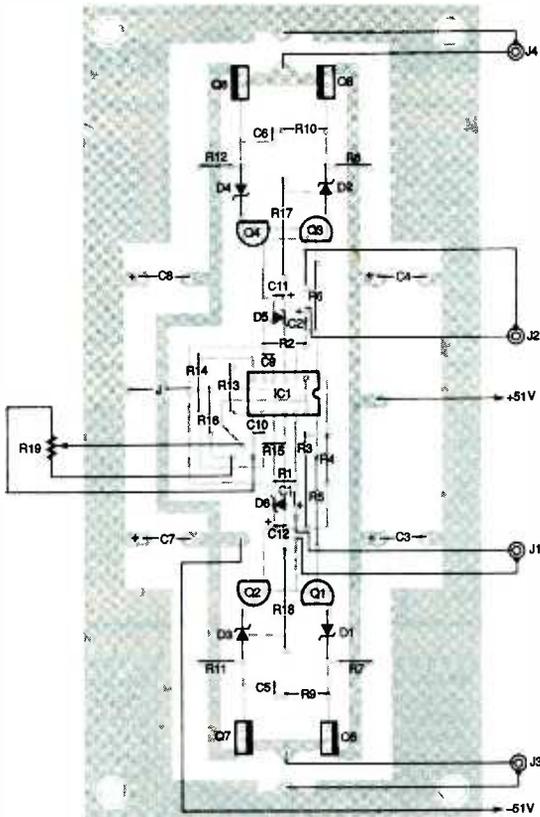


Fig. 5. When assembling the Amplifier board, use this parts-placement diagram as a guide. Watch the polarity of those off-board jack connections!

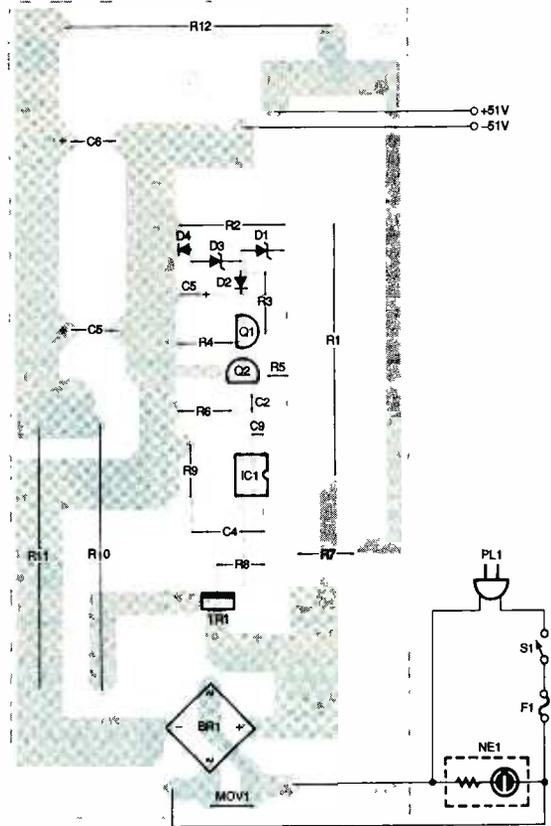


Fig. 6. Here's the parts-placement diagram for the power-supply board.

oxy at the points where the heatsinks meet the board. That is done to ensure that if the heat generated by the diode causes the epoxy at the diode/heatsink junction to deteriorate, the heatsink will remain properly secured.

Next, install the transistors and the MOSFET transistors. The latter also require heatsinks; you can use 5-watt, clip-on types. Notice in the Parts List that IRF9530 and IRF530 transistors are specified—both are 100-volt units. The author actually used 80-volt MOSFETS (IRF9531 and IRF531 types) in the prototype, but those are harder to find. You can get the 100-volt MOSFETS from Mouser Electronics (Tel. 800-346-6873).

Go on to mount the capacitors to the board, being sure to double check the orientation of the electrolytic ones. Solder 18-gauge wires to the board for the connections to potentiometer R19. Then, connect speaker wire to the appropriate points on the board for attaching jacks J1–J4. The jacks and the potentiometer mount on the project enclosure, so they should be connected later on.

Attach two 18-gauge wires to the board for the power connections. Solder a two-connection wire connector of whatever type you can find to the other ends of the wires. You will use a matching connector later on the power-supply board, thereby making it possible to easily attach or separate the two boards. That simplifies testing of the power supply and Amplifier boards, by allowing you to work on each separately.

To complete the on-board assembly, insert the TL074 into its socket. If you can't obtain that chip, do not substitute an LF347 for it. Due to internal differences of those parts, problems will result in the Amplifier's operation. If you must, substitute a TL084 instead.

Now go on to assemble the power-supply board. Keep in mind that the project will derive its output voltage directly off the main AC line. While that doesn't present any dangers during the assembly of the project, you have to make sure you avoid touching the circuit boards while the Amplifier is plugged in.

Start by mounting an IC socket for IC1. Then install the resistors, keeping

the following in mind: In the author's prototype, two of the resistors, R6 and R7, were measured with a DMM to have values of 15,800 and 99,400 ohms, respectively. Those values gave a 51-volt output from the circuit. You might have to get 16,000- and 100,000-ohm resistors that actually measure closer to the values just mentioned to ensure your board outputs the correct voltage.

Next mount the diodes to the board, making sure they are oriented properly. Install the transistors next, followed by the capacitors. Check the orientation of both the transistors and the electrolytic capacitors.

Triac TR1 should be installed next. To ensure cool operation of TR1, you should use a 5-watt, clip-on heatsink on the part.

Next, mount BR1 and MOV1 to the board. Attach wires to the appropriate points on the board for connections to the neon assembly, switch, fuse, and power cord. We'll get to those parts in a moment. Now, also solder on 18-gauge wires for the power connections to the Amplifier  
(Continued on page 105)

*Send simple transmissions  
in the 40-meter amateur band.*

# VACUUM-TUBE Transmitter

BY LARRY LISLE



made. Even though the unit outputs in the 1- to 2-watt range, that should be strong enough to establish plenty of contacts, provided that conditions are right, and that the unit is used with skill and patience.

**Circuit Description.** The schematic for the Transmitter is shown in Fig. 1. In the circuit, power is shown supplied by a 3-volt battery, B1, and a 135-volt battery, B2. The latter battery, B2, can be replaced by a power-supply circuit that we'll get to in a moment. Switch S1 is used to turn the circuit on or off.

The heart of the circuit is a 3A5 tube, V1. Both sections of V1 are connected in parallel in a conventional Miller oscillator. Resistor R1 sets the bias for the tube; the value of R1 might seem low to some because it is only 4700 ohms, but keep in mind that V1 is a transmitting triode operating at class C.

A 2.5-mH, RF-choke coil, L3, is needed to keep the radio frequency where it belongs. Capacitor C1 and inductor L1 resonate at the frequency of a 40-meter (7-7.3 MHz) amateur crystal, XTAL1. Inductor L2 couples RF energy to an attached antenna; C2 is a bypass capacitor.

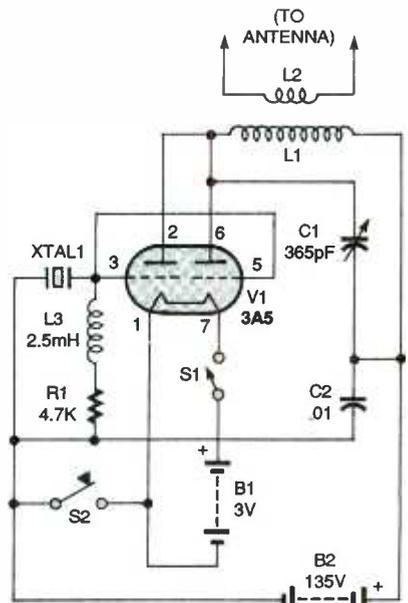
Switch S2 is a telegraph-type key-switch. That's used to generate the content of any transmissions you make.

As mentioned earlier, you can eliminate the need for battery B2 by build-

ing a simple power supply. It's schematic is shown in Fig. 2.

Transformer T1 provides isolation from the power line. The isolated AC voltage is rectified by diode D1 and filtered by capacitor C1.

**Construction.** The author's prototype for the Transmitter was built on a 9- x 5½-inch wood baseboard.



*Fig. 1. This is the schematic for the Vacuum-Tube Transmitter. At the heart of the circuit is V1, a 3A5 tube with two sections that was designed for battery-powered transmitters.*

If you're a licensed radio amateur, or you're just interested in how tube transmitters work, here's a little ham-radio transmitter that can provide you with hours of fun on 40 meters. The *Vacuum-Tube Transmitter* described in this article is an easy-to-build unit, with a fairly low parts count, that is an ideal project even for someone who's never built a transmitter before.

The Transmitter is a low-power (QRP) one-tube unit based around a type-3A5, twin-triode vacuum tube. The 3A5 was one of the few transmitting tubes actually designed to operate on battery power, and was widely used in portable and emergency transmitters in World-War II. Battery power is somewhat safer for a newcomer to tube voltages, and is actually practical with low-cost military surplus batteries. For those who wish to not bother with the hassle of replacing batteries, an optional power-supply circuit is also included.

Before we get to the actual circuit itself, a brief mention of the power output of the Transmitter should be

## PARTS LIST FOR THE BATTERY-TUBE TRANSMITTER

- R1—4700-ohm, 1-watt, 5% resistor
- C1—365-pF, variable capacitor
- C2—0.01- $\mu$ F, ceramic-disc capacitor
- L1—See text
- L2—See text
- L3—2.5-mH, radio-frequency choke coil
- V1—3A5 vacuum tube
- XTAL1—40-meter amateur crystal (see text)
- S1—SPST knife switch
- S2—Key-switch, telegraph type
- B1—3-volt battery (two 1.5-volt D-type batteries in series)
- B2—135-volt battery (three 45-volt batteries in series; see text)
- Wood baseboard (9 × 5½ inches), Plexiglas (9 × 4½ inches), Fahnestock clips, 7-pin miniature tube socket, socket for XTAL1, knob for C1, screws, wire, solder, hardware, etc.

**Note:** The following is available from Antique Electronic Supply (6221 S. Maple Ave., Tempe, AZ 85283; Tel. 602-820-5411); a kit of parts for the Battery-Tube Transmitter, including everything except XTAL1, (K-PE-BT KIT)—\$99.95 (contact Antique Electronic Supply for shipping cost). Arizona residents please add appropriate sales tax.

Fahnestock clips and tube sockets were used to mount the components.

Begin by mounting an octal tube socket (using wood screws) to hold crystal XTAL1. Then insert the crystal you want to use. Remember that you are "rock bound" with the Transmitter. That is, the crystal frequency you select is the only one you will be able to transmit on. Be sure to choose a frequency that's appropriate to your license class and in the CW-portion of the band. You might find it helpful to monitor the frequencies you have in mind before finalizing your decision.

For the preceding reasons, no crystal is supplied with the Transmitter kit available from the source mentioned in the Parts List (the octal socket is supplied, however). If you can't locate and buy the crystal locally, you can order one from either CW Crystals (570 N. Buffalo Street, Marshfield, MO 65706) or from International Crystal Mfg. Co., Inc. (10 N. Lee Street, Oklahoma City, OK 73102).

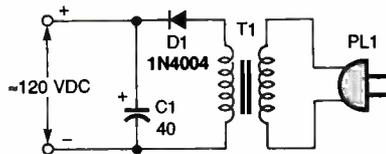


Fig. 2. Here's a simple circuit that can be used instead of batteries to power the Transmitter.

Next mount a 7-pin, miniature tube socket for V1, and insert the tube. Go on to wire R1, C2, and the choke coil. The variable capacitor, C1, is the type used in tube broadcast radios. Mount it towards the edge of the baseboard by passing machine screws through the board from below.

Attach S2, the key-switch, to the Transmitter using insulated wires. Keep S2 off-board, for safest operation.

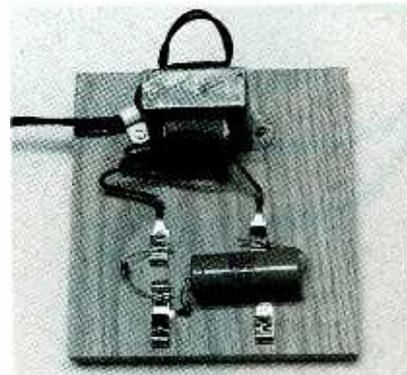
Inductor-coil L1 should be made on a ¼-inch-diameter piece of wood dowel rod. Wind 13 turns of 22-gauge enameled wire and space them so that the coil is 1-inch long. To make L2, wind two turns of wire over L1. Wire the coils into the circuit at this time, and connect Fahnestock clips so that you can attach an antenna later.

The last step in assembling the Transmitter is to wire the power connections. For starters, you will have to wire B1 (two 1.5-volt D cells in series) into the circuit. Then, you have to come to a decision about the other

sure to position power connections as far away from C1 as possible.

Cut a 9- × 4½-inch Plexiglas panel, and prepare to attach it to the edge of the baseboard where C1 is. Cut a hole for the shaft of C1 to protrude through, and drill holes to fasten the panel with screws. When the panel is attached, it will protect you from the voltages present in the unit.

If you would like to use the optional power supply, you will need another wood baseboard, this one measuring



Building this optional power supply will cost just a few dollars, but over time can save you much more than that in the cost of batteries.

approximately 5½ × 6 inches. Begin by mounting the transformer at one end of the board. Then go on to wire diode D1 and capacitor C1. Finally, attach a power cord and plug to the transformer, using a clamp to prevent strain on the cord.

Do not touch any of the components on the power supply when power is applied. Never touch C1 without first discharging it. Unplug the power supply when not in use.

**Using the Transmitter.** Connect an antenna to the Transmitter, and then make sure all power connections are made as well. Before you proceed, you might want to use a good output indicator. If you don't have one, try using a number-49 pilot light in series with one of the antenna leads.

Tune your receiver to the Transmitter crystal frequency. Then close S1 and key the Transmitter using S2. Adjust C1 until a signal is heard in the receiver and the pilot light or output indicator shows that the greatest amount of power is flowing to the antenna. If necessary, you might want to try more or fewer turns on L2 to match the rig to your antenna system. ■

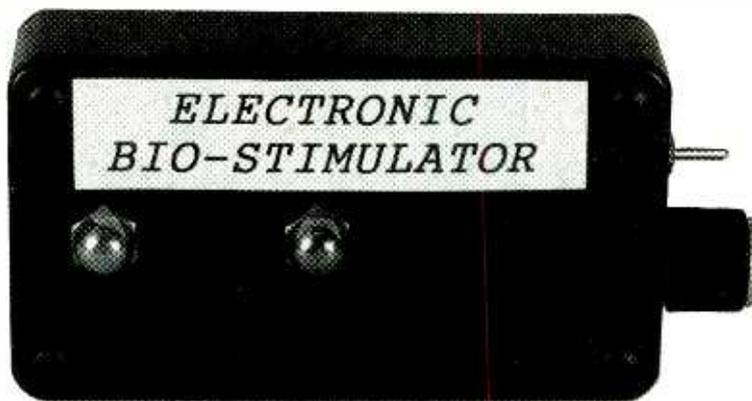
## PARTS LIST FOR THE OPTIONAL POWER SUPPLY

- D1—1N4004 silicon rectifier diode
- C1—40- $\mu$ F, 250-WVDC, electrolytic capacitor
- T1—Power transformer, 117-volt primary, 117- to 125-volt secondary
- PL1—Two-terminal AC plug
- Wood baseboard (5½ × 6 inches), Fahnestock clips, power cord, clamp, wire, solder, hardware, etc.

power source. If you would like to use B2, a 135-volt battery, just wire it into the circuit at this time, and you're almost done (note that B2 is made of three 45-volt batteries in series; use military-surplus types SZ-283 or SZ-284, which are included in the kit, or Eveready No. 455). If you would like to use the optional power supply shown in Fig. 2, just wire Fahnestock clips to the Transmitter for positive and negative connections to the supply. Whatever power source you use, though, make

**Enjoy the benefits of electronic acupuncture without the use of needles.**

# BIO-STIMULATOR



BY ROBERT A. HEIL

**A**sk around and you'll probably find that most people know what acupuncture is. However, not many of those individuals would want to have it actually done. That's because the treatment is often expensive and, let's face it, the idea of having needles poked into one's skin is not all that appealing. Well, with the *Bio-Stimulator* described in this article, you can avoid such drawbacks. The device provides a needleless and painless way to enjoy the benefits of acupuncture.

**Acupuncture Basics.** The Tabers Encyclopedic Medical Dictionary defines acupuncture as "the puncture with needles for diagnostic and therapeutic counter irritation purposes." Here's a look at how that technique came about.

Centuries before the Western world began to understand blood circulation and the nervous system, the ancient Chinese developed the theory that a system of energy circulation is present in the human body. The Chinese stated that vital life energy flows through a series of pathways, or meridians, 12 of which are located in each side of the body. Those meridians were said to course through the deep tissues of the body, surfacing occasionally.

Each of the areas where the meridians touch the surface were considered useful treatment points for ailments to one or more organs. It was believed that inserting needles at such surface points could cure problems with a patient's heart, lungs, colon, gallbladder, liver, or other organs.

Western interest in the technique (eventually called "acupuncture") did not become widespread until the 1970s, when physicians in the People's Republic of China demonstrated that it could be used to control surgical pain. After 20 minutes of stimulation, a recipient of effective acupuncture treatment would be wide awake, alert, and aware of all performed surgical procedures, but not aware of any pain.

The actual mechanisms by which patients are able to tolerate surgery during acupuncture stimulation are still unknown. Some scientists speculate that large sensory fibers are acti-

## WARNING!!!

This article deals with and involves subject matter and the use of materials and substances that may be hazardous to health and life. Do not attempt to implement or use the information contained herein unless you are experienced and skilled with respect to such subject matter and materials. Furthermore the information contained in this article is being provided solely to readers for educational purposes. Nothing contained herein suggests the Bio-Stimulator system described herein can be or should be used by the assembler or anyone else in place of or as an adjunct to professional medical treatment or advice. Neither the publisher nor the author make any representations as for the completeness or the accuracy of the information contained herein and disclaim any liability for damages or injuries, whether caused by or arising from the lack of completeness, inaccuracies of the information, misinterpretations of the directions, misapplication of the information or otherwise.

vated, thereby inhibiting the transmission of impulses from the small fibers carrying the sensory input of pain.

Other scientists believe that naturally produced, morphine-like substances (such as endorphins) might be released within the brain in response to the stimulation. When those types of substances bind to opiate receptor cells, a pain-inhibition system is activated. Patients suffering from pain in the back, head, abdomen, or other areas could experience short-term relief by such a pain-inhibiting process.

Although widely accepted throughout the Far East as a legitimate practice, acupuncture is viewed quite differently by the West. The main influential factor is the American Medical Association (AMA), which does not recognize acupuncture as a legitimate medical procedure to cure the sick.

Without the AMA's acceptance, acupuncture was for several years considered by many to be a form of "black magic." That's not surprising considering how many people find the idea of sticking needles into their skin repulsive. What's more, there is a considerable amount of danger present if the technique is performed by an unlicensed practitioner. One misplaced needle could do considerable damage if a major organ or artery is punctured.

The fear of possible needle damage led to the development of electronic acupuncture. That newer technique uses electronic pulses in place of needles to control pain, tone and strengthen muscles, increase blood flow, and release the body's

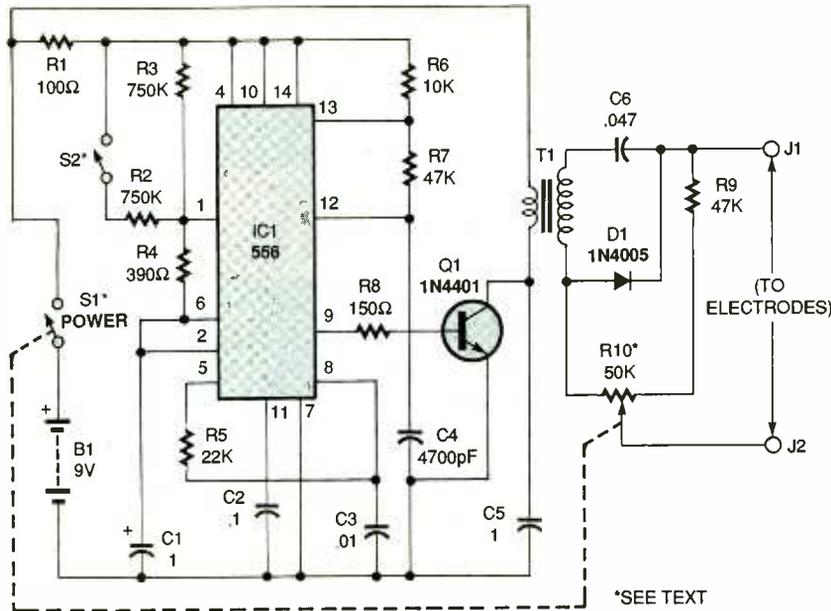


Fig. 1. Here's the schematic diagram for the Bio-Stimulator. Adjusting the settings of potentiometer R10 and switch S2 let you fine tune the output pulse.

the unit on and off, and resistor R1 acts a current limiter for the circuit.

Resistors R2-R4 and capacitor C1 form a timing circuit with IC1, a 555 dual timer. When S2 is open, the charge and discharge time of C1 is set at approximately 2 Hz. Closing S2 increases the charge and discharge time of C1 to approximately 4 Hz. The output of the first timer at pin 5 of IC1 is sent via R5 and C3 to pin 8 of IC1; that section of IC1 and components R7, R8, and C4 complete the second timing circuit. While the first timer creates the delay time in Hz, the second timer creates the actual pulse time for the inductor.

The inductor pulse time is applied to the base of transistor Q1 through a current-limiting resistor, R8. When Q1 conducts, the primary side of audio-transformer T1 is momentarily grounded, thereby energizing T1. Capacitor C5 charges and discharges every time T1 is energized and de-energized. That charge cycle slows down the rise and fall time of the pulse, which in turn increases the duration of the output pulse from T1, and at the same time shapes the edges of the output waveform to more closely resemble a half sine wave.

Components C5, D1, and R9 form the rest of the output-wave-shaping circuit. Potentiometer R10 is used to adjust the amplitude of the pulse up to a maximum of about 200 volts with a duration of 2 ms and an overall current drain of less than 10 mA.

Just a word of caution before we go any further: **Misuse of the Bio-Stimulator can be dangerous.** Do not use the device on the eyes or on open sores, or if you have a pacemaker, are currently under treatment for heart disease or arrhythmia, or are pregnant. Even if you are in perfect health, you might want to consult your doctor before using the device.

**Circuit Description.** The schematic for the Bio-Stimulator is shown in Fig. 1. Power for the circuit is supplied by a 9-volt battery, B1. Switch S1 is used to turn

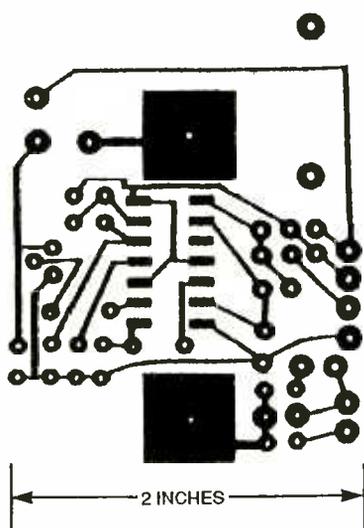


Fig. 2. Use this full-size template to make your own PC board.

own natural pain and inflammation reducers. Although still not fully recognized by the AMA, electronic acupuncture has recently gained acceptance among chiropractic practitioners and a small percentage of physicians as an alternative technique to their therapeutic methods; they feel it is safe and works well for certain problems.

The Bio-Stimulator produces the same basic waveforms found in professional electronic-acupuncture devices. It contains common components and easy-to-find hardware, and is designed to be rugged, easy-to-use, lightweight, and portable.

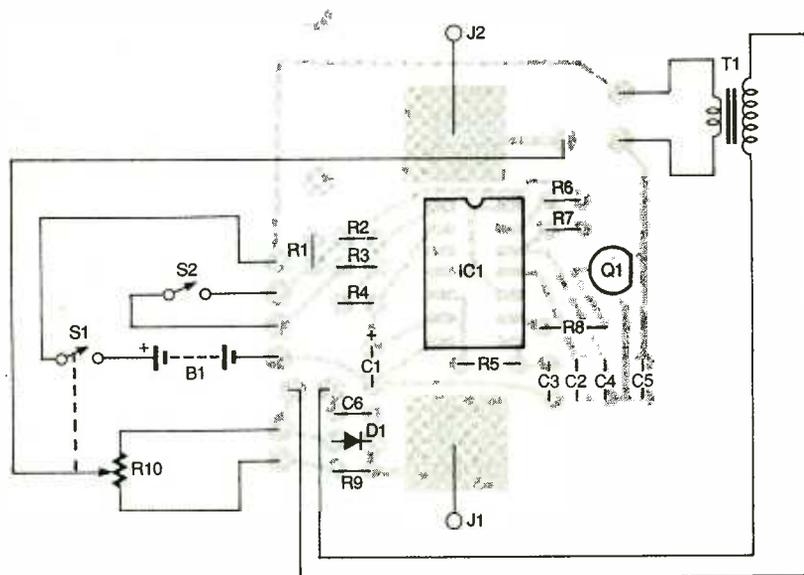
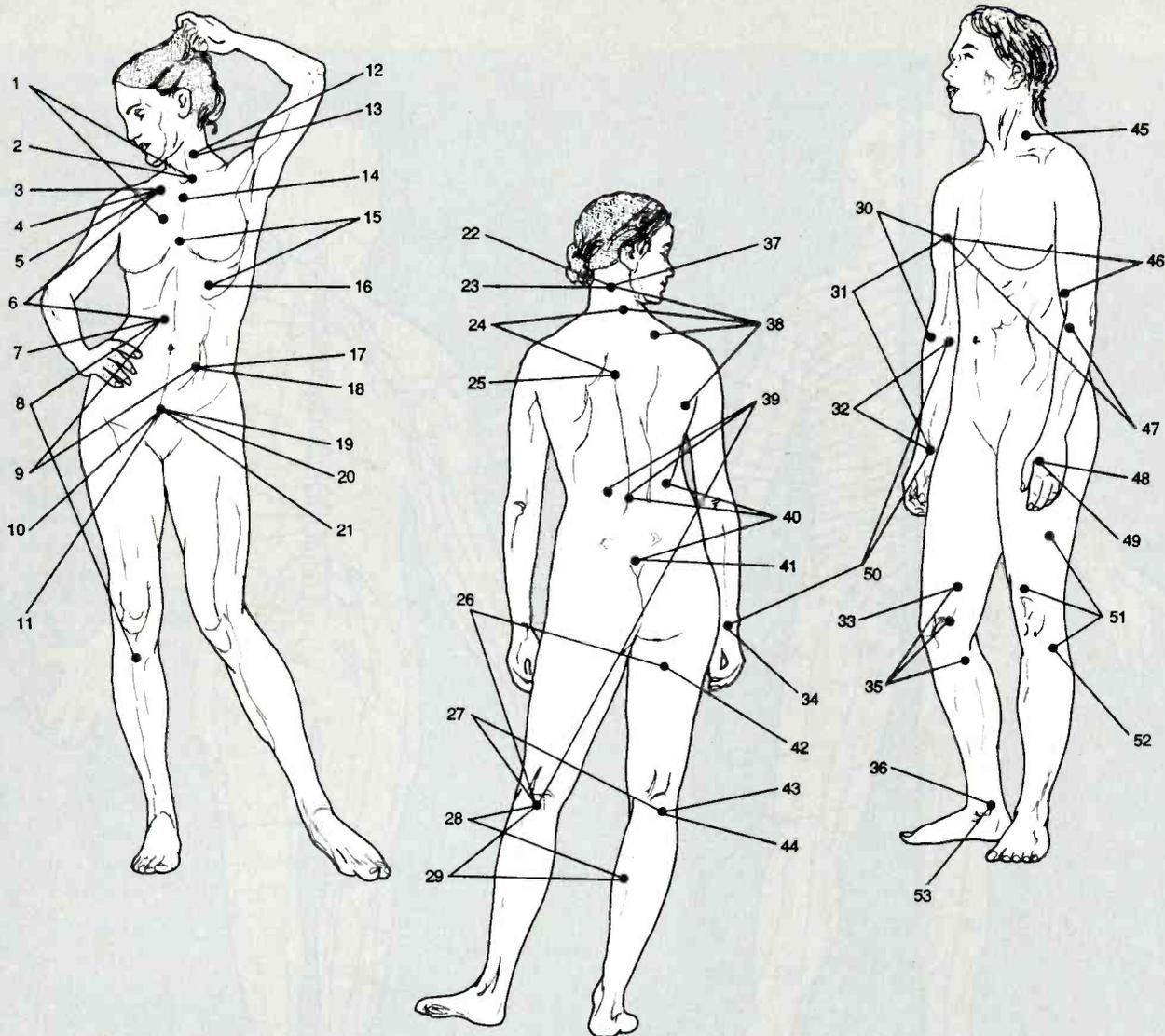


Fig. 3. If you're building the unit on a PC board, use this parts-placement diagram as a guide.



- |                                   |                                |                                    |                                |
|-----------------------------------|--------------------------------|------------------------------------|--------------------------------|
| 1. BRONCHITIS                     | 16. DIABETES                   | 30. HAND-MUSCLE PAIN               | 43. KNEE-JOINT FATIGUE         |
| 2. HYPERTENSION                   | 17. INTESTINE ILLNESS          | 31. PALSY OF THE HAND              | 44. KNEE-JOINT PAIN            |
| 3. SHOULDER DISTRESS              | 18. LIVER AND KIDNEY ILLNESS   | 32. FINGER-JOINT PAIN              | 45. SHOULDER PAIN              |
| 4. PALSY OF THE UPPER EXTREMITIES | 19. ENURESIS                   | 33. GYNECOLOGICAL DISTRESS         | 46. ELBOW-JOINT PAIN           |
| 5. INTERCOSTAL NEURALGIA          | 20. RECOVERY OF FATIGUE        | 34. CONSTIPATION                   | 47. PALSY OF UPPER EXTREMITIES |
| 6. GASTROPTOSIS                   | 21. CONSTIPATION               | 35. KNEE-JOINT PAIN                | 48. EYE STRAIN                 |
| 7. VOMITING                       | 22. HEADACHE                   | 36. EDEMA OF LEGS                  | 49. TOOTHACHE                  |
| 8. STOMACH ILLNESS                | 23. SPASMOTIC PAIN OF THE NECK | 37. ALCOHOLIC DROWSINESS           | 50. HAND-JOINT PAIN            |
| 9. DIARRHEA                       | 24. DIZZINESS                  | 38. SHOULDER DISTRESS              | 51. PALSY OF LOWER EXTREMITIES |
| 10. GYNECOLOGICAL DISTRESS        | 25. GENERAL FATIGUE            | 39. LUMBAGO                        | 52. HYPERTENSION               |
| 11. CYSTITIS                      | 26. SCIATICA                   | 40. RECOVERY OF FATIGUE            | 53. RECOVERY OF FATIGUE        |
| 12. DIZZINESS                     | 27. LEG FATIGUE                | 41. PILES                          |                                |
| 13. CERVICAL NEURALGIA            | 28. CLONUS                     | 42. NEURALGIA OF LOWER EXTREMITIES |                                |
| 14. ASTHMA COUGH                  | 29. PALSY OF LOWER EXTREMITIES |                                    |                                |
| 15. GENERAL FATIGUE               |                                |                                    |                                |

Fig. 4. What ails you? By placing J2 of the Bio-Stimulator on one of these points, and having J1 touch your skin as well, you can explore the possibilities of electronic acupuncture.

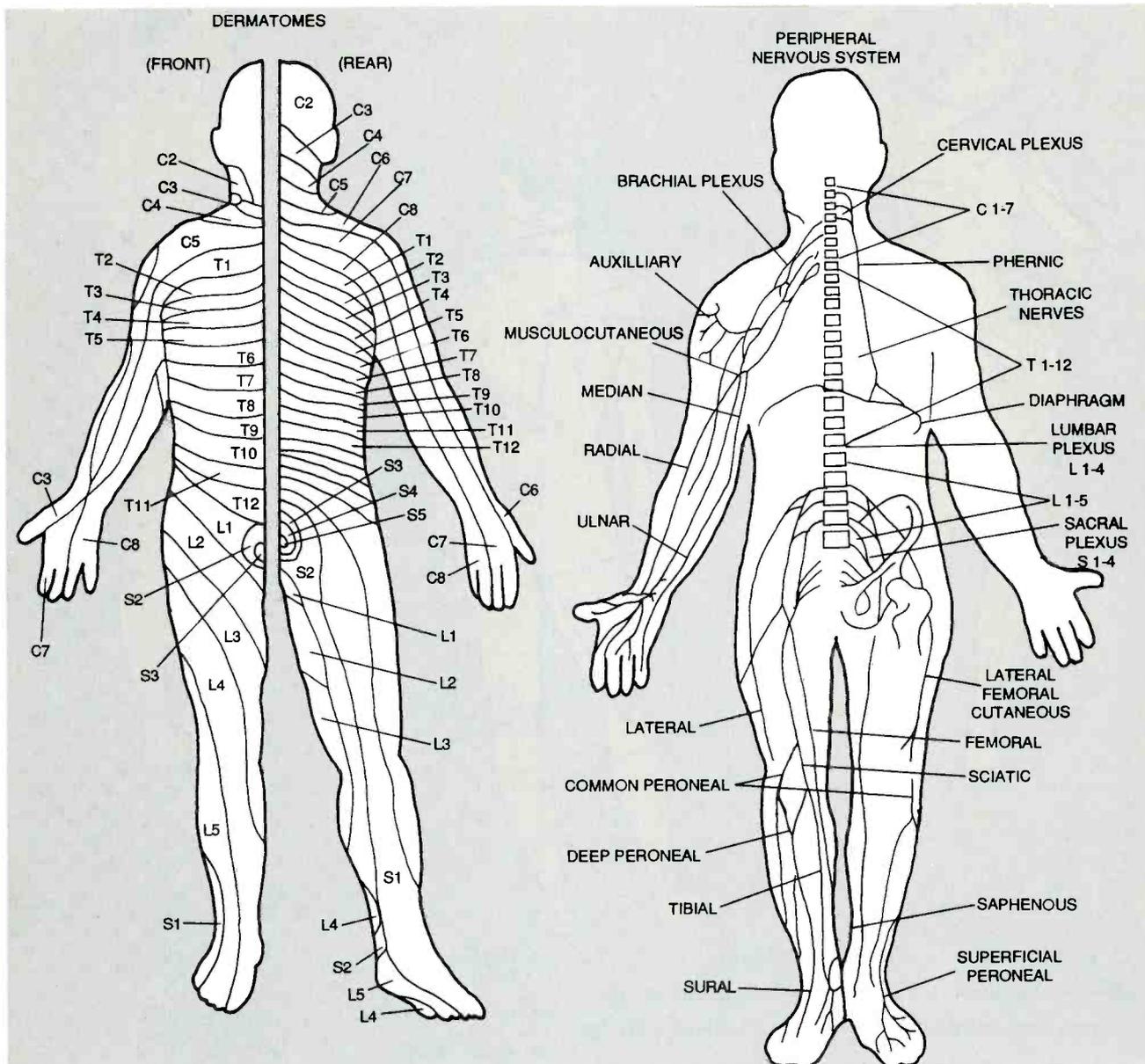


Fig. 5. Want to stimulate entire nerve groups to fight pain? Connect electrodes to the Bio-Stimulator and place them along the appropriate nerves.

**Construction.** The author's prototype was built on a printed-circuit board. That is the preferred way to build the Bio-Stimulator because it prevents stray capacitance and ensures that the unit is kept small. You can either etch your own PC board using the template shown in Fig. 2, or order one from the source mentioned in the Parts List. If you would rather use another assembly method, make sure to keep all wire leads short.

If you're building the circuit on a printed-circuit board, use the parts-placement diagram in Fig. 3 as a guide. Begin by installing an IC socket for IC1. Then solder the resistors and capacitors to the board, making sure

the electrolytic capacitor, C1, is oriented properly. Mount the diode next.

Solder four-inch lengths of 22-gauge insulated wire to the board for the connections to the potentiometer/power switch (R10/S1), toggle switch (S2), and transformer (T1). Next, solder a battery clip to the board. Then complete the on-board assembly by installing Q1 and inserting IC1 into its socket. Check the orientation of both of those components.

The next step is to mount the off-board components and PC board in a suitable project case; the one used in the author's prototype is a Radio Shack enclosure (part number 270-231). If you choose to use another

case, make sure the dimensions are at least 4 x 2 x 1 inches.

At one end of the case, drill two holes and mount R10/S1 and S2. Then install two acorn cap nuts (J1 and J2) on the enclosure. You can either connect J1 and J2 to the PC board with wires, or try to position them directly over the pads and connect them with screws.

Once the jacks are connected, mount the board inside the project case using spacers and screws. To complete assembly, go on to solder the wires already connected to the PC board to their respective off-board components.

(Continued on page 104)

Bring back some of the nostalgia of the golden age of radio with this tuning indicator.

BY LARRY LISLE

# Magic Eye



Anyone who enjoyed radio in the 1940s might remember sitting in front of a big console radio, watching its green, glowing, magic-eye tuning indicator and listening to those great programs. Of course, the golden age of radio faded away in the fifties, taking big consoles and magic-eye tubes with it, but that doesn't mean you can't recapture some of the magic of that bygone era.

The *Magic Eye* described in this article lets you add a for-display-only magic eye (with the same green glow) to your modern stereo. Or, you can add a few parts and use your Magic Eye as an actual tuning indicator for an AM radio. Because the tube used in the project will work on AC as well as DC, no rectifier or filter is needed. For that reason, the project is really simple to build. And best of all, it really looks great in the dark while playing an old-time radio tape!

**Magic-Eye Tubes.** Invented in the mid-1930s, the magic-eye tube is basically a triode vacuum tube with a fluorescent target in the dome of its glass envelope. The target operates at a positive voltage and attracts electrons from the cathode. As a result of those electrons striking the target, a characteristic green glow is formed. A "ray-control" electrode between the cathode and target casts a wedge-shaped shadow on the target, varying from zero to about 100 degrees, depending on its voltage, which is determined by the voltage on the grid of the triode.

In practice, the grid was connected to the automatic-volume-control (AVC) circuit of a superheterodyne receiver. When a station was centered in the bandpass, the AVC voltage would be maximum and the eye would close. Magic-eye tubes were

also used in a variety of test instruments because of their very-high input impedance and because they wouldn't be harmed by a momentary overvoltage.

If you recall, it was mentioned that the tubes work on AC as well as DC. While that is true, when a magic eye is operated with AC on the plate and target, the tube is turned off on the negative peaks. That isn't noticeable, however, and shouldn't affect the application described here.

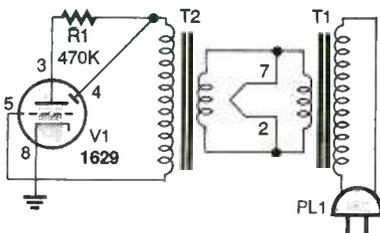


Fig. 1. The simple version of the Magic Eye circuit, shown here, is a for-show-only unit.

**Circuit Description.** Figure 1 shows the schematic for the Magic Eye. The version of the circuit shown in that figure can be used only for show. Transformer T1 steps the 117-volts AC from the wall outlet down to 12.6-volts AC for the filament of the 1629 tube, V1. The other transformer, T2, then steps the voltage back up to 117-volts AC for the target and plate. The two transformers isolate the tube from the power lines for safety.

Figure 2 shows how a few additional components can be added to make the circuit a real tuning indicator for old radios. While the grid of the tube in Fig. 1 is simply grounded, in Fig. 2 it's connected through resistor R2, capacitor C1, and potentiometer R3 to the circuit ground and AVC line of a radio. Potentiometer R3 lets you calibrate the circuit so that the Eye will close when a station is tuned.

**Construction.** The author's pro-

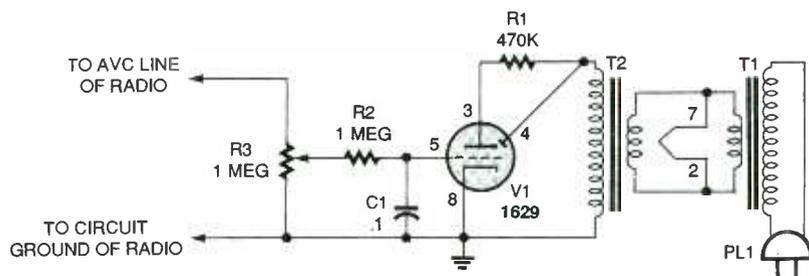


Fig. 2. By adding a few components, you can use the Magic Eye as a tuning indicator. Adjust potentiometer R3 so that the eye tube, V1, will go out when a station is tuned in.

Some types of magic eyes, such as the 6G5 and 6U5, are getting scarce and expensive, and should be reserved to keep radios designed for them glowing. However, the 1629 used in the Magic Eye described in this article, which was made for the "command-set" transmitters of World War II as a calibration indicator, is fairly plentiful.

A prototype of the Magic Eye was built in an 8- x 6- x 3-inch project box, but it could just as easily be built in a wooden box or in the bottom of a speaker enclosure. You can use any project-building method as well, because layout is not critical. However, you really don't need to use a circuit board for the project; simply use the

(Continued on page 103)

**M**ost of us have to spend a good deal of time in our automobiles. During those periods, AM/FM car radios can provide entertainment from local stations; however, some of us would like to be able to get a world-wide assortment of programming. That's where shortwave radio comes in.

Now, there are several ways to get shortwave reception in your car. Two European companies, for instance, offer digital automobile radios with AM/FM/shortwave reception (usually 530 kHz to 30 MHz continuous on AM). The cost of those receivers, however, is in the \$350 to \$1000 range! A cheaper option is to use a portable shortwave radio in your car, but those are not shielded, are difficult to mount in a convenient location, and really aren't loud enough to fill a car with sound and overcome road noise.

That's why we're introducing the *Shortwave Converter*; it provides an inexpensive way to receive shortwave stations on an existing automobile radio set to the AM band. The Converter is a circuit that is connected in series between the automobile antenna and the radio. Shortwave stations are heard over the existing power amplifier and speaker system, so audio power is not a problem.

The Shortwave Converter is built for a single international shortwave band. Multi-band versions are possible, but the circuit complexity would be greatly increased. To have the Converter operate over a wide band, as is popular in simple shortwave superhets, is not practical.

Combining the Converter and an AM radio results in a dual-conversion receiver with an image rejection that is usually better than that of a common, single-conversion shortwave superhet with an IF of about 455 kHz. When the Converter is used, an international band is spread out over a considerable proportion of the tuning-capacitor rotation instead of being compressed into a tiny section, as is the case with analog shortwave superhets.

**Commercial or Homemade?** There are some commercially available shortwave converters, but they do not have tuning capabilities of their own. A problem would arise when using one of those converters with modern,



## Add a Shortwave Converter for your Car

BY LYLE RUSSELL WILLIAMS, KC5KBG

*Let your digital or analog car radio tune in the shortwave band.*

digital automobile radios that tune in 10-kHz steps on the AM band. That 10-kHz-step tuning method works fine for AM because all domestic stations are broadcast at precise 10-kHz intervals. On shortwave, however, stations are supposed to broadcast at 5 kHz intervals (and many stations transmit off frequency).

It is also desirable to be able to tune to one side of a station's frequency in order to avoid interference on the other side. A digital AM receiver used with a commercial converter would completely skip over some stations and not be able to tune optimally for many others. The Converter described in this article overcomes that problem and can be used with digital as well as analog receivers.

The Converter allows for minute adjustments in frequency to minimize interference. It has a dial that lets you set the actual shortwave frequency being received instead of settling for

a medium-wave frequency. Because of the unit's overall superb performance, image frequencies are rarely, if ever, audible. The author's prototype of the Shortwave Converter has been operated over a wide range of temperatures and no frequency drift has been observed. Overall bandwidth depends partly upon the automobile receiver, but is usually around 5 kHz. Strong stations come in surprisingly clear.

Because a single international band for the Converter had to be chosen, the 31-meter band was selected. That band officially extends from 9.5 to 9.9 MHz, making it (unofficially) the widest of international bands. Because there are numerous out-of-band broadcasters, the Converter needs to tune from 9.35 MHz to 10 MHz (incidentally, there is a WWV station at 10-MHz, which could make checking your calibration of the unit easy).

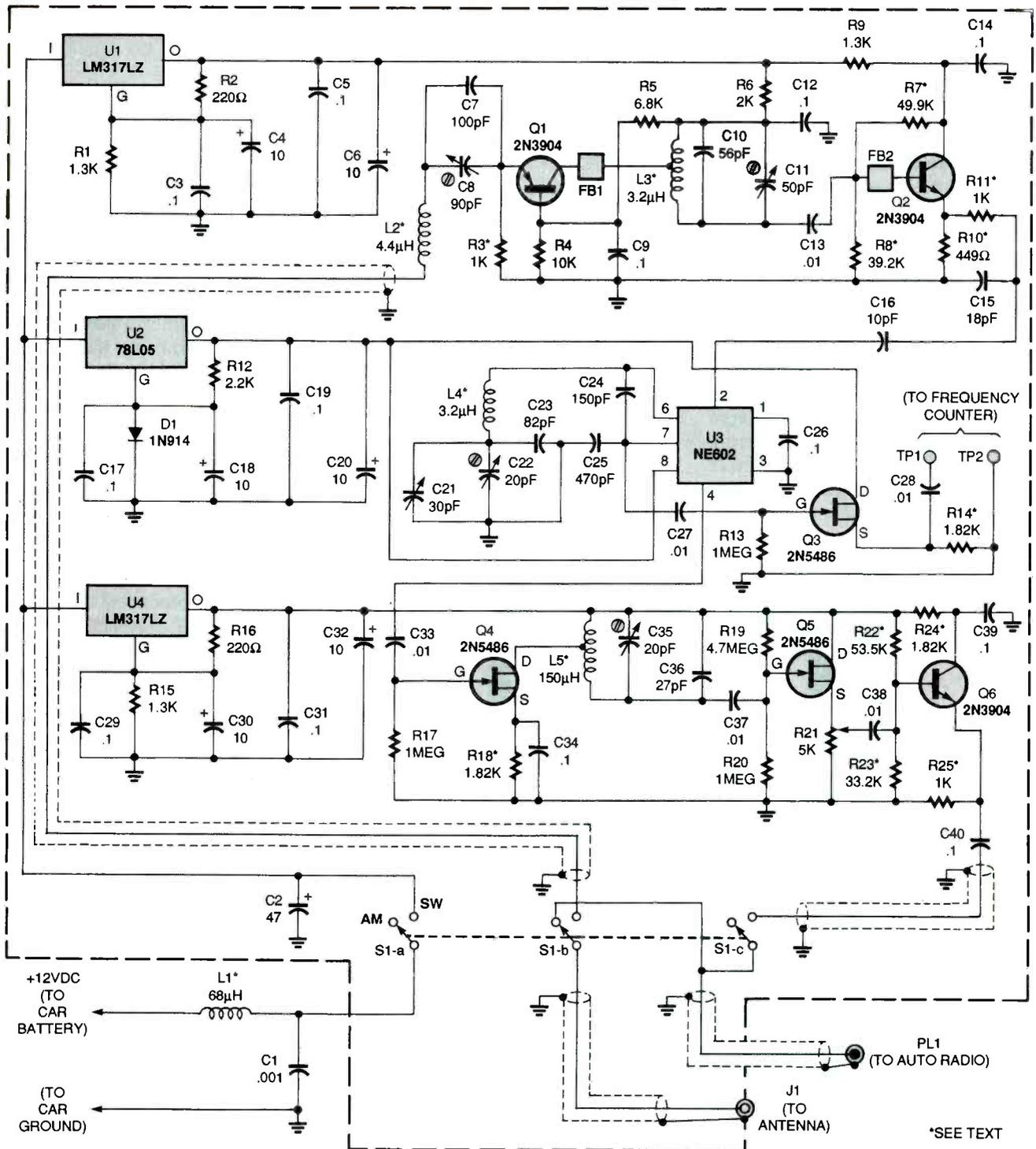


Fig. 1. This Shortwave Converter lets you listen to either AM or SW with a flick of switch S1. And because of tuning-capacitor C21, you can tune in any shortwave station, not just ones that are broadcast in 10-kHz increments.

In the early evening, it is not unusual to be able to receive as many as six English-language stations on that band as well as numerous foreign-language stations. During the daytime, the author can receive good-quality signals from stations that are each about 1000 miles away. But keep in mind that shortwave recep-

tion conditions change radically over time.

In a conventional shortwave converter, when the unit is on, the car-antenna signal is fed to the internal bandpass filter, which passes the entire shortwave band of interest (9.35 to 10 MHz for the 31 meter band). A crystal-controlled local oscillator (which is

fixed at a single frequency, usually 8.5 MHz) and mixer convert the band of shortwave frequencies to a band of medium-wave frequencies (often 850 to 1500 kHz for 31 meters). The output bandpass or lowpass filter removes the unwanted mixer products and passes the signal to an analog broadcast-band receiver.

In the Shortwave Converter described in this article, the local oscillator is made variable and the output is made narrowband on a single frequency—1710 kHz. If your automobile receiver doesn't receive the new AM frequency of 1710 kHz, then 1610 kHz can be used (that difference in output frequency can be accommodated during the calibration procedure discussed later). The tuning capacitor for the local oscillator is fitted with a dial and knob that is accessible to the driver.

**Circuit Description.** The circuit diagram for the Converter is shown in Fig. 1. Power for the circuit is taken from the car battery and is dropped to the proper voltages for three sections of the circuit by three separate regulator ICs: U1, U2, and U4.

Inductor L2 and capacitors C7 and C8 act as the circuit's antenna tuner. The tuned signal is fed to an input bandpass filter composed of L3, C10, and C11. An NE602 oscillator IC, U3, is used as a combined mixer and oscillator. That configuration is known as a "series-tuned Colpitts" or "Clapp" oscillator, and is among the most temperature-stable variable oscillators.

The 1710-kHz output filter mentioned earlier consists of L5, C35, and C36. Each of the filters in the circuit was limited to a single LC section in order to simplify as much as possible the alignment of the Converter. Transistor Q3 is a frequency-counter buffer that is used only during alignment.

The gain of the Converter is sufficient to overload the input of some receivers. Potentiometer R21 can be used to decrease the output level

and prevent overload; but more on that later.

**Construction.** To prevent stray capacitance and ensure the best-sounding reception, you should build the Shortwave Converter on a printed-circuit board. If you'd like to etch your own, you can use the full-size pattern shown in Fig. 2. Or you could order an etched and drilled board from the source given in the Parts List. The PC board was designed to fit in the bottom of a standard 5¼- × 3- × 2½-inch metal Minibox, but any metal enclosure that is large enough can be used.

If you do build the Converter on a PC board, use the parts-placement diagram in Fig. 3 as a guide. When mounting the components, note the orientation of the transistors, voltage regulators, the DIP IC, and the electrolytic capacitors. Before inserting transistors Q1 and Q2, place a ferrite bead on the collector of Q1 and on the base of Q2. Electrically, ferrite beads are insulators, so you don't have to worry about shorting the transistor leads.

Note that several of the resistors are metal-film types. The behavior of those is more predictable at RF frequencies, and they only cost a few cents more than carbon resistors. If a source of metal-film resistors cannot be located, you can freely substitute carbon resistors. The silver mica capacitors that are specified can be replaced with NPO ceramic units if desired.

For C21, the author used a simple, direct-drive tuning capacitor with a pointer knob for his prototype. Tuning was not excessively difficult using that unit, however, a reduction-drive tuning capacitor would be better provided one can be obtained.

The board was originally designed to accommodate LM317LH regulators for use as U1 and U4. However, the more commonly available LM317LZ regulators were used instead, and they have a different pin configuration. Note that the parts-placement diagram shows how to orient the parts and where each pin should be inserted.

Install all board-mounted parts and jumper wires except for capacitor C8 and jumper-wires JU2 and JU4 in the PC board. Those three parts will be

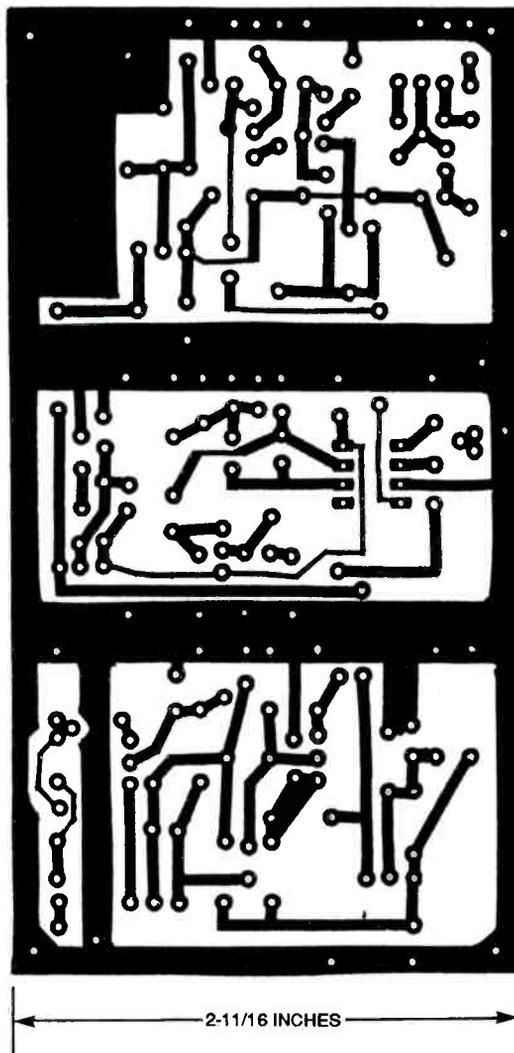


Fig. 2. Building the Converter on a PC board is strongly recommended. You can use this full-size pattern to make your own board.

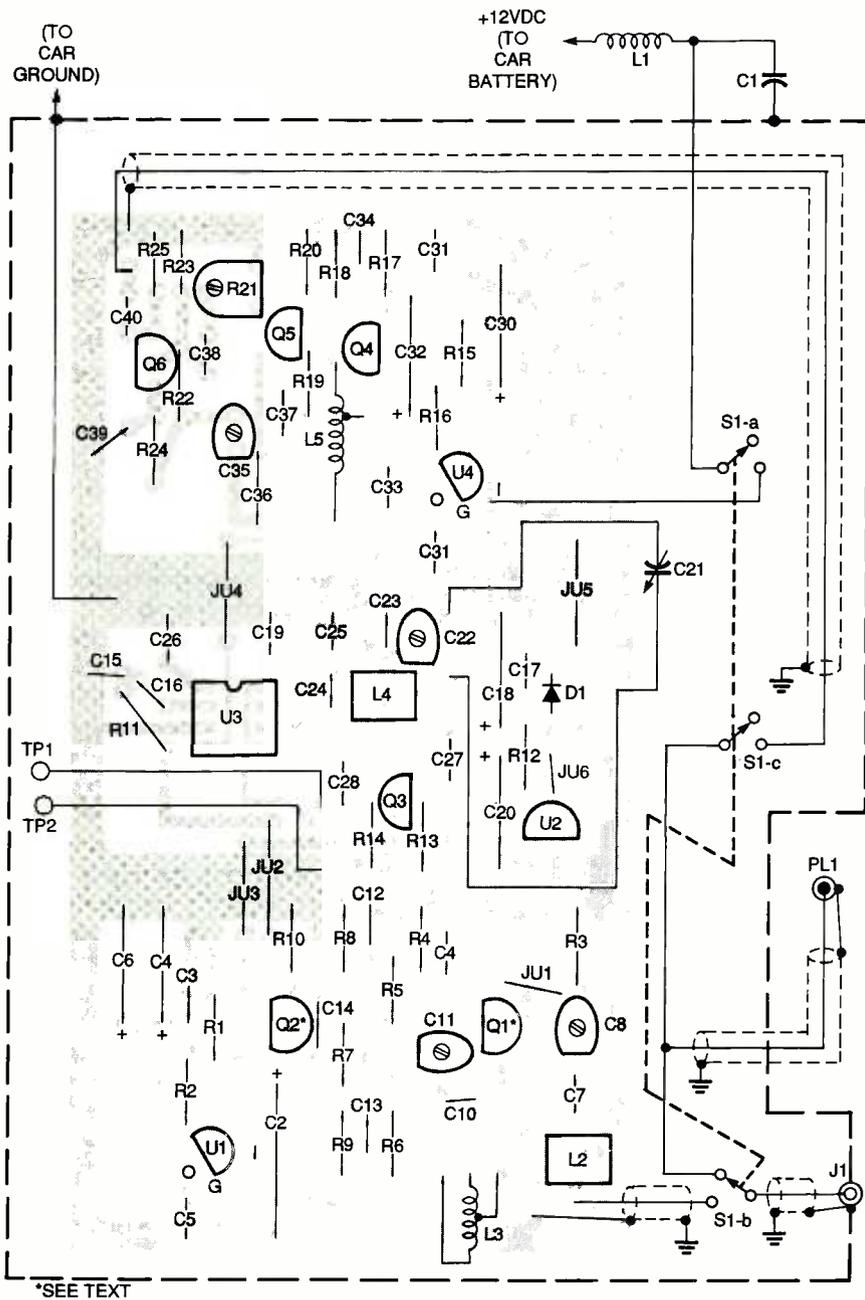


Fig. 3. When mounting the components on the PC board, and doing the off-board wiring, you might want to use this parts-placement diagram as a guide to make things simpler.

added later.

Turning to the inductors, toroidal units were used where possible because they have inexpensive cores, exhibit a high Q, and are fairly easy to wind. Noise-suppression inductor L1 will carry a current of 15 mA and have a self-resonant frequency of 13 MHz or greater. The author's prototype used a 68- $\mu$ H unit (J.W. Miller 9250-683), but an 18- $\mu$ H coil (Mouser 43LS185) will work as well. Inductors L2-L5 require winding on the part of the builder.

To wind coils L2-L5, use the follow-

ing guidelines: Coils L2-L4 can each be wound using an Amidon Associates T-30-2 (red) powdered iron toroidal core and 30-gauge enameled magnet wire. Inductor L2 is a 4.4- $\mu$ H unit that is made by winding 32 turns on the core. Coils L3 and L4 each have a total inductance of 3.2  $\mu$ H, and are made by winding 27 turns on the respective cores. A tap is made on L3 four turns from one end.

Finally, inductor L5 is a 150- $\mu$ H unit (J. W. Miller 73F154AF) with 13 turns of 30-gauge magnet wire added at one

end. Make sure that the added turns are in the same direction as the existing turns, and check that the total inductance of both windings is greater than the original inductor was by itself (the total should be about 180  $\mu$ H). As an alternative, you can wind 56 turns of 30-gauge magnet wire on an Amidon FT-50-43 ferrite toroidal core. Tap the winding eleven turns from one end. The latter coil is larger and doesn't fit the PC board as well, but has about twice the Q (which is desirable).

After the board-mounted inductors are installed on the PC board, they should be covered with a drop of silicone glass sealer. That product is available in automobile supply stores. The sealer will immobilize the windings on the inductors and help protect the inductors from the mechanical shock that the Converter will experience inside an automobile.

**Calibration.** There are several ways to calibrate the Converter. The general idea is to tune the input filter and antenna tuner to a center frequency of 9.675 MHz, tune the output filter to 1710 kHz (or 1610 kHz), and set the oscillator so that the Converter will cover the range of 9.35 to 10 MHz. What follows is a description of the method and equipment used by the author.

You will need the following equipment to calibrate your Converter: a signal generator that will produce the frequency range of 9.35 to 10 MHz and the fixed frequency of 1710 kHz (or 1610 kHz); a receiver (preferably battery operated), with an external antenna input jack and an S meter, that will receive 9.675 MHz and 1710 kHz; and a plug that matches the re-

TABLE 1

CONVERTER-DIAL MARKING (MHz)	LOCAL-OSCILLATOR FREQUENCY FOR 1710 KHz AM	LOCAL-OSCILLATOR FREQUENCY FOR 1610 KHz AM
9.35	11.060	10.960
9.4	11.110	11.010
9.5	11.210	11.110
9.6	11.310	11.210
9.7	11.410	11.310
9.8	11.510	11.410
9.9	11.610	11.510
10.0	11.710	11.610

## PARTS LIST FOR THE SHORTWAVE CONVERTER

### SEMICONDUCTORS

U1, U4—LM317LZ variable voltage regulator, integrated circuit  
 U2—78L05 5-volt regulator, integrated circuit  
 U3—NE602 balanced-modulator oscillator, integrated circuit  
 Q1, Q2, Q6—2N3904 general-purpose NPN transistor  
 Q3—Q5—2N5486 VHF JFET transistor (can substitute an MPF102 or MPF107)  
 D1—1N914 general-purpose silicon diode

### RESISTORS

(All fixed resistors are 1/4-watt, 5% carbon units, unless otherwise noted.)

R1, R9, R15—1300-ohm  
 R2, R16—220-ohm  
 R3, R11, R25—1000-ohm, metal-film, 1%  
 R4—10,000-ohm  
 R5—6800-ohm  
 R6—2000-ohm  
 R7—49,900-ohm, metal-film, 1%  
 R8—39,200-ohm, metal-film, 1%  
 R10—449-ohm, metal-film, 1%  
 R12—2200-ohm  
 R13, R17, R20—1-megohm  
 R14, R18, R24—1820-ohm, metal-film, 1%  
 R19—4.7-megohm  
 R21—5000-ohm miniature potentiometer, board mounted (Radio Shack 271-283 or equivalent)  
 R22—53,500-ohm, metal-film, 1%  
 R23—33,200-ohm, metal-film, 1%

### CAPACITORS

C1—0.001- $\mu$ F standoff or feed-through type  
 C2—47- $\mu$ F, 16-WVDC, electrolytic  
 C3, C5, C9, C12, C14, C17, C19, C26, C29, C31, C34, C39, C40—0.1- $\mu$ F, ceramic-disc  
 C4, C6, C18, C20, C30, C32—10- $\mu$ F, 16-WVDC, electrolytic  
 C7—100-pF, silver-mica  
 C8—8- to 90-pF, ceramic-trimmer  
 C13, C27, C28, C33, C37, C38—

0.01- $\mu$ F, ceramic-disc  
 C10—56-pF, silver-mica  
 C11—9- to 50-pF, ceramic-trimmer  
 C15—18-pF, ceramic-disc  
 C16—10-pF ceramic-disc  
 C21—2.3- to 30-pF, air-variable capacitor, panel-mounting, direct or reduction-drive  
 C22, C35—3.5- to 20-pF, ceramic-trimmer  
 C23—82-pF, silver-mica  
 C24—150-pF, silver-mica  
 C25—470-pF, silver-mica  
 C36—27-pF, silver-mica

### ADDITIONAL PARTS AND MATERIALS

L1—68- $\mu$ H (see text)  
 L2—4.4- $\mu$ H (see text)  
 L3—3.2- $\mu$ H, tapped (see text)  
 L4—3.2- $\mu$ H (see text)  
 L5—150- $\mu$ H (see text)  
 FB1, FB2—Ferrite bead (Amidon Associates FB-43-101 or equivalent)  
 J1—Coaxial jack  
 PL1—Coaxial plug  
 S1—3PDT switch, bushing mounted  
 Printed-circuit materials, aluminum project enclosure (Radio Shack 270-238 or equivalent), coaxial cable, two knobs, dial pointer (if using reduction drive), 2 1/8-inch-diameter aluminum dial, standoff insulator, 20-gauge solid buss wire (for jumpers and test points), wire, solder, hardware, etc.

**Note:** The original parts supplier for the Shortwave Converter is no longer available. The Author is investigating other parts suppliers as possible sources for the builder. To obtain a listing of who supplies what parts, you can e-mail the author at [lrwilliams@nopc.org](mailto:lrwilliams@nopc.org). Otherwise, send a stamped, self-addressed envelope to the Editor of POPTRONIX HOBBYISTS HANDBOOK requesting the latest parts information.

jumper JU2) to the center wire of a coax cable, and attach the shield to board ground. Then connect the proper plug to the other end of the coax cable and plug it into the antenna jack of the receiver. Set the receiver to 9.675 MHz, and set the output of the signal generator as low as possible for an adequate reading on the receiver. Tune capacitor C11 for a maximum reading on the S meter. That calibrates the input filter.

Leave the coax cable connected to the emitter of Q2. Disconnect the signal generator and the blocking capacitor at the emitter of Q1, and install capacitor C8 on the board. Then, attach an automobile antenna jack to the input side of L2, and connect the jack housing with a short wire to the PC-board ground.

Take the board along with the 9-volt batteries and the receiver inside the automobile. Plug the cable from Q2 into the antenna jack of the portable receiver, then plug the cable from automobile antenna into the automobile antenna jack on the board. Extend the automobile antenna to full length and place the signal generator just outside the car near the antenna. Tune the signal generator to 9.675 MHz and attach a short wire antenna if necessary, but do not physically connect the signal generator to the automobile. Tune the receiver to 9.675 MHz. Adjust C8 on the converter for a maximum indication on the S meter of the receiver. That calibrates the antenna tuner for the antenna in your car.

Bring the board and other equipment back indoors. Disconnect the receiver coax cable from the emitter of Q2 and connect it to the pad at the output end of capacitor C40 with the shield to board ground. Set the signal generator to 1710 kHz (or 1610 kHz as required) and apply a signal at the gate of Q4 through capacitor C33 (use the pad for jumper JU4). Tune the receiver to 1710 kHz (or 1610 kHz) and plug the coax cable into its antenna jack. Set the output of the signal generator as low as will allow adequate output, and tune C35 for maximum output (if you are tuning to 1610 kHz, you might have to increase the value of C36). That completes the calibration of the output filter. Install jumpers JU2 and JU4 before you go on to the next step.

ceiver's jack. You'll also need a frequency counter, a plastic alignment screwdriver, some coax cable, two 0.001- $\mu$ F capacitors, and two 9-volt batteries with clips.

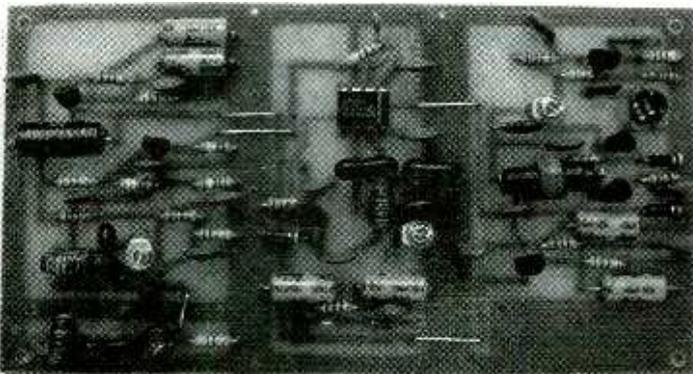
Connect the 9-volt batteries in series, attach the positive lead to the input pad near U4, and the negative lead to ground on the PC board. The

voltage regulators on the board will reduce the resulting 18 volts to the proper levels.

Set the output of the signal generator to 9.675 MHz and apply the signal to the emitter of Q1 (at the pad for capacitor JU1) through a 0.001- $\mu$ F capacitor. Attach a 0.001- $\mu$ F capacitor from the emitter of Q2 (at the pad for

Leave the receiver connected to C40 and tuned to 1710 kHz (or 1610 kHz). Attach tuning-capacitor C21 to the board using short wires, and connect a 4-foot wire antenna to the center terminal of the automobile jack installed at L2. You should now be able to tune in shortwave stations with the Converter that will be heard on the receiver. Tune the signal generator to a frequency near 9.675 MHz; the Converter should pick up the signal without any physical connection (add a short wire antenna to the signal generator if necessary).

Using the signal generator, adjust C22 so that tuning-capacitor C21 covers the frequency range of 9.35 to 10 MHz. If you are using a 1610-kHz output and C22 doesn't have enough capacitance, there is a place on the



*Here's the completed PC board. Building the project in this fashion minimizes stray capacitance and ensures the best performance.*

printed-circuit board where an additional capacitor can be added in parallel with C22. That completes the calibration of the oscillator section.

As mentioned earlier, the gain of the Converter could overload the input of some receivers. Potentiometer R21 is used to adjust that. The potentiometer operates backward, in that the maximum output is at the full counter-clockwise position. When the Converter is installed in an automobile, R21 should be adjusted so that the AM receiver is not overloaded. With the author's radio, best results were obtained with R21 adjusted near the minimum output position (near full clockwise).

#### **Final Assembly and Installation.**

Remove the cable and automobile antenna jack from the printed-circuit board. Drill holes in the project en-

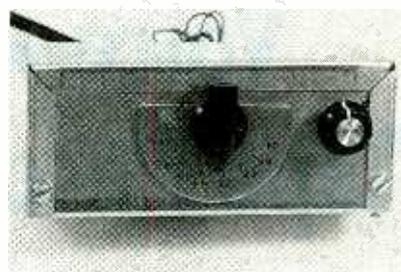
closure in the proper places to accommodate mounting screws for the board, the off-board components, and the cable. Then, install the printed-circuit board, C21, the switch, output cable, automobile antenna jack, C1, standoff, etc. in the enclosure, making sure to check your off-board wiring (again, use Fig. 3 as a guide).

Add a 12-volt power wire to the standoff at the input of L1 and a ground wire from PC board ground. Drill two holes and extend short wires from the output of buffer Q3 through the holes to the outside. Attach a dial and pointer knob to C21. Align the knob so that it points to the left at a maximum capacitance of C21.

The dial has to be individually calibrated for each Converter con-

structed because the variable capacitor and the tuning components L4, C22, C23, C24, and C25 will vary somewhat from those used in the author's prototype. In that unit, a 2½-inch diameter, standard dial plate was used as a base. The dial plate was cut to a semicircular shape because a complete circle was not needed.

Attach a frequency counter to the buffer leads from Q3 and apply 12-volt power to the Converter. Use Table 1 as a guide when calibrating the dial. Rotate C21 until the frequency specified in the second or third column of Table 1 is indicated on the counter, and mark the dial with a pencil at the place indicated by the pointer knob. When all the marks are made, remove the dial from C21. Use wax transfers to cover the pencil marks and place the appropriate frequency number from the first column of



*Here's the finished converter prior to installation in an automobile. The tuning capacitor's dial is homemade and will vary by the band of interest.*

Table 1 next to the marks. When all the wax transfers are placed, spray the dial with clear acrylic lacquer. Insulate the leads from Q3 and tape them against the box for future use.

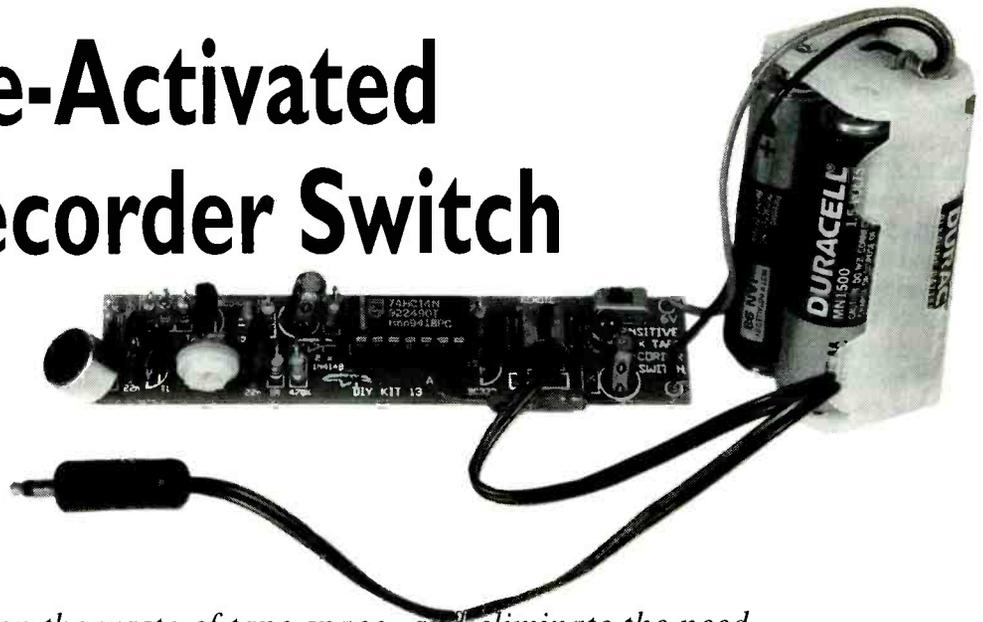
Installation in the automobile is accomplished by drilling two holes with the appropriate spacing at a convenient location in the automobile panel. The Converter is placed behind the panel with the switch and capacitor threaded bushings protruding. Place the dial over the capacitor bushing and secure the box to the panel by putting a second pair of nuts on the bushings (note the dial alignment while tightening the nuts). Install knobs on the switch and capacitor shafts.

Some reduction-drive tuning capacitors mount to the panel with three screws instead of a threaded bushing. With that type of tuning capacitor, the Converter will have to be secured to the automobile panel with a screw on the capacitor side and with the switch bushing on the other. The dial will have to be attached to the automobile panel with small, self-tapping screws.

Connect the power wire to the same 12-volt source that is used by the automobile radio and connect the ground wire to the automobile chassis ground at any convenient place. Plug PL1 into the automobile radio and plug the automobile antenna into jack J1. Turn on the automobile radio and set it to 1710 kHz (or 1610 kHz) AM. Turn switch S1 on the Converter to sw and tune in a shortwave station with C21. You are now set to enjoy a type of radio programming that very few people can get in their cars.

Incidentally, if you wish to contact the author directly with any questions or comments, send e-mail to: [lwilliams@hopc.org](mailto:lwilliams@hopc.org)

# Voice-Activated Tape Recorder Switch



*Stop the waste of tape space, and eliminate the need to fast forward through silence, with this voice-activated switch.*

**D**id you ever have to record a speech, presentation, or conversation and wish that you could do so automatically? Because it makes no sense to record silence, as that only wastes tape and increases playback time, some tape recorders come with voice-activated recording settings. Unfortunately, not *all* tape recorders come with that feature.

This article describes a sensitive, *Voice-Activated Tape-Recorder Switch*. When the circuit detects an audio signal, it grounds a mini plug that can be plugged into the remote

BY MARC SPIWAK

jack on a tape recorder. That has the same effect as operating a remote recording switch. So if you build this neat little device, and have access to a tape recorder with a remote jack, you can easily add voice-sensitive recording to your setup.

**Circuit Description.** A schematic of the Tape-Recorder Switch is shown in Fig. 1. The circuit can be powered by B1, which is four AA batteries in series, or by any 6-volt DC supply.

Audio signals from the electret microphone, MIC1, are coupled via capacitor C1 to two audio-amplification stages centered around transistors Q1 and Q2. A 5000-ohm potentiometer, R12, provides a sensitivity control that sets the audio level at which the Switch will activate a tape recorder.

The audio input to the digital switching section of the circuit is biased at half the supply voltage by two 1%, 1-megohm, metal-film resistors (R6 and R7). Integrated-circuit U1 is a 74HC14 hex Schmitt trigger inverter. With a 6-volt power supply, the Schmitt inverter

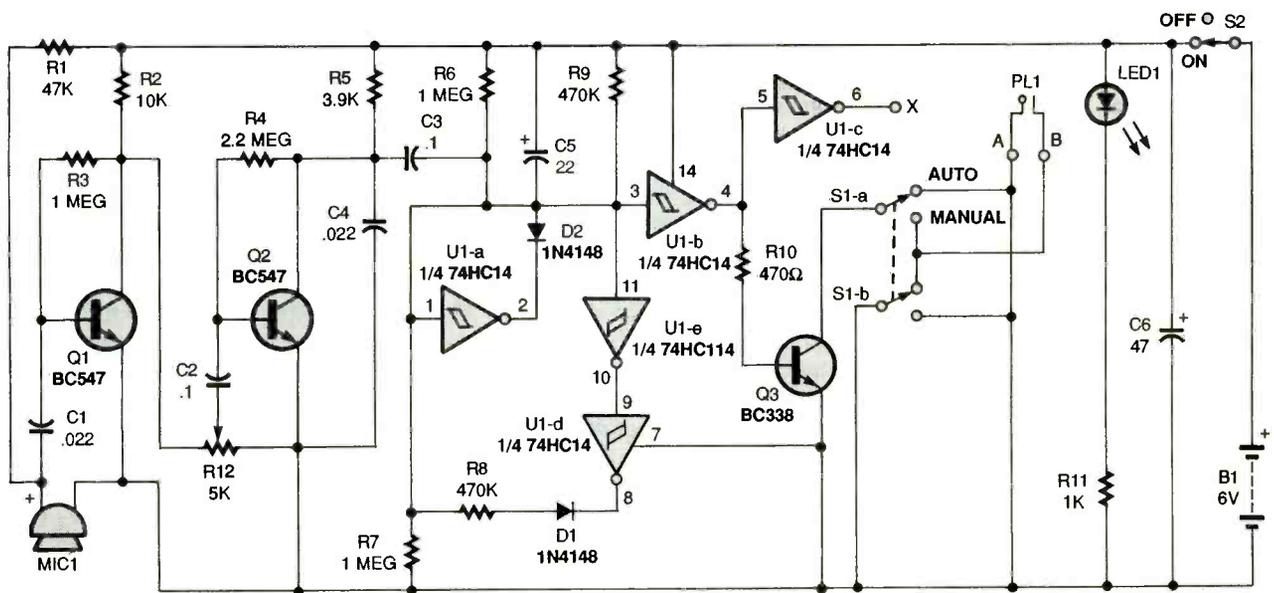


Fig. 1. Here's the schematic for the Voice-Activated Tape-Recorder Switch. A 5000-ohm potentiometer, R12, provides a sensitivity control for the audio level at which the switch will activate a tape recorder.

gates will have a 1-volt hysteresis gap between 2.2 volts and 3.2 volts. That means that the input to a Schmitt inverter must rise above 3.2 volts for the output to go low, but must fall below 2.2 volts for the output to return to a high.

Now assume that the input to U1-a (pin 1) is held high by an audio signal from the microphone and that the output (pin 2) would be low. That causes capacitor C5 to charge rapidly through diode D2. The low from pin 2 also pulls the input to U1-b (pin 3) low; the output of U1-b (pin 4) would then be high. That resulting high from pin 4 turns on transistor Q1, which then grounds terminal A if S1 is in the "Auto" position. Terminal B is held to ground by S1-b. That has the effect of shorting terminals A and B together, and thus the two conductors of PL1, which is the mini plug connected to the terminals. With S1 in the "Manual" position, both terminals are grounded, thereby keeping the recorder turned on regardless of the presence of audio.

The low on pin 3 of U1-b in the presence of audio is presented to pin 11 of U1-e and ends up at pin 8 of U1-d. That will pull pin 1 low in the absence of an

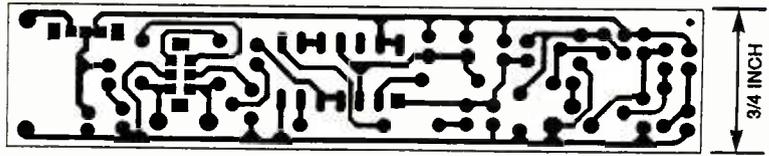


Fig. 2. Use this template to etch your own PC board for the Tape-Recorder Switch.

audio signal from the microphone, making pin 2 high.

Diode D2 blocks the discharging of C5 through its original charging path, so C5 starts to discharge through R9 with a time constant of  $R9 \times C5$ , or about 10.3 seconds. The turn-off time is determined by the relative turn-on voltage of the Schmitt inverter, which is about half of the supply voltage. That time works out to a delay of about 6 seconds. After that delay, the voltage at pin 3 rises above 3.2 volts, causing pin 4 to go low, thus removing the connection from terminal A to ground, and turning off the tape recorder. A continuous audio input to pin 1 will hold pin 4 high, but as soon as it ceases, the time-out process begins.

When power is applied to the circuit using switch S2, LED1 lights. However, if the ground connection to R11 is removed, and that end of the resistor

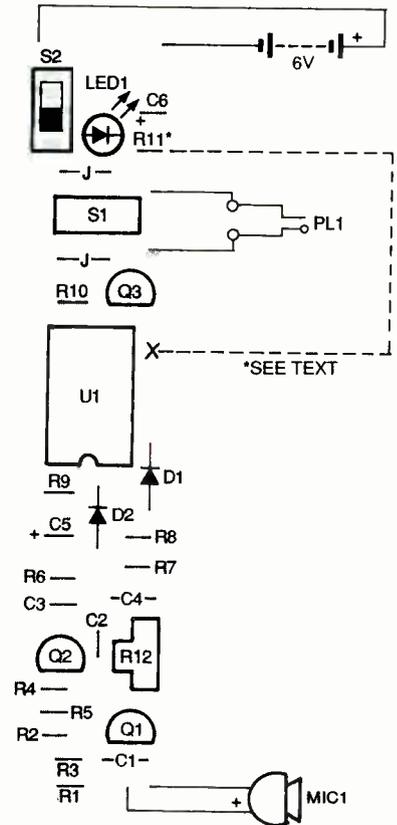


Fig. 3. This parts-placement diagram should make assembling the circuit easier. Fixed resistors must be mounted vertically. The orientation of Q3 might vary depending on the unit you use.

is then connected to terminal X (pin 6 of U1-c), the LED will instead light only when the output of the circuit is active (more on that later).

**Construction and Checkout.** The author's prototype for the Tape-Recorder Switch was built on a small PC board. You can build the circuit on a perforated construction board instead, but a PC board makes the project more compact. A pre-etched and drilled PC board is available as part of a complete kit of parts from the source mentioned in the Parts List. If you would like to etch your own PC board, a foil pattern is provided in Fig. 2.

For those using a PC board, a parts-  
(Continued on page 102)

## PARTS LIST FOR THE VOICE-ACTIVATED TAPE-RECORDER SWITCH

### SEMICONDUCTORS

U1—74HC14 hex Schmitt trigger inverter, integrated circuit  
Q1, Q2—BC547, NTE 123A, or equivalent NPN transistor  
Q3—BC338, NTE123AP, or equivalent NPN transistor (see text)  
D1, D2—1N4148 silicon diode  
LED1—Light-emitting diode, any color

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units, unless otherwise noted.)  
R1—47,000-ohm  
R2—10,000-ohm  
R3—1-megohm  
R4—2.2-megohm  
R5—3900-ohm  
R6, R7—1-megohm, 1/4-watt, 1% metal-film  
R8, R9—470,000-ohm  
R10—470-ohm  
R11—1000-ohm  
R12—5000-ohm, PC-mount potentiometer

### CAPACITORS

C1, C4—0.022- $\mu$ F, Mylar

C2, C3—0.1- $\mu$ F, ceramic-disc  
C5—22- $\mu$ F, 16-WDVC electrolytic  
C6—47- $\mu$ F, 16-WDVC electrolytic

### ADDITIONAL PARTS AND MATERIALS

MIC1—Electret microphone  
PL1—2.5-mm mini plug  
S1—DPDT, PC-mount switch  
S2—SPDT, PC-mount switch  
B1—6-volt battery (4 AA cells in series)  
Printed-circuit materials, 4-AA cell battery holder, 2-conductor wire, solder, hardware, etc.

**Note:** The following is available from Marlin P. Jones & Associates, Inc. (P.O. Box 12685, Lake Park, FL 33403-0685; Tel. 800-OK 2 ORDER or 407-848-8236; Fax: 407-844-8764): Voice-Activated Tape-Recorder Switch Kit (#6013-KT)—includes everything specified in the Parts List, except batteries)—\$12.95 plus \$3.00 shipping and handling. Florida residents please add appropriate sales tax.

# TV Transmitter

*Use is to rebroadcast video signals throughout your house.*



BY MARC SPIWAK

One of the most useful gadgets a video enthusiast can have is a TV transmitter. Such a device can transmit a signal from a VCR to any TV in a home or backyard. Imagine the convenience of being able to sit by the pool watching your favorite movie on a portable TV, with a tape or laserdisc playing indoors. Videotapes can also be dubbed from one VCR to another without a cable connecting the two machines together. Further, when connected to a video camera, a TV transmitter can be used in surveillance for monitoring a particular location.

The main problem a video enthusiast has in obtaining a TV transmitter, though, is that a commercial unit can be somewhat expensive. However, we have some good news for all you video enthusiasts who are electronics enthusiasts as well: You can build the *TV Transmitter* presented in this article for less than \$30, in one evening! The easiest way to do that is to order the kit that's available from the source given in the Parts List (a custom case for the kit is also available). However, we present enough information here to build the TV Transmitter from scratch, if you wish.

The TV Transmitter combines line-level audio and video signals and transmits the resulting signal up to 300 feet. Although the circuit can be powered from a 9-volt battery, it is best to use a 12-volt DC supply during alignment, and also to obtain the maximum transmission range and best possible picture. Aligning the TV Transmitter requires no special equipment whatsoever, and it is a very simple procedure. The Transmitter's output can be tuned to be received

on any TV channel from 2 to 6. That range of channels should be wide enough not to interfere with other TV viewers who are nearby. To comply with FCC rules, it is mandatory that nearby TV viewers are not disturbed

by the transmission. If your activities interfere with the reception of a licensed station, regardless of the reason, you must shut down the unit.

**Circuit Description.** Figure 1 is the schematic of the TV Transmitter circuit. Video signals input at jack J1 are first terminated by resistor R6 and coupled through capacitor C1 to clamping-diode D1. The clamping forces the sync pulses to a fixed DC level to reduce blooming effects. Potentiometer R3 is used to set the gain of the video signal; its effect is similar to that of the contrast control on a TV set. Bias-control R7 can be used to adjust the black level of the picture so that

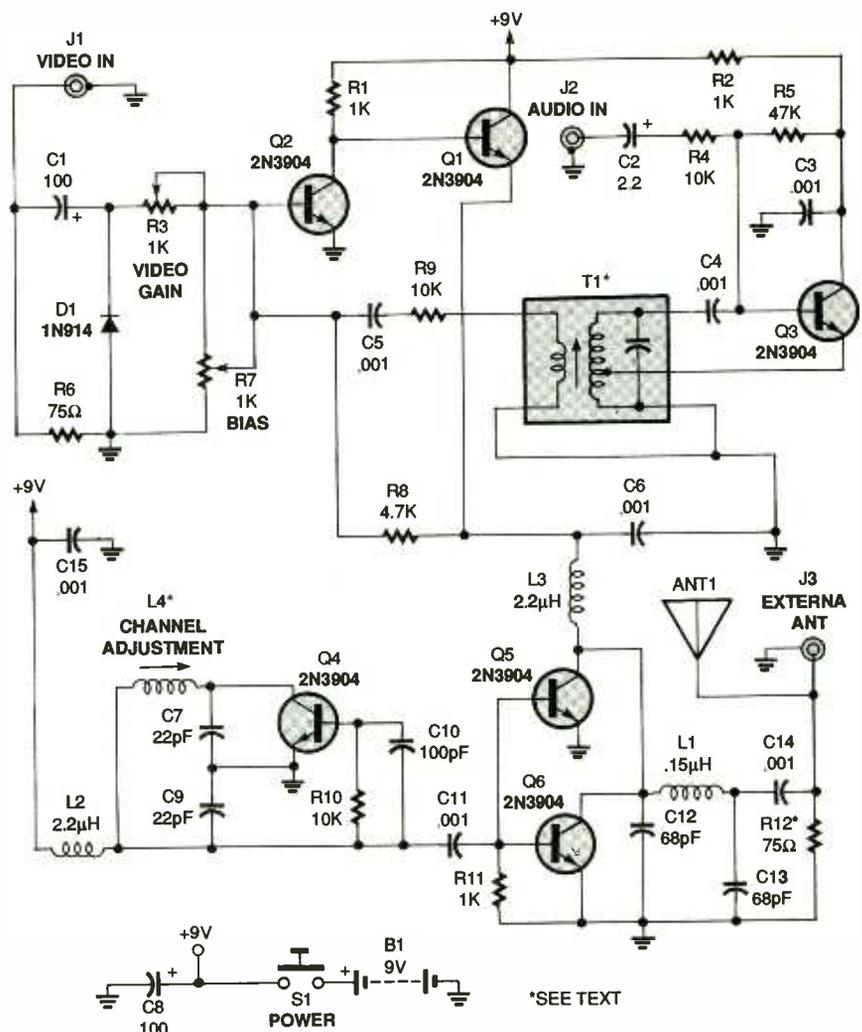
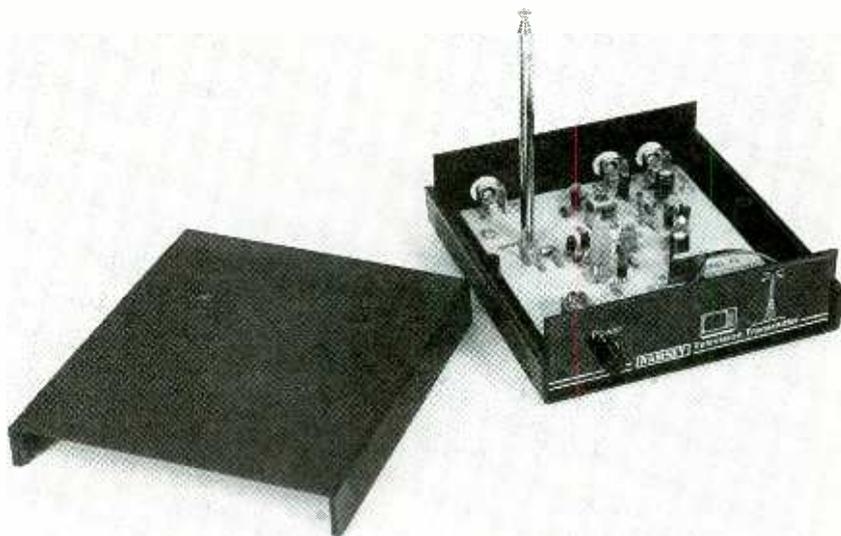


Fig. 1. As this schematic shows, hooking up the Transmitter to other equipment is easy. There's a video-input jack, J1; an audio-input jack, J2; and an external-antenna jack, J3 (although the unit works fine with ANT1, a telescopic-whip antenna).

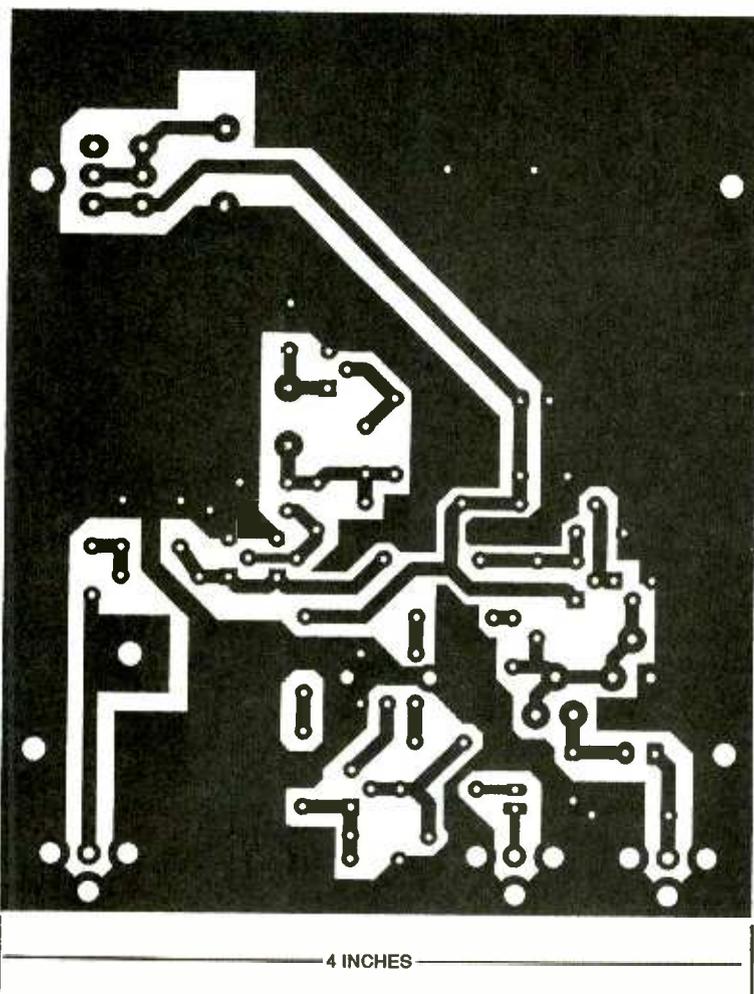
some level of signal is transmitted, even for a totally dark picture. That way, a TV receiver can maintain proper sync. As we'll get to later, potentiometers R3 and R7 are adjusted in conjunction for the best all-around performance.

RF-transformer T1 and its internal capacitor form the tank circuit of a Hartley oscillator that's tuned to 4.5 megahertz. Audio signals input at J2 are coupled to the base of Q3 via C2 and R4; the audio signal modulates the base signal of Q3 to form an audio subcarrier that's 4.5-megahertz higher than the video-carrier frequency. The FM modulated subcarrier is applied to the modulator section through C5 and R9. Resistor R9 adjusts the level of the subcarrier with respect to the video signal.

Transistors Q1 and Q2 amplitude-modulate the video and audio signals onto an RF-carrier signal. The operating frequency is set by coil L4, which is



*This Transmitter case allows easy access to the circuit board for alignment purposes.*



*Fig. 2. If you wish, you can use this foil pattern to make your own PC board for the TV Transmitter.*

3.5 turns of 24-gauge enameled wire on a form containing a standard ferrite slug. That coil is part of a Colpitts tank circuit also containing C7 and C9. The tank circuit forms Q4's feedback network, so Q4 oscillates at the set frequency.

The RF output from the oscillator section is amplified by Q5 and Q6, whose supply voltage comes from the modulator section. Antenna matching and low-pass filtering is performed by C12, C13, and L1. Resistor R12 is optional; it is added to help match the output signal to any kind of antenna (more on that in a moment).

**Construction.** Before we go on, while it is certainly possible to build the unit from scratch, unless you are an experienced builder and an accomplished parts scrounger, it is strongly recommended that you purchase the complete kit, or, at the very least, the

**WARNING!!**

The publisher makes no representations as to the legality of constructing and/or using the TV Transmitter referred to in this article. The construction and/or use of the transmitter described in this article may violate federal and/or state law. Readers are advised to obtain independent advice as to the propriety of its construction and the use thereof based upon their individual circumstances and jurisdiction.

## PARTS LIST FOR THE TV TRANSMITTER

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

- R1, R2, R11—1000-ohm
- R3, R7—1000-ohm trimmer potentiometer, PC-mount
- R4, R9, R10—10,000-ohm
- R5—47,000-ohm
- R6—75-ohm
- R8—4700-ohm
- R12—75-ohm (optional, see text)

### CAPACITORS

- C1, C8—100- $\mu$ F, 16-WVDC, electrolytic
- C2—2.2- $\mu$ F, 50-WVDC, electrolytic
- C3—C6, C11, C14, C15—0.001- $\mu$ F, ceramic-disc
- C7, C9—22-pF, ceramic-disc
- C10—100-pF, ceramic-disc
- C12, C13—68-pF, ceramic-disc

### ADDITIONAL PARTS AND MATERIALS

- Q1—Q6—2N3904 NPN transistor
- D1—1N914 silicon diode
- T1—4.5-MHz IF-can-style RF transformer (see text)
- L1—0.15- $\mu$ H miniature inductor
- L2, L3—2.2- $\mu$ H miniature inductor
- L4—0.14- to 0.24- $\mu$ H adjustable slug-tuned coil (see text)
- S1—SPST pushbutton switch, normally open
- J1—J3—RCA jack, PC-mount
- ANT1—Telescopic-whip antenna
- B1—9-volt battery
- Printed-circuit materials or board, battery holder and connector, pair of RCA patch cords, solder, hardware, etc.

**Note:** The following items are available from Ramsey Electronics, Inc. (793 Canning Parkway, Victor, NY 14564, Tel. 716-924-4560): TV-6 TV Transmitter Kit (includes PC board and all components except R12)—\$27.95; kit of all components (except R12)—\$17.95; PC board only—\$10.00; CTV matching-case set—\$14.95. NY residents please add appropriate sales tax.

component kit from the source mentioned in the Parts List. While most of the parts are readily available, two can be a real headache to obtain.

The 4.5-MHz RF transformer (T1) used in the kit is an OEM Toko part that is not available via traditional sources. While just about any 4.5-MHz RF trans-

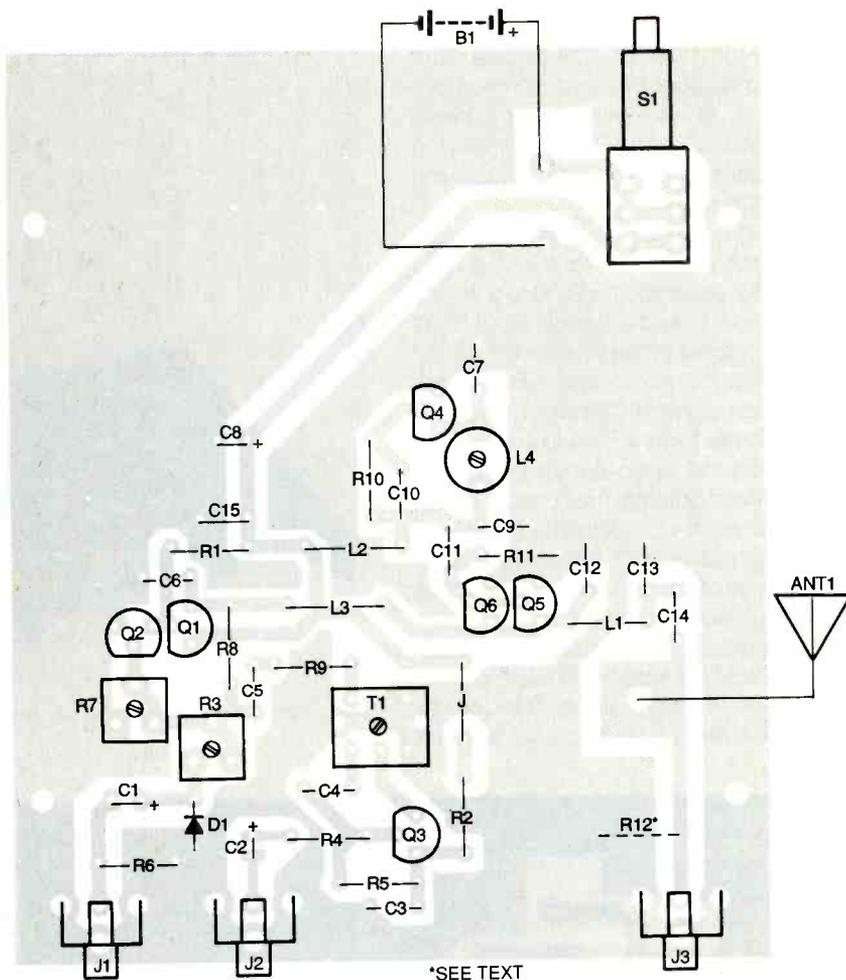


Fig. 3. Building the project is easy if you use this parts-placement diagram. Resistor R12 must be tack soldered on the solder side of the board between the antenna output and ground.

former that is similar to the one described in the article (internal capacitor, tapped secondary) can be used, such units are hard to obtain from hobbyist-friendly sources. If you are determined to go that route, your best bet is to contact Toko directly (1250 Feehanville Dr., Mt. Prospect, IL 60056; Tel. 708-297-0070) to obtain the location of your nearest full-line distributor. Also, coil L4 is a custom unit. It can, however, be home made using the parameters given earlier.

The TV Transmitter should be built on a PC board for best performance. You can make a board from the foil pattern provided in Fig. 2, or use the one that's included with the kit.

Parts are installed on the board as shown in the parts-placement diagram (see Fig. 3). Pay careful attention to the orientation of the transistors, electrolytic capacitors, and the diode. If resistor R12 (not in-

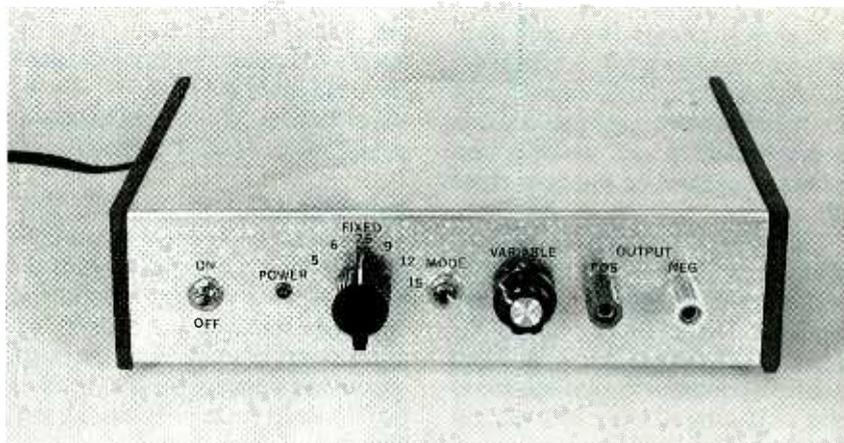
cluded in the kit) is used, it must be tack-soldered on the solder side of the board between the antenna output and ground. That resistor should be installed if you intend to use anything other than the built-in whip to provide proper matching between the antenna and the circuit.

The outline of the switch (S1) that is shown in Fig. 3 is the same as the one that comes with the kit, an SPST push-button switch that is normally open. However, you can use any kind of toggle switch as a replacement. A simple whip antenna mounts to the board with a single machine screw; the whip antenna is suitable for most applications. The battery holder can be soldered to the board with scraps of jumper wire or mounted with double-sided tape or screws.

When the board is finished, it must be mounted in a case. The case avail-

(Continued on page 109)

# Universal Power Supply



*It's an inexpensive and useful addition to any hobbyist's workbench.*

**A**ny project that you ever decide to build is going to need a power supply—any electronic project, that is. So once you have decided on a particular circuit design, the biggest concern is what sort of power supply it needs.

Power can come from many sources, including batteries, AC adapters, and benchtop supplies. For that reason, one can never have too many power supplies on his or her test bench. With every circuit requiring at least one operating voltage, and some needing more than just one voltage, you can see why that's so. Batteries are perhaps the easiest form of power to use, but constantly buying batteries can end up sucking your wallet dry after a while. Clearly, an AC adapter is a more economical method of delivering power, and perfectly suitable for a project as long as portability is not a priority.

However, the main problem with AC adapters is that, with the wide range of necessary operating voltages, all those adapters can really clutter up your test bench or home. And many inexpensive AC adapters simply can't supply enough current for some circuits. What's really needed is a variable-output, AC-derived, benchtop power supply. But most hobbyists know that commercial units of that type can get expensive.

Why should power supplies cost so much? After all, there's really nothing exotic inside most of them—the transformer is usually the most expensive component. So I decided to save some money and build the *Universal Power Supply* described in this article.

BY MARC SPIWAK

When planning the project, I decided that its two main duties would be to replace a drawer full of AC adapters, and to also be a useful supply for my test bench.

With low cost being a paramount concern, I decided to use as many junk-box components as possible. Over the years, I have accumulated quite a collection of "junk" parts. And because most of our hobbyist readers also have large collections of the stuff, I don't hesitate to recommend using recycled parts as a cost-saving option where possible. Those without junk boxes that are as full as mine shouldn't worry either—the project uses only commonly available parts.

After digging, scrounging, and can-

nibalizing for some time, I determined that the only part I would have to buy would be a rotary switch from Radio Shack, and that costs less than two dollars, which was my total cash outlay for this project. Even the case I used was an old, unused leftover that I was never sure what to do with. Perhaps you can keep costs down to a similar level, or maybe even cheaper—you might have a rotary switch in your junk collection!

**Circuit Description.** Figure 1 shows the schematic for the Universal Power Supply. The simple circuit outputs a variety of voltages (customizable by you), and can output up to one amp of current—that's a lot more than most AC adapters. As shown, the Supply outputs between 5- and 15-volts DC.

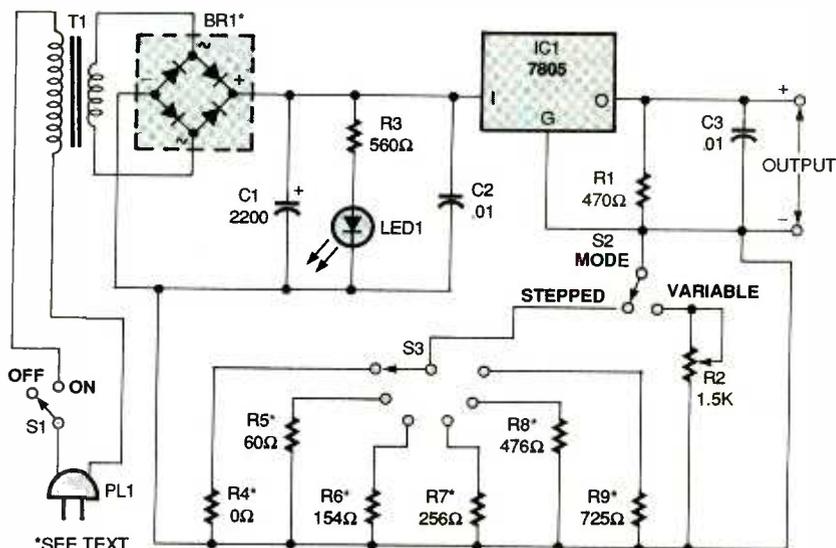


Fig. 1. The Power Supply circuit has an output that can be varied linearly by potentiometer R2 or switched to specific levels by rotary-switch S3.

When PL1 is plugged into an AC outlet, and power-switch S1 is turned on, 117 VAC are fed to transformer T1. That transformer steps the voltage down to approximately 18 VAC, which is then full-wave rectified by bridge-rectifier BR1.

Capacitor C1 smoothes any rippling caused by the bridge rectifier, and stores a charge for the voltage regulator. The other capacitors, C2 and C3, are bypass capacitors that also help condition the voltage fed to and output by IC1, a 7805 voltage regulator.

In most circuits containing them, 7805 regulators are used to output a fixed 5 volts. However, in the configuration shown, the regulator's output can be varied between about 5 and 17 volts (although, as mentioned, 15 volts is set as the maximum).

Here's how the configuration works: Normally, an input voltage higher than 5 volts is applied to the input pin of a 7805 regulator. Pin 2 (G) of the device is normally grounded and it will then regulate the output at pin 3 (O) to 5 volts higher than the potential at pin 2 (normally 0 volts, or ground). But if pin 2 is held at some voltage above or below ground, the output voltage will equal the potential at pin 2 plus 5 volts.

In this circuit, the voltage at pin 2 of the regulator is maintained by a voltage divider made of R1 and either potentiometer R2 or one of resistors R4 through R9. Each of those latter six resistors sets the output to a specific voltage level, while potentiometer R2 allows for a fully variable output.

Assume for the moment that switch S2 is set so that potentiometer R2 is part of the voltage divider. While IC1 tries to maintain exactly 5 volts at its output, the voltage at pin 2 can be varied by changing the resistance of the bottom half of the divider. Therefore, the output voltage is always 5 volts plus the voltage at the divider junction. As IC1's output voltage increases, so does the voltage at the divider junction, which then increases the output voltage, and so on, and so on, until it "runs out" of input voltage. That's how the 7805 regulator is made to have a variable output.

When switch S2 is set so that it connects pin 2 of the regulator to rotary-switch S3, one of resistors R4 through R9 then becomes the bottom half of

the divider. The values for those resistors were chosen so that the output could be set to exactly 5-, 6-, 7.5-, 9-, 12-, or 15-volts DC. We'll get to how to determine those values later on.

**Construction.** The author's prototype was built on perforated construction board using point-to-point wiring. A piece of board measuring approximately 2 × 4 inches should leave plenty of room for all the parts, except the transformer, which should be mounted separately on the enclosure.

## PARTS LIST FOR THE UNIVERSAL POWER SUPPLY

### SEMICONDUCTORS

- IC1—LM7805 5-volt regulator, integrated circuit
- BR1—50-volt, 1-amp bridge rectifier, or four 1N4001 diodes (see text)
- LED1—Light-emitting diode, any color

### RESISTORS

- (All resistors are 1/4-watt, 5% units, unless noted.)
- R1—470-ohm
- R2—1500-ohm, panel-mount potentiometer
- R3—560-ohm
- R4—0 ohm (approximate value—see text and Table 1)
- R5—60-ohm (approximate value—see text and Table 1)
- R6—154-ohm (approximate value—see text and Table 1)
- R7—256-ohm (approximate value—see text and Table 1)
- R8—476-ohm (approximate value—see text and Table 1)
- R9—725-ohm (approximate value—see text and Table 1)

### ADDITIONAL PARTS AND MATERIALS

- C1—2200- $\mu$ F, 50-WVDC, electrolytic capacitor
- C2, C3—0.01- $\mu$ F, ceramic-disc capacitor
- T1—120- to 12-volt AC transformer (see text)
- S1, S2—SPDT toggle switch
- S3—6-position rotary switch (Radio Shack no. 275-1386 or equivalent)
- PL1—2-conductor, AC plug
- Perforated construction board, project case, heat sink, two insulated binding posts, coaxial jack, four coaxial plugs, mini phono plug, 9-volt battery connector, banana plugs, power cord, grommet, wire, solder, hardware, etc.

To determine where you will position the circuit board in your project enclosure, begin by mounting transformer T1, which is a common, 120- to 12-VAC, 1-ampere model. Connect a power cord and plug to the transformer. Then wire switch S1 into the circuit.

Next, begin mounting the on-board components, starting with the bridge rectifier. You can use a regular bridge, rectifier or four discrete diodes as mentioned in the Parts List.

Next, install capacitor C1, the 2200- $\mu$ F unit. Because C1's purpose is simply to smooth ripples from the bridge rectifier, any large-value (1000- $\mu$ F or higher) electrolytic can be used, though the one listed in the Parts List is a good and commonly available choice. Go on to install capacitors C2 and C3, resistors R1 and R3, and LED1.

Continue with installation by mounting the voltage regulator. Connect a heatsink to the regulator to prevent it from overheating when it is outputting more than just a few-hundred milliamps. If you are using a metal case, a wall of the case can serve as a heatsink for the regulator if you mount the regulator on the edge of the board and mount the board up against the wall of the case after assembly is complete.

Connect potentiometer R2 and switch S2 off-board. The output voltage from the circuit should be connected to a pair of binding posts. You can use leads or banana plugs to connect the Power Supply to other circuits, or you can build a custom cable that will be described later on.

Before you can install fixed-resistors R4–R9, you will have to determine what values will work best for your circuit. Because of component tolerances and other factors, the values will probably be different than the ones in the prototype, even if you use similar parts.

Set S2 to VARIABLE, plug the circuit in, and turn on S1. Connect a DMM to the binding posts, and adjust R2 to make sure that the output voltage varies. Next, determine what fixed voltages you would like your power supply to output, and then write them down (you might want to use the ones mentioned earlier).

Adjust R2 to get the first voltage on your list at your output terminals. Then

switch S2 to STEPPED (which is an open setting, as it's not connected to anything yet), and measure the exact resistance of the potentiometer using a DMM. Be careful not to disturb the setting. Write down the value of the resistance that gives you the desired output voltage, turn S2 back to VARIABLE again, and perform the same procedures for each output voltage you want.

The next step is to piece together the exact resistance value for each output from individual resistors. In most cases you should be able to get the exact value you need by connecting only two resistors in series—and only one if you're lucky. Three resistors might be needed for some of the values, depending on how well stocked your resistor bin is. Table 1 shows the potentiometer values that were mea-

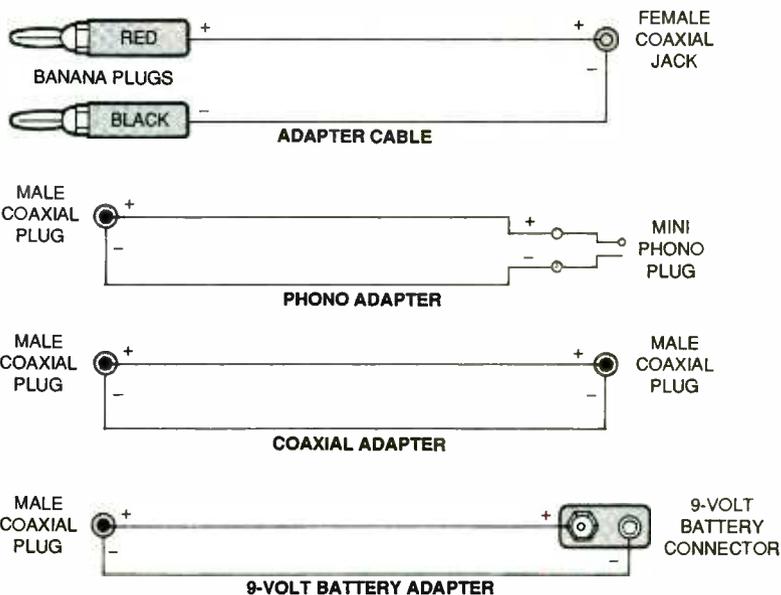


Fig. 2. Assembling these adapter cables makes it easy to connect the power supply to a variety of appliances.

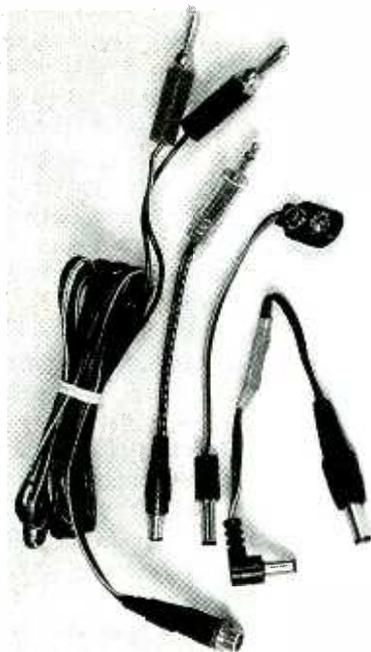
TABLE 1

Desired Output	Measured R2 Resistance	Fixed Resistors Used
5 volts	0 ohms	wire jumper
6 volts	60 ohms	56 + 4.7 ohms
7.5 volts	154 ohms	150 + 3.9 ohms
9 volts	256 ohms	220 + 18 + 18 ohms
12 volts	476 ohms	470 + 5.6 ohms
15 volts	725 ohms	680 + 47 ohms

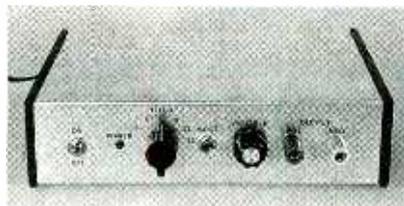
sured for the prototype's output voltages, and the fixed resistors that had to be connected in series to equal those values.

Once you have determined what resistors will be used, you can add them and rotary-switch S3 to the circuit. That switch in the author's prototype is a 2-pole, 6-position switch (Radio Shack # 275-1386), of which only half is used, providing six fixed settings. After you're done wiring the resistors, use a DMM to make sure each setting is correct.

Carefully lay out and drill holes for the LED, switches, binding posts, and potentiometer in the case you are using. If you are using a metal case, the binding posts must be insulated from it (binding posts come with special plastic spacers that, with the right hole size drilled in the front panel, will keep the center conductor away from the panel). Once all the panel components are mounted, make sure to clearly label the panel so you can identify voltage settings.



Here's what the adapter cables look like when completed.



The finished power supply can furnish a variety of fixed and variable voltages.

**Convenience Cable.** Because one of the intended uses for this power supply is as an AC-adapter replacement, you might want to build a custom cable to do the job. Let's look at how to do that.

Figure 2 contains the wiring connections of the custom cable. Begin by soldering a pair of banana plugs—red (positive) and black (negative)—to the leads at one end of a two-conductor wire. At the other end, attach a female coaxial jack, with the center conductor being positive.

Next make adapters for various jacks that you might want to plug the supply into (Fig. 2 shows a few examples). All the adapters have a male coaxial plug on one end for connecting to the female plug on the end of the banana cable, and some type of plug on the other end. For example, one adapter has a male coaxial plug, another a mini phono plug, and another a 9-volt battery connector. That way, anything that has a coaxial power jack, a mini-plug jack, or uses a 9-volt battery, can be powered quickly and conveniently.

*Add what's been missing to your own home-theater or audio system, or just have some fun with vocals with this neat little gadget.*



## REVERB AND SURROUND-EFFECTS GENERATOR

BY MARC SPIWAK

If it seems that you don't hear people talking about surround sound and home theater as much anymore; maybe that's because most people are now at home actually enjoying home-theater sound. As you probably know by now, real Dolby Surround Sound adds a rear channel to the traditional left and right audio channels to add more depth and realism to movies and music. It does that by decoding special information embedded within a video signal. But what you might not know is that you don't need expensive equipment just to add more depth to audio. In fact, all you have to do to add depth to audio is to add some delayed sound, preferably from behind where you are sitting.

The *Reverb and Surround Effects Generator* described in this article can add a variable time delay to a stereo audio signal or can be set up in mono-only configurations—you can use the unit with a microphone, for example, to obtain interesting reverb effects on your voice. Those with experience using reverb units will like the Effects Generator because its time delay can be varied (between zero and half a second); you can make adjustments for decay time, volume, delay rate, and reverb duration.

The circuit can be built from a kit that sells for under \$60, or from scratch, as we will present complete

plans for it in this article. The unit can be configured for line-level or microphone inputs and speaker, microphone-level, or line-level outputs.

**Circuitry.** The schematic for the Effects Generator is shown in Fig. 1. Power for the circuit is obtained from either a 9-volt battery or a 9-volt DC supply plugged into power-jack J5.

Even though the parts count isn't that large, the circuit is somewhat complex. At its heart is a fairly specialized integrated circuit, IC3, which is an MN3007 1024-stage bucket-brigade device (BBD). That IC uses a set of switched capacitors to pass charges from one "bucket" to the next on every clock cycle. In general, a signal presented to the input of a BBD will be delayed at the output, with the time delay depending on the clock rate and the number of "buckets" contained within the IC—in this case it's a 1024-stage device. When the delayed sound is fed back into the input, it has the effect of adding reverb, or an echo.

Before we go any further, it's important to note that the jumpers shown in the schematic, JU1–JU9, are not all supposed to be in place. As we'll discuss later on, the configuration of the jumpers determines what kind of set-up the unit can be used in. For the sake of this circuit description, assume that only jumpers JU5 and JU7 are in place. That's the configuration for a surround-sound reverb effect on a

stereo audio signal; the inputs are set for line-level to accommodate the signal of equipment like a stereo VCR or laser-disc player.

Now back to the circuit. The left and right inputs at jacks J1 and J2 are passed directly to the outputs at J3 and J4 via resistors R1 and R4. That allows the original signal to be heard with no delay, if you wish. Both the left and right inputs are also added together in IC1-a, an LM324 op-amp, and amplified or attenuated depending on the setting of trimmer-potentiometer R25. The output of IC1-a is fed to the input of IC3, the BBD. A MN3101 clock generator, IC2, in combination with potentiometer R16 and the surrounding components set the delay for the BBD.

Trimmer-potentiometer R33, in series with R35 and C19, lets you control the feedback level to the inputs. That level determines how long a delayed signal will be allowed to recycle through the circuit. The delayed output from IC3 is low-pass filtered by IC1-c and the surrounding components to remove the clock signal from the BBD output. Then, part of the filtered output is fed to the left channel and some of it is fed back to the input to create the reverb effect.

For the surround-sound effect, the output of IC1-c is sent to inverting-amplifier IC1-d, which generates a signal that is 180 degrees out of phase with that at the output of IC1-c. When that out-of-phase signal is fed to the right channel, it cancels some of the audio from the left channel when played through speakers. Because the can-

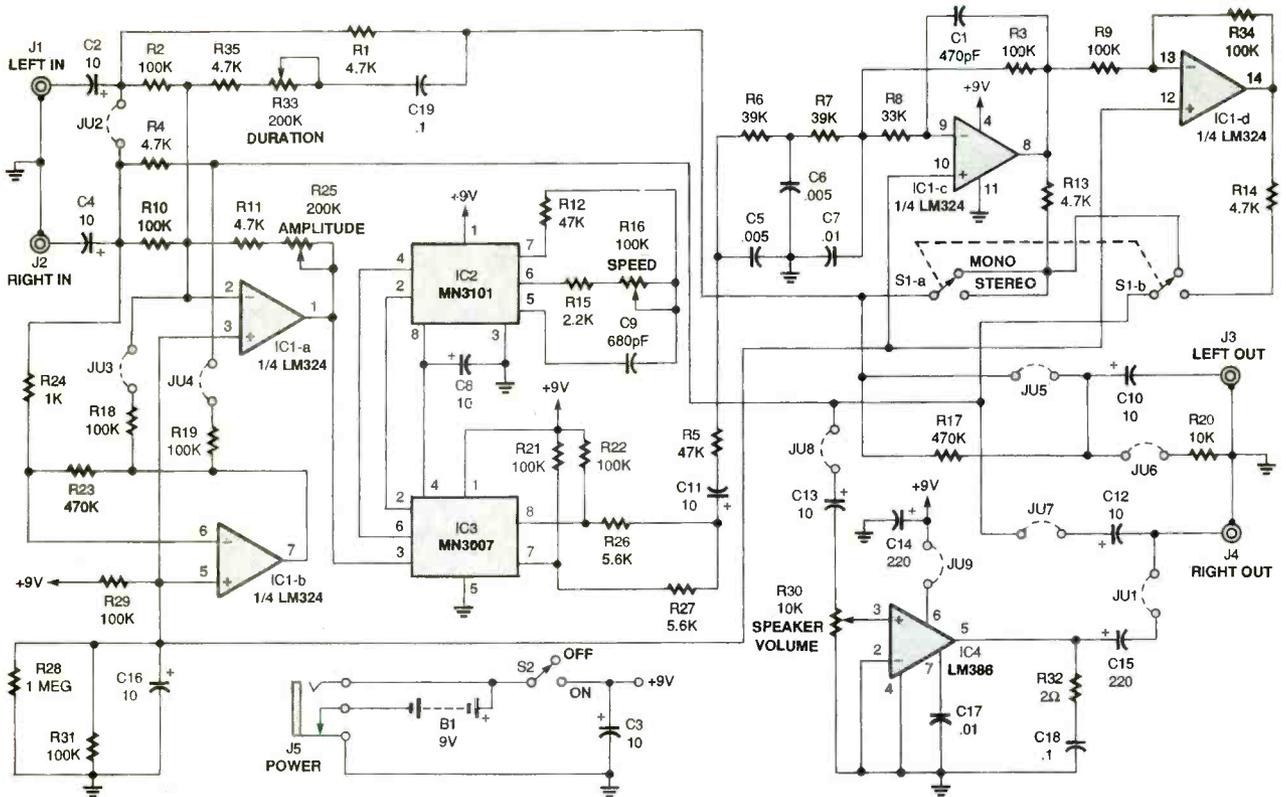


Fig. 1. Here's the schematic for the Reverb and Surround Effects Generator. The heart of the circuit, IC3, is an MN3007 1024-stage bucket-brigade device.

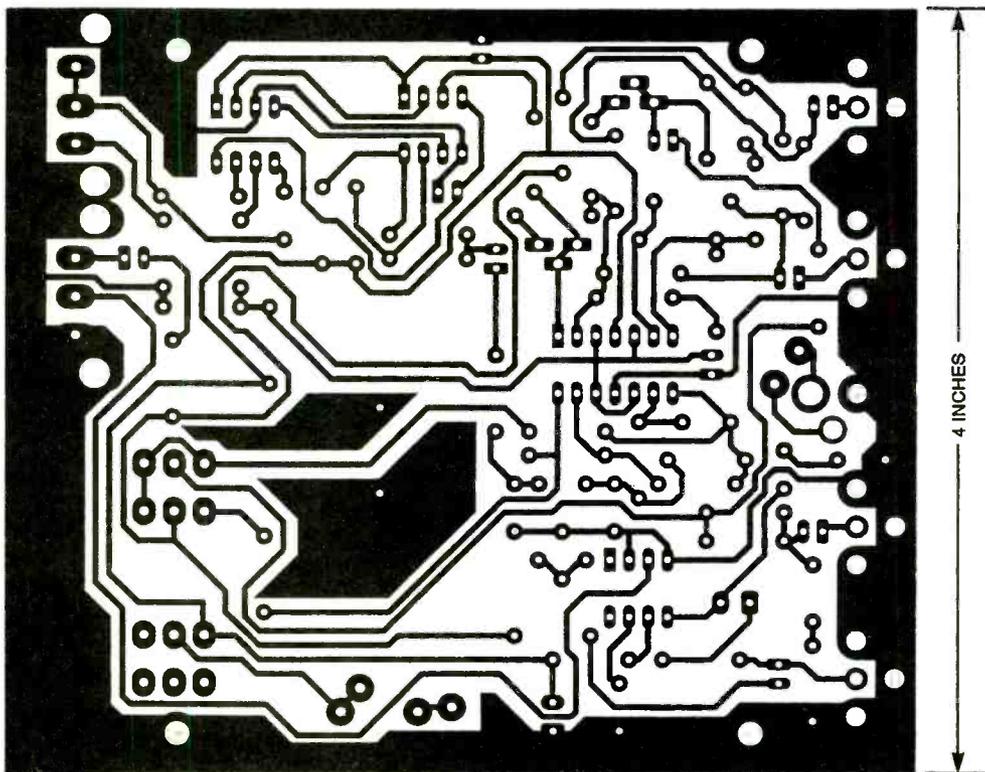


Fig. 2. If you'd like to etch your own PC board, use this full-size template.

celed audio is from the delayed sound and not the original sound, it has the effect of widening the sound

field, or making your speakers sound like they are spaced farther apart.

Switch S1 lets you select between

the surround effect, or stereo mode, and the normal effect, or mono mode, where the output from the low-

## PARTS LIST FOR THE REVERB AND SURROUND EFFECTS GENERATOR

### SEMICONDUCTORS

- IC1—LM324 quad op-amp, integrated circuit  
 IC2—MN3101 BBD clock generator, integrated circuit (Digi-Key MN3101-ND or equivalent)  
 IC3—MN3007 bucket-brigade device, integrated circuit (Digi-Key MN3007-ND or equivalent)  
 IC4—LM386 audio amplifier, integrated circuit

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

- R1, R4, R11, R13, R14, R35—4700-ohm  
 R2, R3, R9, R10, R18, R19, R21, R22, R29, R31, R34—100,000-ohm  
 R5, R12—47,000-ohm  
 R6, R7—39,000-ohm  
 R8—33,000-ohm  
 R15—2200-ohm  
 R16—100,000-ohm, potentiometer  
 R17, R23—470,000-ohm  
 R20—10,000-ohm  
 R24—1000-ohm  
 R25, R33—200,000-ohm, PC-mount trimmer potentiometer  
 R26, R27—5600-ohm  
 R28—1-megohm  
 R30—10,000-ohm, potentiometer  
 R32—2-ohm

### CAPACITORS

- C1—470-pF, ceramic-disc  
 C2—C4, C8, C10—C13, C16—10- $\mu$ F, 25-WVDC, electrolytic  
 C5, C6—0.005- $\mu$ F, ceramic-disc  
 C7, C17—0.01- $\mu$ F, ceramic-disc  
 C9—680-pF, ceramic-disc  
 C14, C15—220- $\mu$ F, 16-WVDC, electrolytic  
 C18, C19—0.1- $\mu$ F, ceramic-disc

### ADDITIONAL PARTS AND MATERIALS

#### MATERIALS

- J1—J4—RCA jack  
 J5—Power jack  
 S1—DPDT switch, PC-mount  
 S2—SPDT switch, PC-mount  
 B1—9-volt battery

Printed-circuit materials, project enclosure, battery connector, PC-mount battery holder (optional), AC-to-DC adapter (which matches power-jack J5), wire, solder, etc.

**Note:** The following items are available from Ramsey Electronics (793 Canning Parkway, Victor, NY 14564; Tel. 716-924-4560 or 800-446-2295): RV-1 Reverb Effects/Surround Sound Kit (includes all parts and PC board)—\$59.95; custom case—\$14.95.

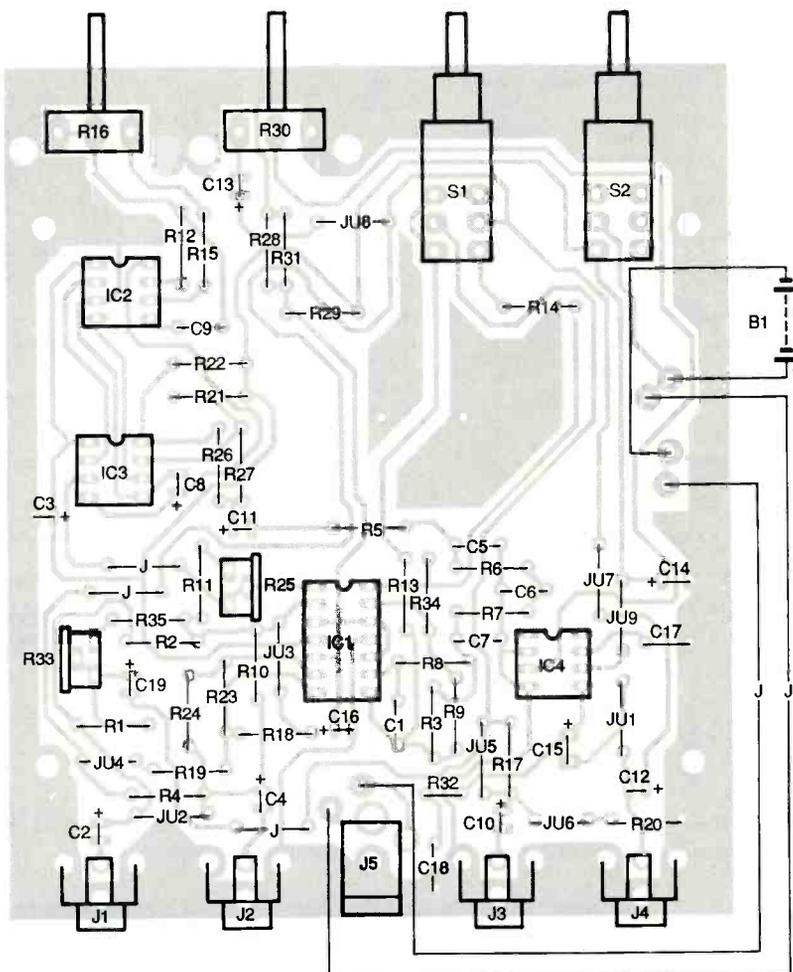


Fig. 3. Use this parts-placement diagram as a guide when assembling the board. Consult Table 1 to determine which jumpers should be installed for your particular application.

TABLE 1

Installed Jumpers									Resistors		Sound Effect	Inputs	Outputs
JU1	JU2	JU3	JU4	JU5	JU6	JU7	JU8	JU9	R1	R4			
				X		X			in	in	stereo reverb	line	line
	X			X		X			in	in	simulated stereo reverb	mono	line
X		X	X		X		X	X	in	in	mono reverb	mic	speaker
		X	X	X		X			in	in	mono reverb	mic	line
				X		X			out	out	TV surround	line	line

pass filter is fed directly to both the left and right outputs. If jumper JU2 is also installed, a mono signal can be input at J1 or J2 and a simulated stereo signal will be heard at the outputs.

For a microphone input, only jumpers JU1, JU3, JU4, JU6, JU8, and JU9 must be installed. The microphone should be plugged into J2. In that configuration the right output at J4 is a speaker-level amplified output from an LM386 op-amp (IC4) and the left

output at J3 is a microphone-level output. Potentiometer R30 controls the volume of a speaker connected to J4. Amplifier IC4 and all components between JU8 and JU9 are not used if the microphone-input option is not used.

If only jumpers JU3, JU4, JU5, and JU7 are installed, the unit will have a microphone input and a surround-effect, line-level output. If only jumpers JU5 and JU7 are installed and R1

and R4 are removed, only the delayed signal and none of the original will be present at the outputs. That is best suited for the rear channels in a television surround system.

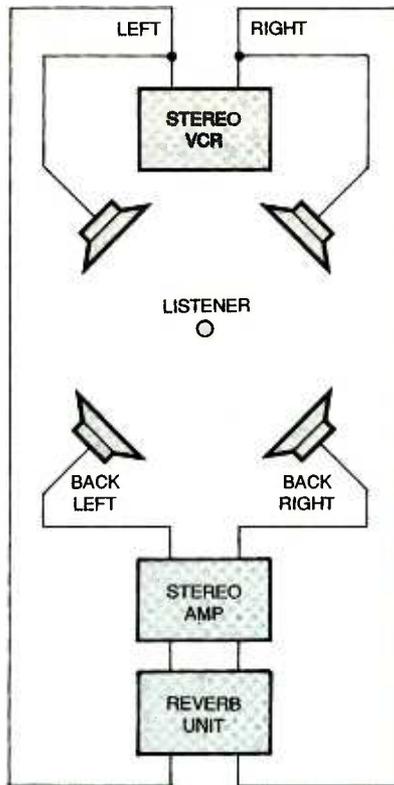
To prevent confusion regarding the preceding configuration details, refer to Table 1. It shows at a glance what jumpers to use and whether you need R1 and R4 for the various applications for this very versatile circuit.

**Construction.** Although there's no specific reason why you can't build the circuit on a perforated board using point-to-point wiring, audio projects are always better overall when done on a PC board. You can use the foil pattern shown in Fig. 2 to make your own board, or order a pre-drilled and etched board as part of the kit available from the source mentioned in the Parts List.

While all of the components are obtainable from hobbyist sources, you might be best off buying the unit as a kit because two of the ICs alone, the BBD and its associated clock generator, will cost you more than \$10; those two devices are relatively obscure and not likely to be found in even the most well-stocked "junk box." Add in the rest of the parts and the cost and time involved in making a PC board, and the kit price of \$59.95 seems more and more attractive.

On the other hand, if you have access to a hoard of parts, and only need to buy the BBD and the clock generator, you might want to simply get those two ICs. They're available from Digi-Key (Tel. 800-DIGI-KEY) as well as other hobbyist sources.

Assuming you decide to build the circuit on a PC board as suggested,



*Fig. 4. If you would like to set the unit up for surround effects, feed it a stereo signal and amplify the resulting output with a stereo amplifier.*

an appropriate parts-placement diagram is shown in Fig. 3. Begin by installing the fixed resistors, except for R1 and R4. Then go on to mount the capacitors, making sure the electrolytic ones are oriented properly.

Mount the potentiometers, switches, and jacks next. Then solder the battery connector leads to the board. The kit also comes with a holder for a 9-volt battery; solder that in place next if you have it. You can then install the four ICs.

To complete the assembly, you will have to decide which jumpers to install and whether to add resistors R1 and R4. Those decisions depend on your intended application. Again, refer to Table 1 for configuration details. **Note:** Regardless of your application, all of the *un*-numbered jumpers shown in Fig. 3 must be installed!

If you are using point-to-point wiring, you will need to make connections in the circuit that reflect your particular configuration of choice. In other words, if JU1 is called for, make sure C12 is connected to C15 in your circuit, etc. Also, remember that this is an audio project and that leads should be kept as short as possible and that inputs and outputs must be shielded.

The finished board can be mounted in the case of your choice or in the custom one available from the source mentioned in the Parts List. That case comes complete with matching knobs.

Before shutting the case, you can set R25 and R33 to their minimum resistance. That will provide your unit with the greatest duration and amplitude. You can of course experiment with those trimmer settings as well.

**Setups.** As mentioned earlier, the Effects Generator is basically intended for stereo surround effects, stereo simulation from a mono source, and vocal reverb effects. During assembly, you had to configure the board as appropriate for your intended application. Let's now look at the external connections that are necessary for each of those.

Figure 4 shows how to set up the unit for surround effects. The Effects Generator should be fed with a stereo signal and its outputs amplified by a stereo amplifier. You could also connect the unit directly to a pair of amplified speakers.

To connect the unit for stereo simulation from a mono source, input the mono signal at either J1 or J2. Simulated stereo outputs are then available at J3 and J4.

To set up the unit for vocal effects, input the microphone signal to J2. That signal is both delayed and amplified by the unit, and a microphone-level output is available at J3. You can plug a speaker into J4 to make use of the amplified output. ■



*The finished unit can be housed in this attractive custom case, which is available from the source given in the Parts List.*

One of the greatest benefits to being an electronics hobbyist is that you can build equipment you need rather than spending a lot of money to buy it. A great example of such a money-saving, do-it-yourself project is the Adaptable DTMF Tone Pad described in this article; it can be built for about \$20 (that's a fraction of the cost of commercial units). The Tone Pad can generate all 16 standard DTMF tone pairs (0–9, \*, #, A, B, C, and D), will automatically key a connected transceiver whenever any key is pressed, and contains a built-in monitor amplifier and speaker that allows the actual tone pairs to be heard as they are transmitted.

**Circuit Description.** The schematic diagram for the DTMF Tone Pad is shown in Fig. 1. An input 12-volts DC (which can most likely be provided by a transceiver) is regulated by transistor Q1, resistor R1, and Zener-diode D2 to provide the circuit with a 5-volt supply.

A telephone-type keypad, KPD1, is used to enter a desired DTMF tone. When a button is pressed, a column and a row of the keypad are both connected to ground. Then, a TP5089N DTMF dialer (IC1), in conjunction with a 3.58-MHz color-burst crystal (XTAL1), generates the corresponding tone.

Switch S1 makes it possible to select all 16 DTMF tone pairs with the 12-button keypad, KPD1. When S1 is in the NORM (normal) position, column 3 on the keypad operates normally. But when S1 is placed in the exp (expanded) position, DTMF tone pairs representing "digits" A, B, C, and D are generated in place of digits 3, 6, 9, and #, respectively.

When any key is pressed, pin 10 on IC1 goes low. That low is applied to the base of transistor Q2 through resistor R3, and causes 5 volts to appear at Q2's collector. Then, LED1 lights and, at the same time, transistor Q3 turns on via diode D3, which then keys the transceiver.

Resistor R5 and capacitor C3 create a short time delay that keeps the transceiver keyed between dialed digits. That keying circuit is compatible with the majority of modern transceivers using electronic switching. If the Tone Pad is used with a transceiver that uses relay switching, a spike-suppression diode (D5) should

# The Adaptable DTMF TONE PAD



*It's an affordable way to add a DTMF keypad to your current transceiver.*

BY BRIAN PLILER

be added as shown in Fig. 1. That will prevent damage from occurring to transistor Q3.

The DTMF tone output from IC1 is coupled to trimmer-potentiometer R7, which controls the amplitude of

the transmitted DTMF tones. Transistor Q4 operates as a buffer amplifier with an output impedance of approximately 500 ohms (that allows for direct connection to the microphone input on most transceivers). If the transceiver used with the Tone Pad has an input impedance that is greater than 500–600 ohms, the value of R10 must be changed accordingly.

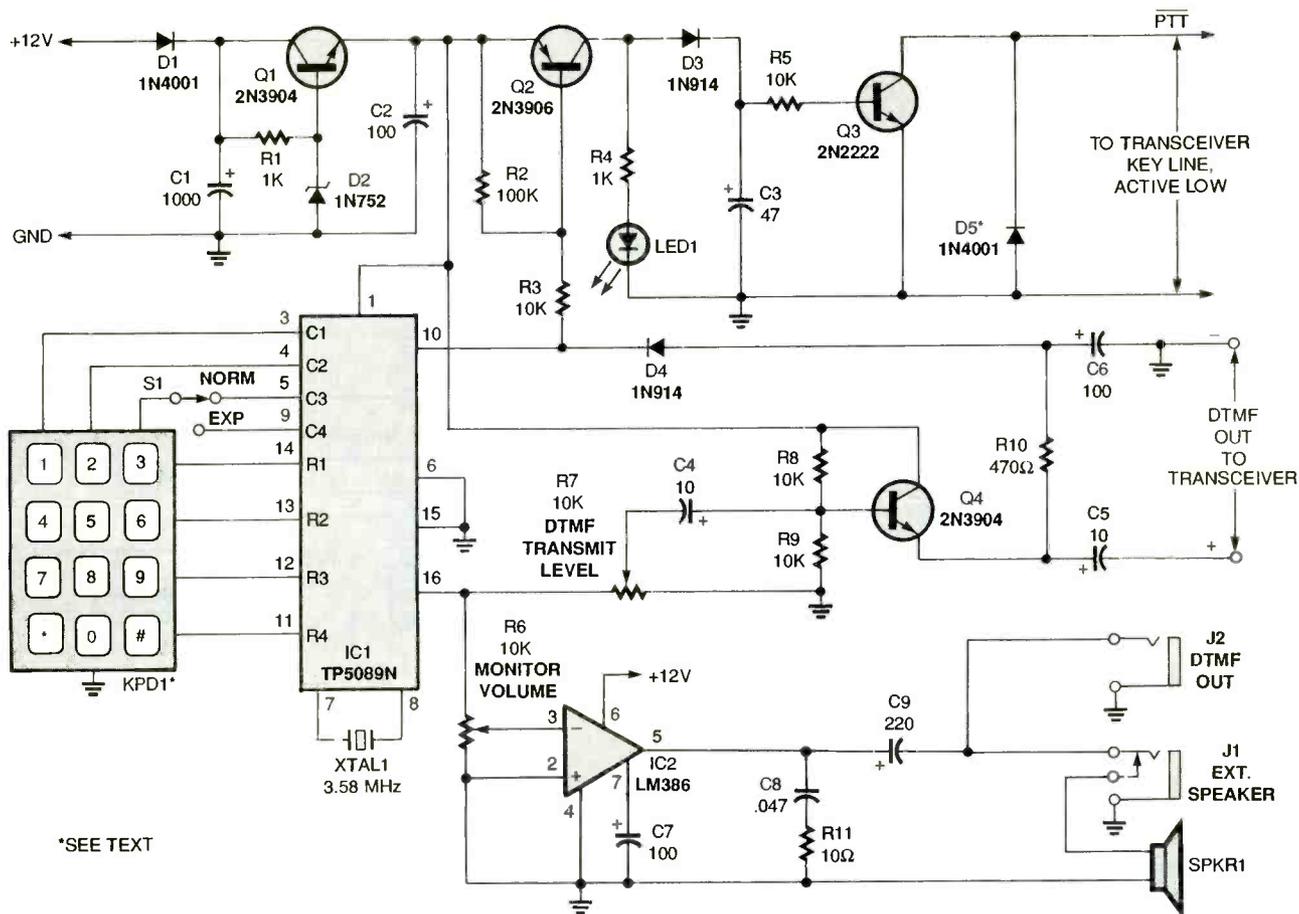
Note that resistor R10 is not connected directly to ground, but to the anode of diode D4 and to capacitor C6 instead. That allows the buffer amplifier to be disabled when it is not needed. Recall that pin 10 on IC1 goes low when any key is pressed. That low pulls R10 low via diode D4 and discharges capacitor C6, thereby allowing the buffer amplifier to operate. As soon as the key is released, pin 10 on IC1 goes high, C6 charges, and the buffer amplifier is disabled once again.

The DTMF tone output from IC1 is also coupled to trimmer-potentiometer R6, which controls the unit's monitor volume. An LM386 audio amplifier, IC2, changes the low-level DTMF output from IC1 into a signal suitable for driving speaker SPKR1. Switching-jack J1 is wired so that when a plug is inserted, SPKR1 is disconnected and audio comes from the jack. Jack J2 provides speaker-level audio without silencing SPKR1.

**Construction.** The author's prototype was assembled on a small section of perforated board using point-to-point wiring. However, if you'd like to build the project on a printed-circuit board, you can use the foil pattern shown in Fig. 2 to etch and drill one. For those building the project on a printed-circuit board, a parts-placement diagram is provided in Fig. 3.

To make assembly of the tight circuit board easier, it is recommended that you mount low-profile parts first. Begin with sockets for IC1 and IC2. Next, install the jumper wires and resistors (mount R2, R4, R9, and R10 vertically), followed by the two trimmer potentiometers. Continue by adding the diodes, being sure to check their polarity (as mentioned earlier, whether or not D5 is installed depends on the type of transceiver you plan on using with the Tone Pad).

Go on to solder the capacitors next,



\*SEE TEXT

Fig. 1. This is the schematic for the DTMF Tone Pad. Switch S1 makes it possible to get 16 DTMF tones from a 12-digit keypad, KPD1. Just set S1 to EXP and digits 3, 6, 9, and # will produce tones A, B, C, and D, respectively.

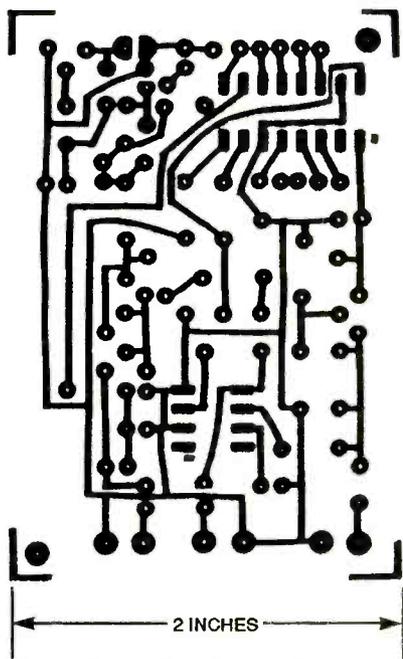


Fig. 2. Here's the full-size foil pattern for the Tone Pad PC board.

noting the polarity of the electrolytic units. Then install the transistors, being

sure to orient them as shown in the parts-placement diagram. Before continuing with assembly, double check all connections and perform the following two tests:

Apply power to the board to confirm that the 5-volt regulator circuitry is operating correctly. Capacitor C2 should be supplying +5 volts. If that voltage is missing, ensure that diodes D1 and D2 are installed correctly. After you confirm that the regulator circuitry is working properly, temporarily connect LED1 to its pads on the board, and use an insulated jumper wire to temporarily ground the junction of resistor R3 and diode D4. As long as that jumper is held in place, LED1 should stay lit.

Disconnect the power source you just used from the board before continuing with assembly. Solder wires to the circuit board to facilitate the off-board connections to the keypad, jacks, switch, speaker, and LED. Also, solder long wires to the points on the board that will go to power and trans-

ceiver connections. Then insert IC1 and IC2 into their respective sockets to complete the on-board assembly.

Mount the 12-digit keypad to the enclosure you will use. If you have a difficult time buying a suitable keypad locally, you can do one of the following: First, try salvaging a keypad from an existing piece of telephone equipment (the keypad in the author's prototype came from a non-working cordless telephone). If that fails, try ordering one from Alitronics Corp. (2300 Zanker Road, San Jose, CA 95131), Electronic Goldmine (PO. Box 5408, Scottsdale, AZ 85261), Electronix Express (365 Blair Road, Avenel, NJ 07001), or MECI (340 East First Street, Dayton, OH 45402). Write and ask for a catalog from one or all of those sources.

Another option is to make your own keypad, although the amount of parts and effort required might make finding a pre-existing keypad seem more desirable. To make a keypad of your own, wire normally open, SPST

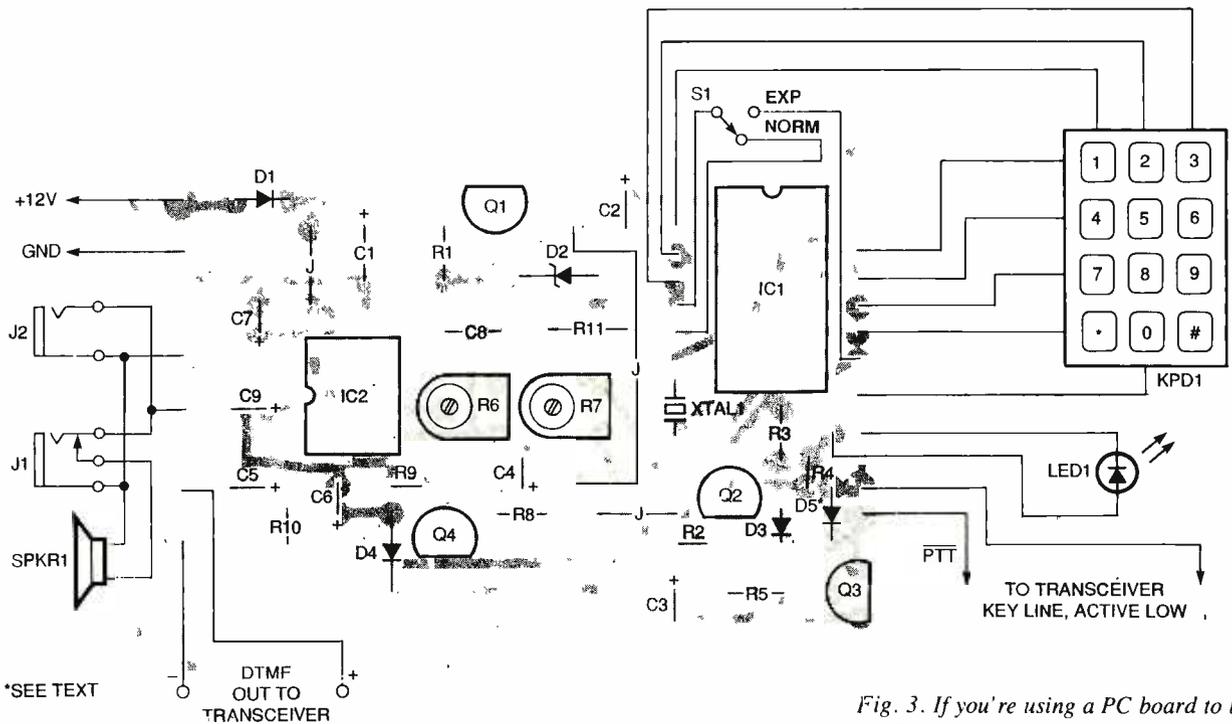


Fig. 3. If you're using a PC board to build the Tone Pad, this parts-placement diagram should make assembly easy.

### PARTS LIST FOR THE VERSATILE DTMF TONE PAD

#### SEMICONDUCTORS

IC1—TP5089N, TCM5089N, LR4089, or ECG1690 DTMF dialer, integrated circuit (Digi-Key TP5089N-ND or equivalent)  
 IC2—LM386 low-power audio amplifier, integrated circuit  
 Q1, Q4—2N3904 general-purpose NPN transistor  
 Q2—2N3906 general-purpose PNP transistor  
 Q3—2N2222 general-purpose NPN transistor  
 D1—1N4001 silicon rectifier diode  
 D2—1N752 Zener diode  
 D3, D4—1N914 general-purpose silicon diode  
 D5—1N4001 silicon rectifier diode (optional, see text)  
 LED1—Light-emitting diode, red

#### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)  
 R1, R4—1000-ohm  
 R2—100,000-ohm  
 R3, R5, R8, R9—10,000-ohm  
 R6, R7—10,000-ohm trimmer potentiometer, PC-mount (Digi-Key D4AA14-ND, Circuit Specialists, Inc., P.O. Box 3047, Scotts-

dale, AZ 85271-3047; 1-800-528-1417.)  
 R10—470-ohm  
 R11—10-ohm

#### CAPACITORS

C1—1000- $\mu$ F, 16-WVDC, electrolytic  
 C2, C6, C7—100- $\mu$ F, 16-WVDC, electrolytic  
 C3—47- $\mu$ F, 16-WVDC, electrolytic  
 C4, C5—10- $\mu$ F, 16-WVDC, electrolytic  
 C8—0.047- $\mu$ F, Mylar  
 C9—220- $\mu$ F, 16-WVDC, electrolytic

#### ADDITIONAL PARTS AND MATERIALS

XTAL1—3.58-MHz color-burst crystal  
 J1—3.5-mm switching panel-mount jack, normally closed  
 J2—3.5-mm panel-mount jack  
 KPD1—12-button telephone keypad (3  $\times$  4 matrix with common)  
 SPKR1—8-ohm, 0.2-watt, 2-inch diameter speaker  
 S1—SPDT miniature toggle switch  
 Printed-circuit materials, project enclosure, IC sockets, rub-on labels, clear lacquer, wire, solder, hardware, etc.

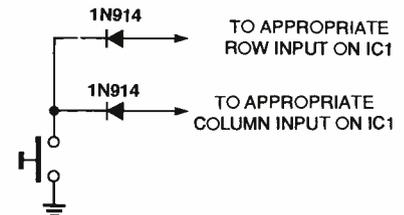


Fig. 4. This diagram shows you how to wire switches and diodes for use instead of KPD1 in the circuit.

circuit board as shown in Fig. 3. Then, before mounting the circuit board, reapply power and make sure that the unit operates properly. Pushing a button on KPD1 should result in a tone being heard from SPKR1. If that is not the case, recheck your connections. Adjust trimmer-potentiometer R6 at this time to vary the speaker volume. Then, set the transmission-level potentiometer, R7; about halfway should be fine for now, although you might want to change it after you've used the unit with your transceiver.

When the project is working, mount the board, close up the enclosure, and prepare to label it. Labels are necessary to prevent confusion as to which jack is which, and to make it easier to remember which setting of S1 will yield the expanded tones. The author used rub-on labels and  
*(Continued on page 104)*

pushbutton switches as shown in Fig. 4. Note that each "digit" will require one switch and two 1N914 diodes.

Once you have mounted the key-

pad, go on to mount the jacks, switch, speaker, and LED to the enclosure. Make the connections between all those off-board components and the

# SMART STRIP



*It lets you turn on up to three devices just by powering up another one.*

**W**atching TV these days often involves a tiresome routine of flipping on switches, scrambling for remote controls, and turning on accessories. A similar ritual is performed by computer users each time they want to power up their systems and peripherals.

Although most power strips feature a power switch, plugging everything in to an ordinary outlet strip has some unfortunate drawbacks. First of all, placing the strip in a place where the switch can be easily reached usually means that the strip will also be easily seen. And who wants to look at an ugly mess of wires?

Another problem, in the case of connecting all your TV equipment to one strip, is that disconnecting power from a VCR will clear any timer preset programs and reset the clock to that annoying, blinking "12:00." Furthermore, even when remote-control devices are plugged into an outlet strip, the strip must still be turned on manually.

What can you do to avoid all those problems? The answer is simple: Build the *Smart Strip* described in this article. It solves power-control problems by "sensing" when one device is powered on, and automatically turning on the other devices plugged in to it!

For example, a VCR can be plugged into the "sense" outlet of the Smart Strip, and a TV, home-theater system, and cable box can be plugged into the "switched" outlets. The VCR would retain its clock setting and programs, and all of the other plugged-in devices will come on together just by turning on the VCR. Computer equipment can also be easily controlled. A monitor, printer,

**BY RODRICK SEELY**

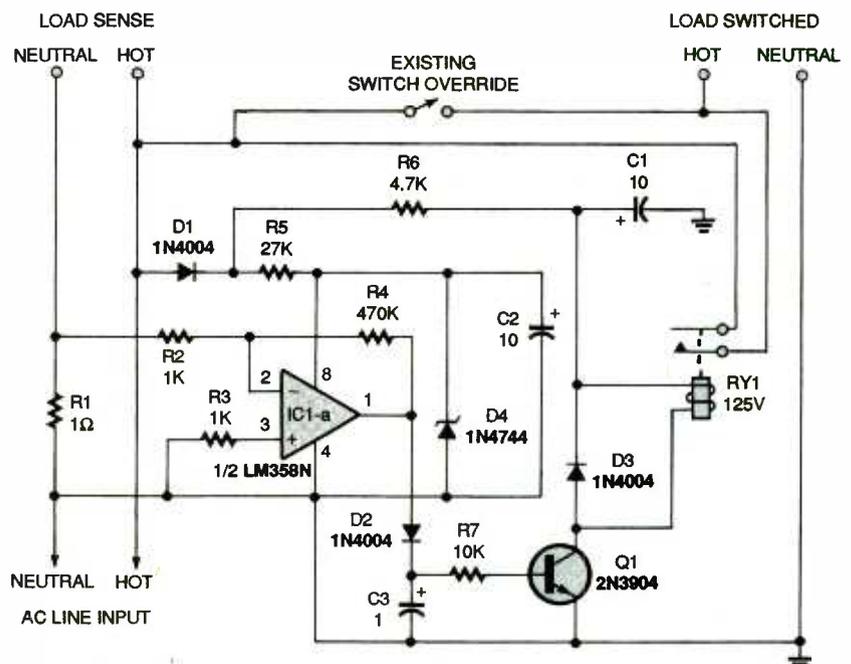
and external modem could all come on just by turning on the computer.

**Circuit Description.** The schematic of the Smart Strip circuit is shown in Fig. 1. The "AC line input" is connected directly to the 117-volt-AC line of a power strip. That voltage is rectified by diode D1 and filtered by capacitor C2.

The "load-sense" lines are connected to the AC socket in the power strip that will contain the device that will be used to turn the others on. When the load-sense device is turned on, current flows through R1, a 0.1-ohm, 10-watt resistor. The power in R1

is equal to the resistor's value multiplied by the current squared. To limit the power in R1 to 5 watts, therefore, a maximum load of no more than 5 amps should be connected to the load-sense outlet. The resulting voltage drop across R1 is fed to one section of an LM358N op-amp, IC1-a, through resistors R2 and R3. Zener-diode D4 limits the supply for the op-amp to 15-volts DC.

The voltage drop across R1 could be very small if the device plugged into the load-sense socket does not draw much current. To ensure that the circuit is sensitive enough to detect such small-load devices, the gain of IC1-a is set at 470 by resistors R2 and R4. To make the circuit less sensitive, R4 should be a lower value.



*Fig. 1. Here's the schematic diagram for the Smart Strip. When a device connected to the load-sense lines is turned on, the circuit powers up any devices connected to the load-switched lines.*

Because the output of IC1-a is half-wave rectified, diode D2 and capacitor C3 are used to form a peak-hold circuit. As long as C3 is charged to 0.7 volt or more (when a powered-up load-sense device is detected), transistor Q1 will be on, and relay RY1 will close. When those normally open contacts close, the "hot" line is connected to the "load-switched" sockets, effectively turning on any devices that are connected to those outlets. Diode D1, resistor R6, and capacitor C1 provide a DC supply for the 12-volt coil of the relay; diode D3 acts as a clamping diode.

**Construction.** Let's begin our discussion of building the Smart Strip with a **warning:** Because the circuit connects directly to 117-volts AC, extreme care should be taken in its assembly and use. Be sure to observe all safety

### PARTS LIST FOR THE SMART STRIP

#### SEMICONDUCTORS

IC1—LM358N dual op-amp, integrated circuit

Q1—2N3904 NPN transistor

D1—D3—1N4004 silicon rectifier diode

D4—1N4744, 15-volt, 1-watt Zener diode

#### RESISTORS

(All resistors are 1/4-watt, 5% units unless otherwise specified.)

R1—0.1-ohm, 10-watt

R2, R3—1000-ohm

R4—470,000-ohm

R5—27,000-ohm, 1/2-watt

R6—4700-ohm, 2-watt

R7—10,000-ohm

#### CAPACITORS

C1—10- $\mu$ F, 100-WVDC, electrolytic

C2—10- $\mu$ F, 35-WVDC, electrolytic

C3—1- $\mu$ F, 35-WVDC, electrolytic

#### ADDITIONAL PARTS AND MATERIALS

RY1—SPST relay; 12-VDC coil; 10-ampere, 125-VAC contacts (Aromat JS1E-12 or equivalent)

Printed-circuit materials, six-socket power strip, 1/4-inch nylon spacers, wire, solder, hardware, etc.

**Note:** The following is available from Lynn-Eren Electronics (17093 SW Lynnly Way, Sherwood, OR 97140; Tel. 503-625-2205): pre-etched and drilled PC board—\$15. MasterCard, VISA, Check, or Money Order accepted.

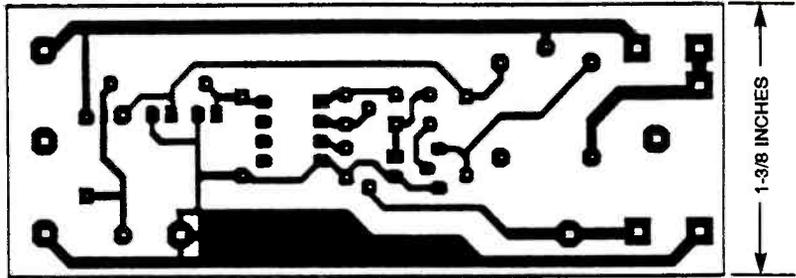


Fig. 2. If you'd like to etch your own PC board, use this full-size foil pattern.

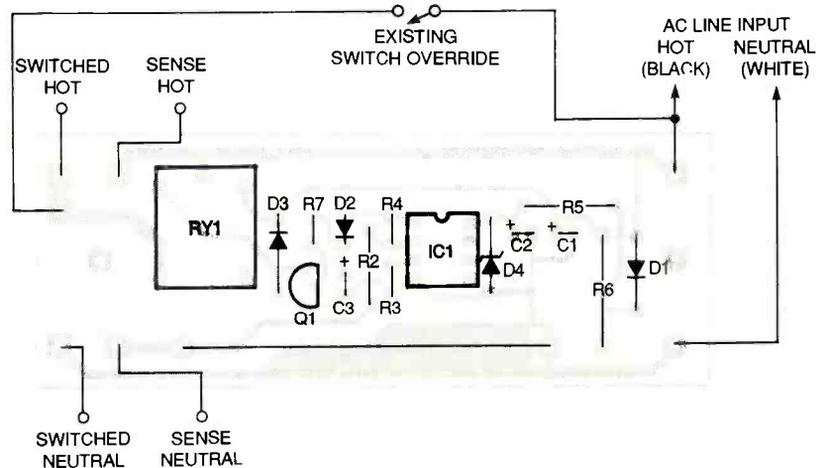


Fig. 3. When installing components onto the PC board, use this parts-placement diagram as a guide.

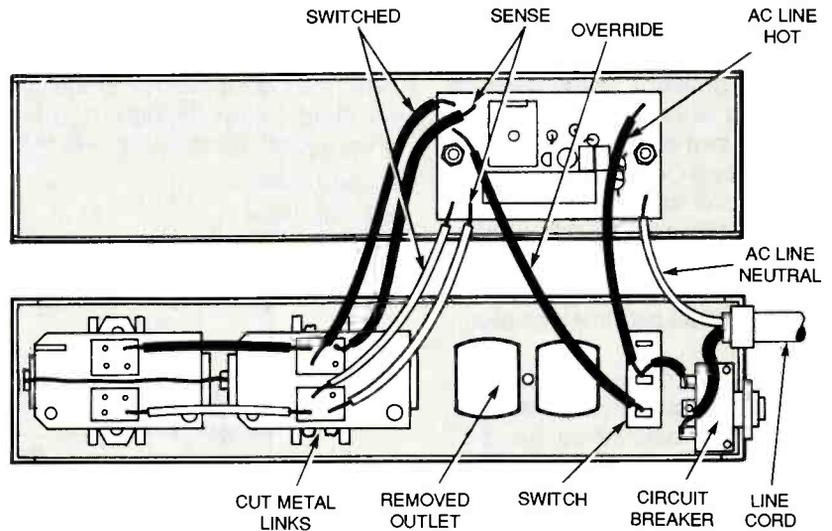


Fig. 4. This diagram shows all the wiring connections you need to make to install the circuit board in a power strip.

precautions that are appropriate when working with 117-volt AC circuits.

The prototype was built on a PC board. That project-building method is recommended to keep the circuit compact enough to fit in a power strip. You can either etch your own board using the pattern shown in Fig. 2, or buy a pre-etched board from the source mentioned in the Parts List.

Use the parts-placement diagram shown in Fig. 3 to make assembling the board easier. Begin by mounting the resistors, then go on to install the capacitors. Be sure to check the polarity of the latter.

Continue by soldering the diodes and transistor to the board, making sure they are oriented properly. Next

(Continued on page 108)

This simple device down-converts signals in the 800- to 950-MHz band so that an ordinary scanner can “hear” them.

# SCANNER CONVERTER



BY MARC SPIWAK

Every day we are bombarded with communications signals on numerous different frequencies. And many people take advantage of those signals—some people use them to communicate with others, while other people simply listen to the signals as a form of entertainment.

The common scanner can receive many different frequencies, but some frequencies, specifically from 800 to 950 MHz, are out-of-reach for most scanners. Police, fire, and other services communicate within that band. Sometimes certain signals are out of a scanner's reach because of physical limitations of the electronics, and other times the signals are deliberately “blocked,” or the scanner is programmed *not* to receive them. One reason for that could be that certain signals are not supposed to be accessible. For example, it is illegal to tap into cellular telephone transmissions which also happen to exist between 800 and 950 MHz.

The Scanner Converter presented in this article down-converts signals between 800 and 950 MHz by 400 MHz, so that ordinary scanners can receive them between 400 and 550 MHz. You can get all the parts needed to build the Converter as a kit (see the Parts List for supplier information), or you can build the circuit from scratch. We don't recommend the latter, however, and we'll say more about why later.

But no matter where you get the parts to build the circuit, the best thing about the Converter is that there are no calibration or alignment procedures whatsoever. Power it up and it should work.

**Basic Theory.** When signals approach 1 GHz (gigahertz, or one-billion hertz), special considerations must be taken into account in the design and construction of a circuit that will receive them. Fortunately for us, the most critical part of the Converter circuit is the PC board itself, and if the right parts are soldered onto it, it should then work properly right off the bat.

As shown in Fig. 1, the basic theory behind the Scanner Converter circuit is to mix input signals (A) with a 400-MHz local-oscillator frequency (B). The output of the mixer is then the sum (A + B) and difference (A - B) frequencies. With a 400-MHz local oscillator, the difference frequencies of signals

## WARNING!

Please note that unauthorized wire and electronic communications interception and interception of oral communications is illegal under Federal and State Law. In addition Federal law renders illegal the intentional manufacturing, assembling, possessing or selling any electronic, mechanical or other device, knowing or having reason to know that the design of such device renders it primarily useful for the purpose of surreptitious interception of wire, oral or electronic communications. Federal law imposes both civil and criminal penalties for violations of the applicable statutes. Thus, the use of the Scanner Converter described in this article is intended for and should be restricted to educational, scientific and/or informational purposes. This is not intended to constitute legal advice and readers are advised to obtain independent advice as to the propriety of their use thereof based upon their individual circumstances and jurisdictions.

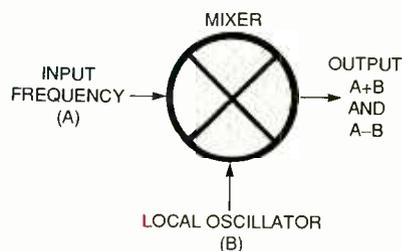


Fig. 1. The basic theory behind the Scanner Converter circuit is to mix incoming signals (A) with a 400-MHz local-oscillator frequency (B). The output is the sum (A + B) and difference (A - B) frequencies.

between 800 and 950 MHz end up being between 400 and 550 MHz. That allows the frequencies to be received with just an ordinary scanner.

**Circuit Description.** Figure 2 is the schematic of the Converter. The circuit can be powered from any 9- to 12-volt DC source, including a good alkaline 9-volt battery. Switch S1 either puts the unit into its bypass mode, where a scanner connected to J3 will receive its normal signals, or it applies power to the circuit and down-converts all 800- to 950-MHz signals as follows:

At the heart of the circuit is OSC1, a 40-MHz oscillator module. Transistor Q1 amplifies the oscillator's output, which is then bandpass filtered four times so that only the tenth harmonic at 400 MHz is presented to the input of U1, a Mini Circuits MAR1 wideband UHF/VHF amplifier.

Signals from an antenna connected to J2 are high-pass filtered by capacitors C4-C7 in conjunction with inductors L2-L4. Those inductors are etched into the tracings on the PC board, making the exact PC board

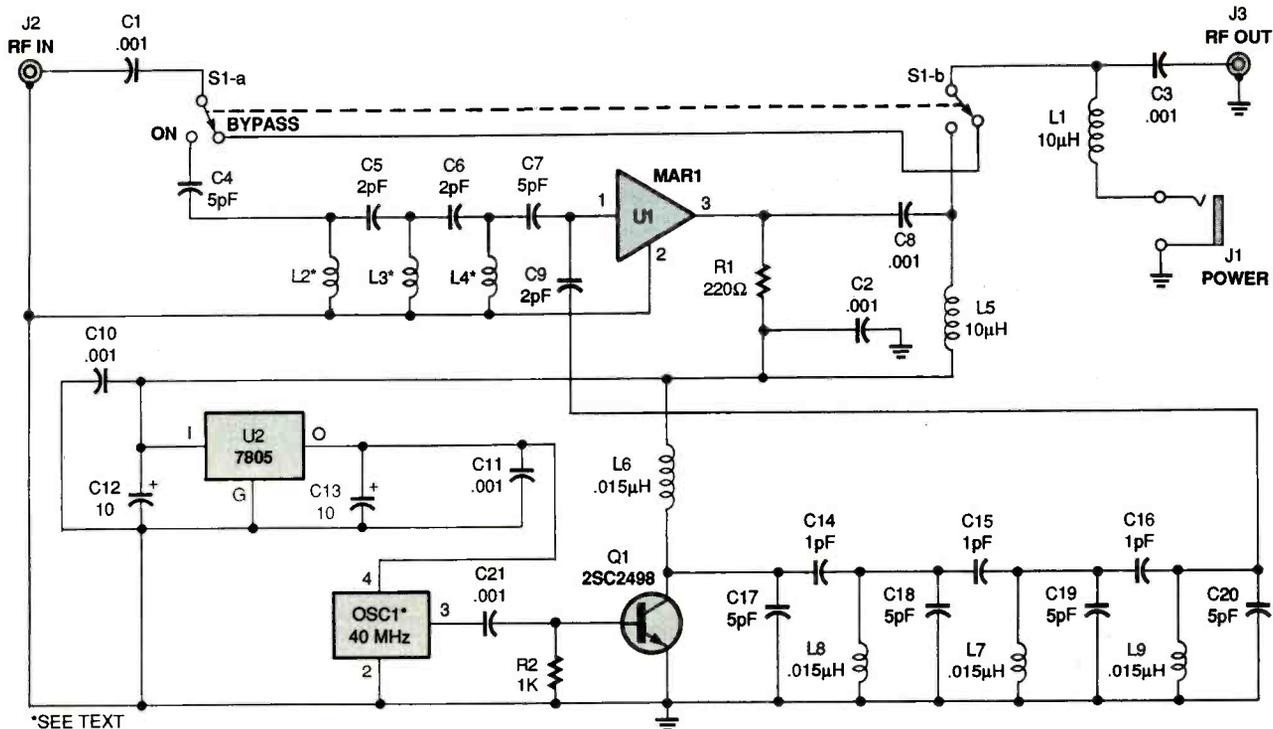


Fig. 2. At the heart of the Converter circuit is OSC1, a 40-MHz oscillator module. Only the 10th harmonic at 400 MHz is presented to the input of U1.

layout a necessary part in order for the circuit to function (in other words, as we will deal with later, the circuit cannot be wire wrapped). Mixer U1 amplifies and mixes the two inputs—signals between 800 and 950 MHz and the 400-MHz local oscillator—and passes the 400- to 550-MHz output to J3.

**Construction.** The main thing to consider when building this project is the PC board. In order to design a circuit to operate at such high frequencies, and require nothing in the way of alignment, certain components, namely inductors etched onto the PC board itself, must be of exact values. That is known as stripline construction, and it is the only suitable method for building this project. For that reason, the circuit cannot be made using point-to-point wiring or wire-wrapping.

If you are skilled at making your own PC boards, then you can probably make the double-sided one for this project as we have provided the foil pattern for the solder side of the board in Fig. 3 and the one for the component side in Fig. 4. The component side is plated and acts as a ground plane.

Note the size of the circular white areas in the Fig. 4 pattern. While some

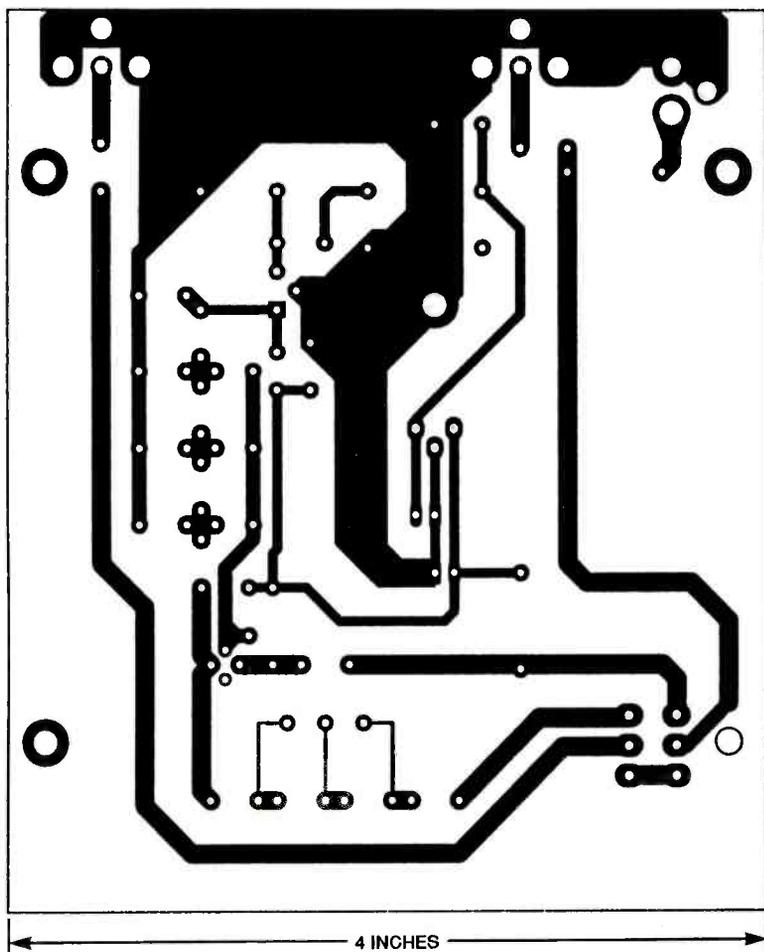


Fig. 3. This is the solder side of the double-sided board. Three of the components, L2-L4, are stripline parts that are etched into the board.

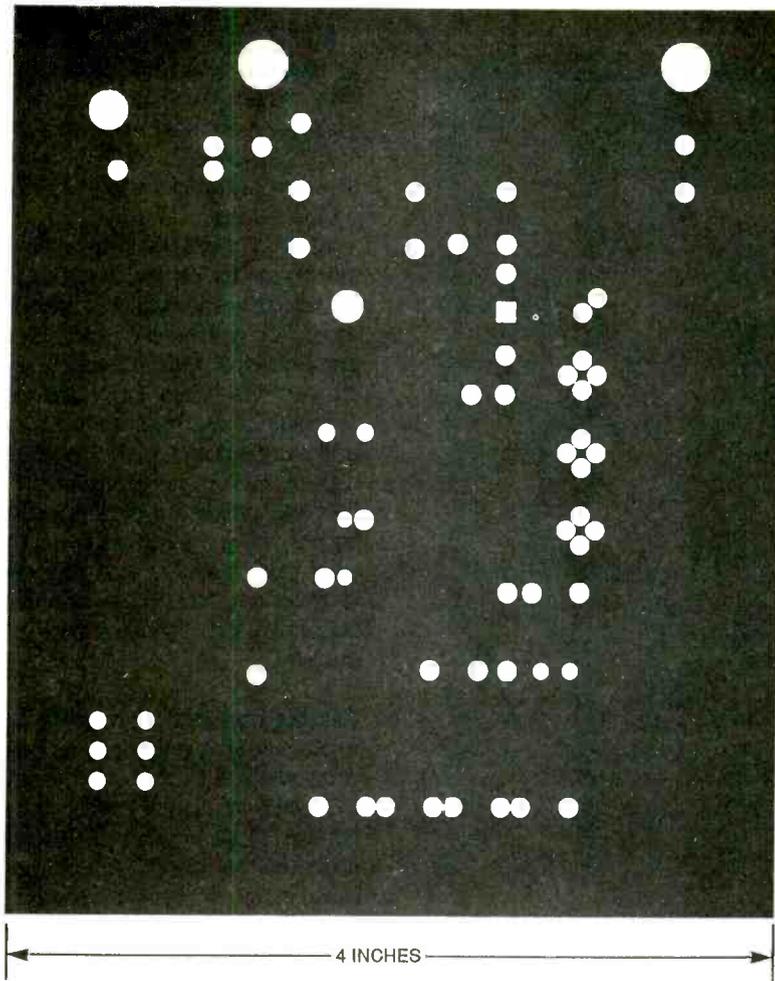
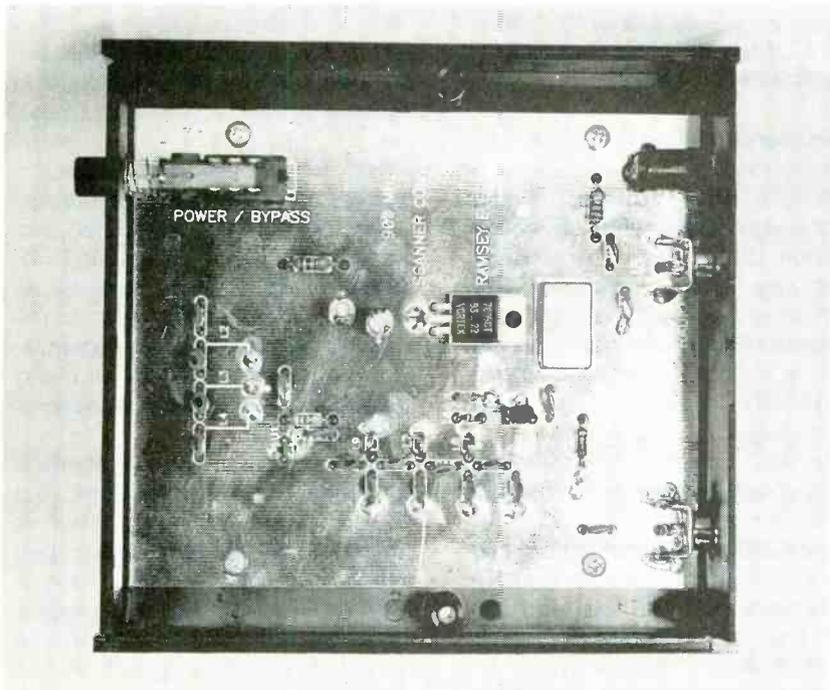


Fig. 4. Here's the component side of the board: it's really just a ground plane with circular etched areas.



Here's a view of the board showing that the entire top surface is a ground plane. The board also contains, on its other side, three stripline inductors, which makes the use of a PC board for this project mandatory.

## PARTS LIST FOR THE SCANNER CONVERTER

### SEMICONDUCTORS

- U1—MAR1 wideband MMIC amplifier (Mini Circuits, see text)
- U2—7805 5-volt regulator
- Q1—2SC2498 NPN transistor

### CAPACITORS

- C1—C3, C8, C10, C11, C21—0.001- $\mu$ F, ceramic-disc
- C4, C7, C17—C20—5-pF, ceramic-disc
- C5, C6, C9—2-pF, ceramic-disc
- C12, C13—10- $\mu$ F, 25-WVDC, electrolytic
- C14—C16—1-pF, ceramic-disc

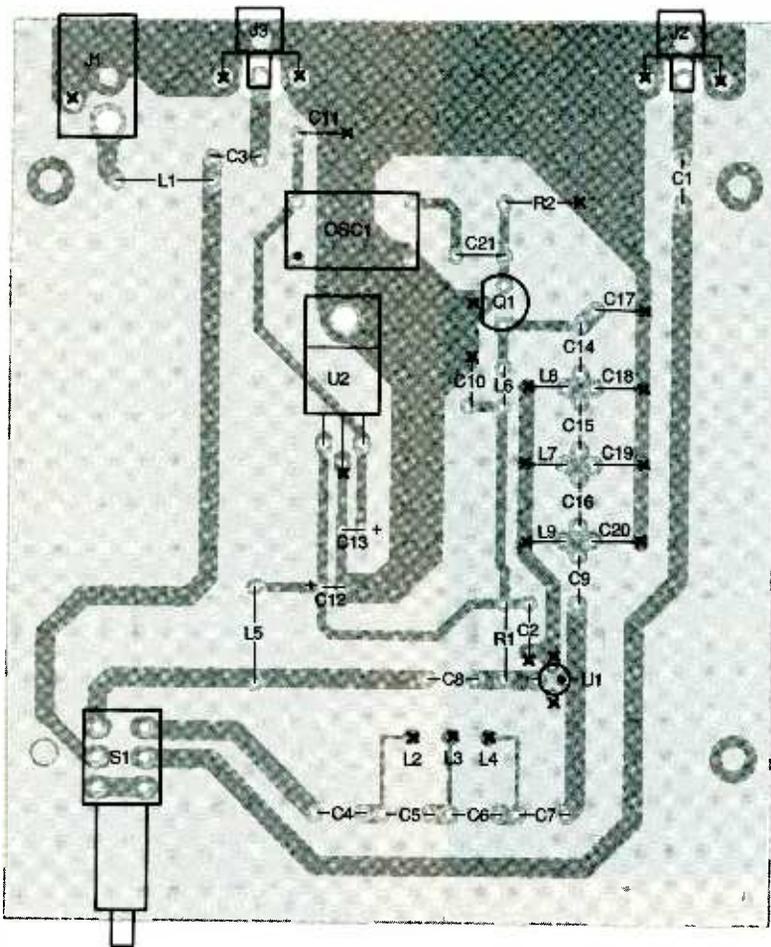
### ADDITIONAL PARTS AND MATERIALS

- R1—220-ohm, 1/4-watt, 5% resistor
  - R2—1000-ohm, 1/4-watt, 5% resistor
  - L1, L5—10- $\mu$ H axial inductor
  - L2—L4—Stripline inductor, see text
  - L6—L9—0.015- $\mu$ H (see text)
  - OSC1—40-MHz oscillator module (Digi-Key part number CTX-120-ND or equivalent)
  - J1—2.5-mm power jack
  - J2, J3—PC-mount RCA jack
  - S1—DPDT pushbutton switch
- Printed-circuit materials, project enclosure, 9- to 12-volt DC supply, wire, solder, hardware, etc.

**Note:** The following items are available from Ramsey Electronics, Inc. (793 Canning Parkway, Victor, NY 14564, Tel. 716-924-4560):  
 SCN-1 Scanner Converter kit—\$49.95; matching case set—\$14.95; assembled and tested SCN-1 with matching case—\$89.95. Shipping and handling is \$4.95. New York residents please add appropriate sales tax.

of the component leads must be soldered on both sides of the board, any lead that does not get soldered to both sides must not make contact with the top ground plane; the large white areas are what make that possible. Therefore, if you are making your own board, you will have to make sure that the holes you drill through the solder side fall into the center of the circular etched areas on the component side.

Leads that must be soldered on both sides of the board are indicated by an "X" in the parts-placement diagram shown in Fig. 5. Any leads not marked with an "X" in Fig. 5 must be kept from touching the ground plane as just described. If making sure that



X = SOLDER ON BOTH SIDES, SEE TEXT

Fig. 5. Use this parts-placement diagram to make assembling the unit much easier. Leads that must be soldered on both sides of the board are marked with an "X." Note the three feedthroughs that go through the board at L2, L3, and L4; those are made from scrap component leads and are soldered on both sides of the board.

the holes are drilled that way sounds like more trouble than it's worth, and it might just be, then you might want to consider buying the kit described in the Parts List. It will definitely save you a lot of trouble and you are assured of having a good printed-circuit board to work with.

Once you have a board, begin by installing the capacitors and resistors. Be sure to double-check the orientation of all the polarized capacitors. Then install transistor Q1, making sure that component is oriented properly as well.

Oscillator OSC1 will have a dot on one corner, or a notch, or one corner that's more pointed (less rounded) than the other three, to indicate pin 1. Be sure to match that with the orientation in the parts-placement diagram. The 7805 voltage regulator, U2, must be mounted flat on the board as

shown; bend its leads to fit the board before soldering.

You will have to install three feedthroughs at the ends of stripline inductors L2, L3, and L4, and solder them on both sides. Those feedthroughs connect the stripline inductors to the ground plane on the top side. You can use trimmed resistor leads to make your own feedthroughs.

The MAR1 amplifier, available from its manufacturer, Mini Circuits (P.O. Box 350166, Brooklyn, NY 11235-0003; Tel. 718-934-4500); other distributors; and as part of the kit described in the Parts List, is a tiny part with four leads. An even tinier dot indicates pin one; if you can't see the dot, use a magnifying glass—it's that small. Mount the part with pin 1 oriented as shown in Fig. 5 and with the dot visible on the top side and solder all four leads.

If you don't buy the kit, you will have to wind your own inductors for L6–L9. They are each made of 2 turns of 26-gauge enameled wire and should have a diameter of 1/8-inch each. Mount those and the other inductors on the board.

When all parts are installed, inspect the board for proper soldering, and also double-check that any leads that should be soldered on both sides of the board actually are. If you purchased the matching case for the Scanner Converter from the Supplier, or are using a similar enclosure, now is a good time to install the board in it. That will prevent the bottom traces from shorting against anything. Otherwise take precautions to prevent shorts during testing (i.e. don't let the board rest on a surface that is conductive).

**Testing and Use.** To test the board, make sure S1 is in the bypass position, and apply a 9- to 12-volt regulated DC supply to power jack J1 (the center pin of J1 is positive). Locate or make a shielded cable with an RCA plug on one end and a connector on the other end that matches the antenna input on your scanner. Connect the RCA end of that cable to J3 on the Converter, and the other end to the scanner's antenna input. Also connect an antenna to J2 on the Converter. If you don't have a suitable antenna, see the article elsewhere in this issue that shows you how to make one.

Turn on the Converter by pressing S1 and tune your scanner to receive any multiple of 40 MHz—40, 80, 120, etc. Background noise on the scanner should cease at those frequencies and the signal-strength meter on the scanner should show an increase. That is due to the scanner receiving the output of the Converter's oscillator or its harmonics.

Now tune your scanner to receive a signal between 400 and 550 MHz. As a result, you will actually tune in signals that are 400 MHz higher. For example, want to hear 800 MHz? Just tune in 400 MHz. Pressing S1 on the Converter should return the scanner to normal operation.

With your scanner converter complete, you are now ready to experience hours of listening pleasure. Enjoy your added reception! ■

**W**ant an extra Christmas decoration that doesn't shed needles, require water, or take up a lot of room? If that's the case, then the *Electronic Xmas Tree* described in this article is definitely for you. It's a simple project that is sure to be an eye-catching conversation piece when finished.

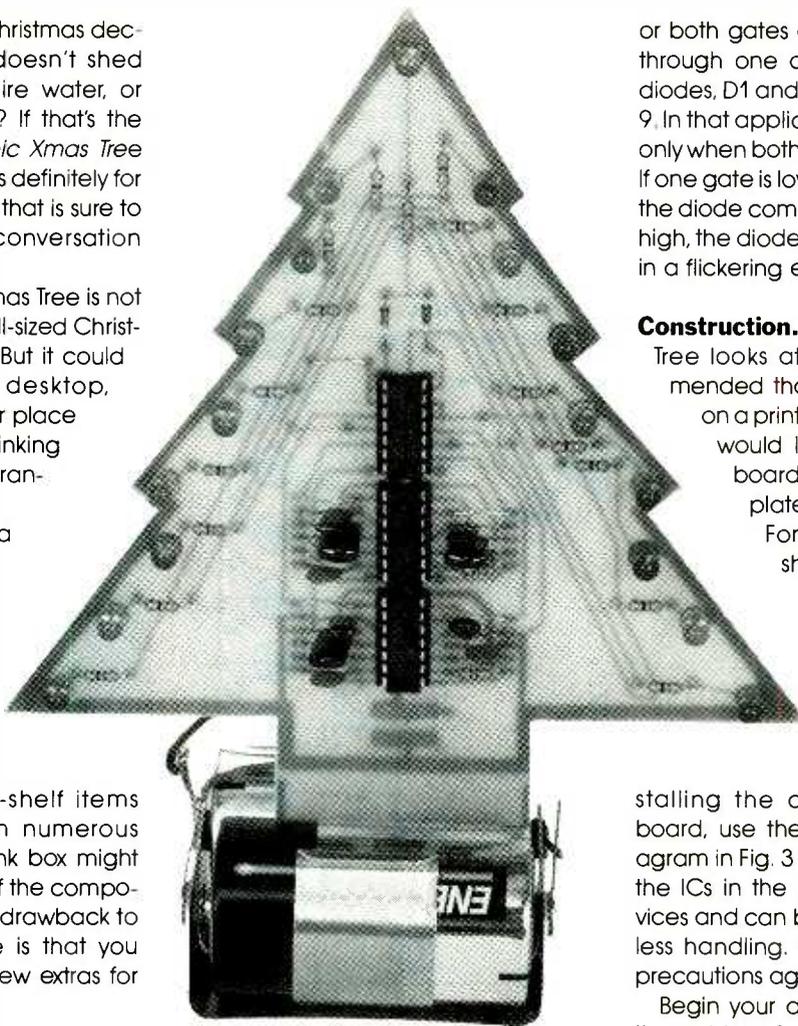
Of course, the little Xmas Tree is not meant to replace the full-sized Christmas tree on your floor. But it could help brighten up a desktop, bookshelf, or some other place with holiday cheer by blinking its LEDs in a seemingly random fashion.

Even though there's a fair number of components in the circuit, the Xmas Tree is suited to novices as well as experienced hobbyists. All of the parts are inexpensive and standard off-the-shelf items readily available from numerous sources. In fact, your junk box might contain most, if not all, of the components needed. The only drawback to building the Xmas Tree is that you might need to build a few extras for family and close friends!

**Circuit Description.** The schematic diagram for the Electronic Xmas Tree is shown in Fig. 1. Power is supplied from two D batteries in series.

The circuit uses a pair of 7556 dual timers, U1 and U2, to achieve the random blinking effect. Each half of each timer is used as an astable multivibrator (clock generator) set to a different clock speed. Slow speeds were selected to imitate the flashing bulbs used on real Christmas trees; the clock rates are 0.58, 1.02, 1.25, and 1.77 Hz. Those four clock signals are delivered to a 74HC04 (high-speed CMOS) hex inverter, U3.

Four of the inverters, U3-a, U3-b, U3-e, and U3-f, each receive one of the incoming clock signals from U1-a, U1-b, U2-a, and U2-b. When the inverter input is low, the output is high, and vice versa. Each inverter drives four LEDs interspersed around the edge of the



*Use it to brighten  
up your home  
this Holiday Season.*

# Electronic Xmas Tree

BY GARY CLIFTON

board; by mixing the colors of the LEDs, a random effect is achieved.

The two remaining inverters, U3-c and U3-d, are used to drive the top LED. They are joined together in a "diode or" configuration, so when either

or both gates are high, current flows through one or both of the 1N4148 diodes, D1 and D2, to the top LED, LED 9. In that application the top LED is off only when both of those gates are low. If one gate is low and the other is high, the diode comes on; if both gates are high, the diode gets brighter, resulting in a flickering effect.

**Construction.** To ensure your Xmas Tree looks attractive, it is recommended that the project be built on a printed-circuit board. If you would like to etch your own board, you can use the template shown in Fig. 2. (Note: For space reasons, it is shown here at half size.) For those who would like to order one, the board is available from the source mentioned in the Parts List.

When installing the components on the board, use the parts-placement diagram in Fig. 3 as a guide. All three of the ICs in the circuit are CMOS devices and can be damaged by careless handling. For that reason, take precautions against static discharge.

Begin your assembly by mounting the resistors. Solder them as close to the board as possible and clip the leads close to the board. Save the trimmed resistor leads for use as jumper wires, which should be installed next as some of them would be difficult to install later on. After that, solder in the IC sockets with pin 1 toward the bottom of the Tree as shown in the parts-placement diagram. Do not install the ICs at this time.

Next install the capacitors. Remember to keep the tip clean on the soldering iron and avoid using excessive solder; spacing is pretty tight around the capacitors and you don't

want to cause a short. Solder in the two diodes next, being sure to orient their bands toward the top of the Tree.

You can now install the LEDs. The cathodes go toward the outside edge of the board and can be identified two ways. Looking at the LED from the bottom, the cathode is nearest

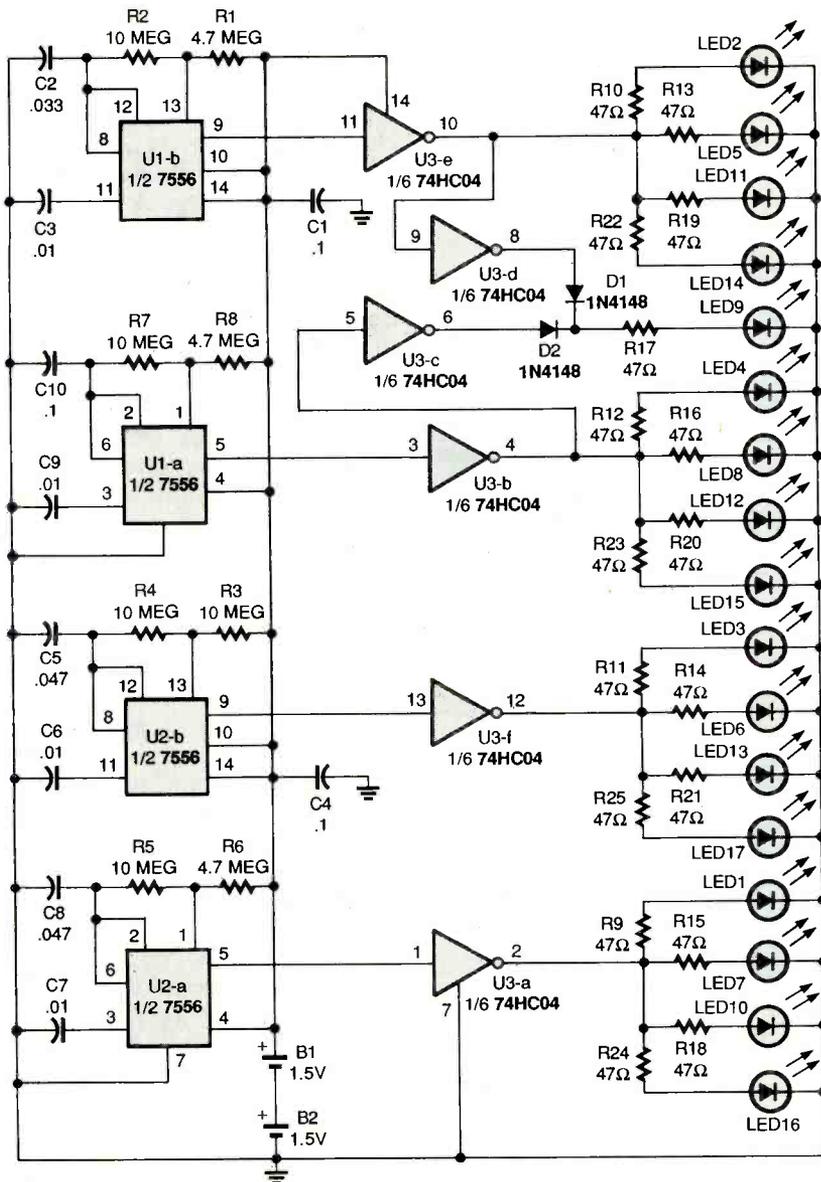


Fig. 1. This is the schematic of the Electronic Xmas Tree. Timers U1 and U2 are used as astable multivibrators set to different clock speeds. Those clock signals are inverted by a 74HC04 hex inverter. U3, which drives groups of four LEDs, causing them to blink in seemingly random patterns.

### PARTS LIST FOR THE ELECTRONIC XMAS TREE

#### SEMICONDUCTORS

- U1, U2—7556 dual timer, integrated circuit
- U3—74HC04 hex inverter, integrated circuit
- D1, D2—1N4148 small-signal switching diode
- LED1, LED5, LED7, LED10, LED14, LED17—Green light-emitting diode
- LED2, LED4, LED8, LED11, LED13, LED16—Yellow light-emitting diode
- LED3, LED6, LED9, LED12, LED15—Red light-emitting diode

#### RESISTORS

- (All resistors are 1/4-watt, 5% units.)
- R1, R6, R8—4.7-megohm
  - R2-R5, R7—10-megohm
  - R9-R25—47-ohm

#### CAPACITORS

- C1, C4, C10—0.1- $\mu$ F, ceramic-disc
- C2—0.033- $\mu$ F, Mylar
- C3, C6, C7, C9—0.01- $\mu$ F, Mylar
- C5, C8—0.047- $\mu$ F, Mylar

#### ADDITIONAL PARTS AND MATERIALS

- B1, B2—1.5-volt alkaline battery, D-type
- Printed-circuit materials, battery holder (Keystone 2227 or equivalent), wire, solder, hardware, etc.

**Note:** The following are available from DC Electronics (2334 N. Scottsdale Road, Scottsdale, AZ 85257; Tel. 800-467-7736): complete kit of all parts, including the PC board—\$19.95; etched and drilled PC board cut to shape—\$12.95. Shipping and handling is \$4.00. Arizona residents please add appropriate sales tax.

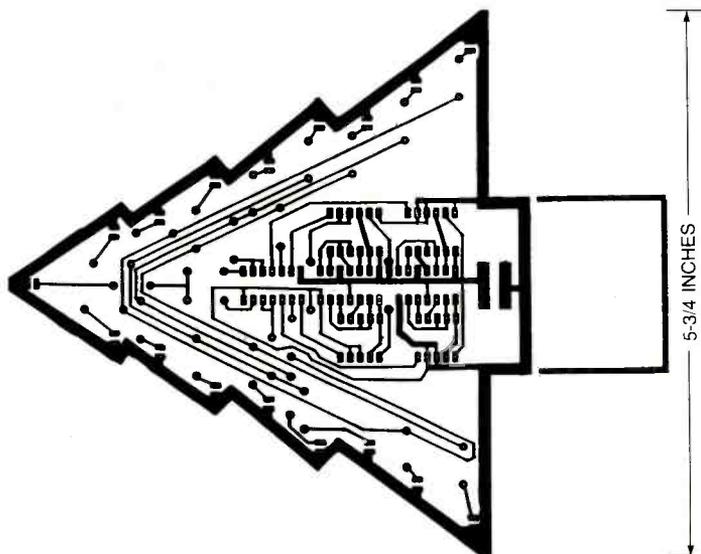


Fig. 2. The pattern for the Xmas Tree PC board is shown here half size.

the flat spot. Also, the cathode lead usually is shorter than the anode on new LEDs.

The holder specified in the Parts List (also available from the source mentioned there) is used to hold up the circuit board; the board can be wedged, standing up, between the  
(Continued on page 100)

**W**hile still in the womb, we are first exposed to the sounds of our mothers' breathing as well as the pounding of their hearts. From that point, through birth and on, we are constantly surrounded with sound. But not all of the sounds we are exposed to each day are completely safe for our hearing.

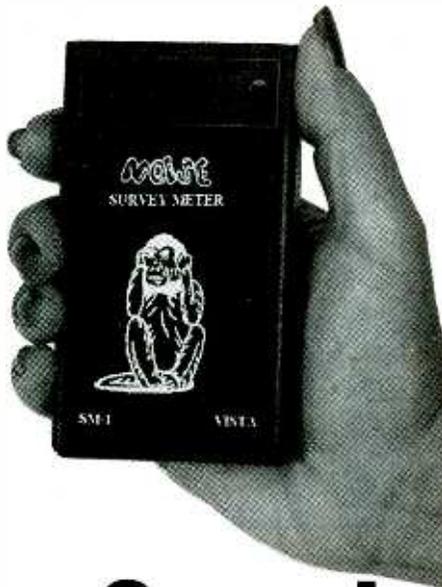
It is common today, for example, to see people jogging while immersed in sound from a set of headphones connected to a portable CD player. However, chances are you will also be able to hear their music selection as they pass by, which is a good indication that they might be damaging their hearing. Similarly, while car manufacturers have tried to reduce road noise and wind noise, they have also surrounded drivers and passengers with multi-speaker stereo systems that can achieve levels dangerous to hearing.

What can you do to make sure your surroundings are safe for your ears? Well, you can either walk around with earplugs on, just in case, or build the practical *Sound-Level Meter* described in this article. The unit provides a visual readout of just how many decibels (dB) you're absorbing, using a solid-state LED bar graph with a dynamic range from 30 to 120 dB. It is shirt-pocket sized and highly portable, so you can take it with you to work, to a club, or even to the theater.

**Sound and Hearing.** Just about everything that moves through the air produces vibrations that we perceive as sound. In nature, the loudest sounds are produced by hurricanes, volcanic eruptions, and of course, thunder. Sounds made by humans are the most intense as well as the most persistent, though. Anyone who listens to a jack hammer for half an hour or who goes to a rock concert can attest to that.

At frequencies below 500 hertz, almost any part of the body can detect vibrations; the fingertips are especially sensitive to such vibrations. But the vibration required to stimulate the hearing threshold is still far more sensitive. At the human-hearing threshold, the vibration of the eardrum causes a displacement of one-billionth of a centimeter, less than the diameter of a single hydrogen atom.

The sensitivity of a high-impedance



# Sound Level Meter

BY RICHARD PANOSH

*Use it to find out just how safe your surroundings are for your hearing.*

microphone is generally expressed as so many dB down from a reference. Usually that reference is:

$$0 \text{ dB} = 1V_{\text{rms}}/\mu\text{Bar}$$

where 1 atmosphere of air pressure = 1 Bar at 1 kHz. The Panasonic WM-52BM microphone used in the Sound-Level Meter has a rated sensitivity of  $-64 \pm 2$  dB, and will provide  $631 \pm 147 \mu\text{V}_{\text{rms}}/\mu\text{Bar}$ . Today the proper unit for that microphone is  $-44 \pm 2$  dB where the reference is  $0 \text{ dB} = 1V_{\text{rms}}/\text{Pa}$  (pascal) at 1 kHz. Pascal units increase the older  $\mu\text{Bar}$  units by exactly +20 dB.

A human ear operates exactly like a microphone to detect sound-pressure waves and convert them to electrical signals that are sent to the brain for processing. The intensity of those pressure waves is interpreted as loudness while the frequency of the wave produces the tone of the sound. Now,

the sound intensity perceived by the ear cannot be directly measured, but it has been related to a sound-pressure level (SPL) through careful measurements.

The threshold at which we can perceive a 1-kHz tone is taken as the 0-dB SPL that corresponds to  $0.0002 \mu\text{Bars}$ . That is a remarkably small pressure change that indicates the extreme sensitivity of human hearing.

Table 1 illustrates the SPL levels of typical sounds and environments. Ordinary breathing at 10 dB corresponds to a pressure change of  $0.0006 \mu\text{Bar}$ . At the other extreme, a space launch produces a pressure vibration of 140 dB, over three million times larger, or 0.002 Bar. Sounds above 100 dB are disagreeable to most people, and prolonged exposure to intensities above 80–90 dB can produce noise-induced hearing loss. Those losses begin with the higher frequencies and progress downward to lower frequencies. A person might recover from such noise-induced hearing loss after a period of rest in a quiet environment, but routine ex-

TABLE 1

Perceived Sound and the Decibel Scale	
Decibel	Description
0	Threshold of hearing
10	Ordinary breathing (barely audible)
20	Rustling leaves in a gentle breeze
30	Country house (quiet)
40	City house
50	Classroom, quiet restaurant (moderate)
60	Large store, ordinary conversation
70	Factory, inside car in heavy traffic (noisy)
80	Downtown street at rush hour, vacuum cleaner
90	Large truck that is 45 feet away (very noisy)
100	Subway train
110	Construction site (nearly intolerable)
120	Jet plane taking off from 180 feet away
130	Machine gun fire at close range (intolerable)
140	Space launch, thunder with nearby lightning stroke (painful)

posure to that condition over a prolonged duration will lead to permanent hearing damage.

At an SPL level of 100 dB, the pressure changes become 100,000 times larger (20  $\mu$ Bars). It is not surprising, then, that sound pressures of extreme intensity can damage our hearing. The level at which damage is sustained is also a function of duration. Federal, state, and local agencies have established standards on acceptable levels and duration. Table 2 presents one standard from the U.S. Department of Labor for noise regulation. Amplified rock music can easily exceed those limits at just 100 dB(A) for a couple hours.

Note that in Table 2 and in several places in this article the dB measurements are given in terms of dB(A). Here's what that term refers to: The greatest sensitivity of human hearing occurs just above 1 kHz; that sensitivity decreases as frequencies go lower or higher. A device designed to follow the response of the human ear works on a weighted curve—an A-weighted curve. Therefore, the unit is dB(A).

Because sound waves generally radiate spherically outward in all directions, the SPL decreases as the square of the distance. The distance between the source of sound and the point of measurement is, therefore, very important. Table 3 gives the dB attenuation for several convenient measuring distances. Notice that when the distance increases ten times, the dB attenuation is just -20 dB (that relationship only holds for spherical waves in a large room without reflections). The 10-dB-per-segment display of the Sound-Level Meter and its large dynamic range can be easily used to demonstrate that relationship.

**Logarithmic Amplifiers.** The design of the Sound-Level Meter is based upon the successive log-detection amplifier used in the Signetics NE614 high-frequency IF amplifier. That IC was originally designed for cellular-telephone applications. It belongs to a family of related devices, one of which also includes an NE602-type mixer on a single die to make a complete, low-power, single-chip, high-performance receiver.

The successive log amplifier provides a detected output signal, re-

TABLE 2

Acceptable Noise Levels (U.S. Department of Labor)	
Sound level (dB(A))	Duration per day (Hours)
90	8
92	6
95	4
97	3
100	2
102	1.5
105	1
110	0.5
115	0.25 or less

TABLE 3

Increase in distance	Sound pressure reduction (dB)
2 times	-6.02
3 times	-9.54
4 times	-12.04
5 times	-13.98
6 times	-15.56
7 times	-16.90
8 times	-18.06
9 times	-19.08
10 times	-20.00

ferred to as the RSSI (Received Signal Strength Indicator), which is proportional to the received signal strength over about a 90-dB dynamic range. In cellular telephones, that feature is valuable to indicate the operating extremes of the communications channel and to indicate the proper times to exchange cells to maintain a solid signal-to-noise ratio.

Logarithmic amplifiers fall into a category between linear amplifiers that can handle perhaps a 20-dB dynamic range and limiting amplifiers, where most of the amplitude information is lost through clipping action. What also makes a logarithmic amplifier ideal for this project is that it offers instantaneous signal compression with fast response as compared to an automatic gain-control stage or a range-changing amplifier.

**Circuit Description.** Figure 1 shows the schematic diagram of the Sound-Level Meter. Power for the circuit is provided by B1, a 9-volt battery. Total battery current is 14.5 mA, so an al-

kaline battery should last about 40 hours.

Audio signals are picked up by microphone MIC1. The output of MIC1 is buffered by Q1 to maintain the 3000-ohm load of resistor R2. The input impedance at pin 16 of the NE614 (U1) is 1600 ohms; R4 provides an additional 1600 ohms of resistance to reduce the gain on the high end and preserve the RSSI linearity. Capacitors C2 and C3 provide low- and high-frequency roll-off, respectively (that allows the unit to follow an A-weighted curve).

Capacitors C4 and C7-C9 are used as filters to bypass internal bias voltages within U1. An external coupling scheme is used between pins 14 and 12 of U1 to couple the first, internal, IF-amplifier stage to the second-stage limiter amplifier.

The RSSI signal is a current source that flows through R6 to establish a voltage at pin 5 of U1; the RSSI output voltage is a function of the input SPL. Capacitor C10 filters that voltage to remove high-frequency components. The slope of the RSSI line is nominally 0.084  $V_{cc}/10$  dB. Op-amp U2-b is configured as a non-inverting voltage buffer with a gain of 1.2; that gain, multiplied by the RSSI slope, produces a slope of 0.1  $V_{cc}/10$  dB to the remaining circuitry, which includes the display and the power supply.

The components connected between U2-b and U2-a make up a low-pass filter to give the meter a slow response. A slow response is desirable so that the unit responds to an average of the noise and not the peak.

The display, DISP1, is a ten-bar LED that is used to indicate sound level in 10-dB increments from 30 to 120 dB(A). The display is driven by an LM3914 linear bar-graph driver, U5. The internal voltage regulator of U5 functions by establishing a constant current through R15, because the voltage between pins 7 and 8 is maintained at 1.25 volts. The resulting voltage at the emitter of Q2 is about 5 volts, which powers U1, U3, and the internal voltage-divider string of U5 at pin 6.

While the divider string is temperature dependent, the division ratio is very stable and accurate. When powered from Q2 at a constant voltage ( $V_{cc}$ ), U5's voltage steps remain stable at a slope of  $V_{cc}$  divided by the ten steps. The resulting slope is therefore 0.1  $V_{cc}/step$ , which compares nic-

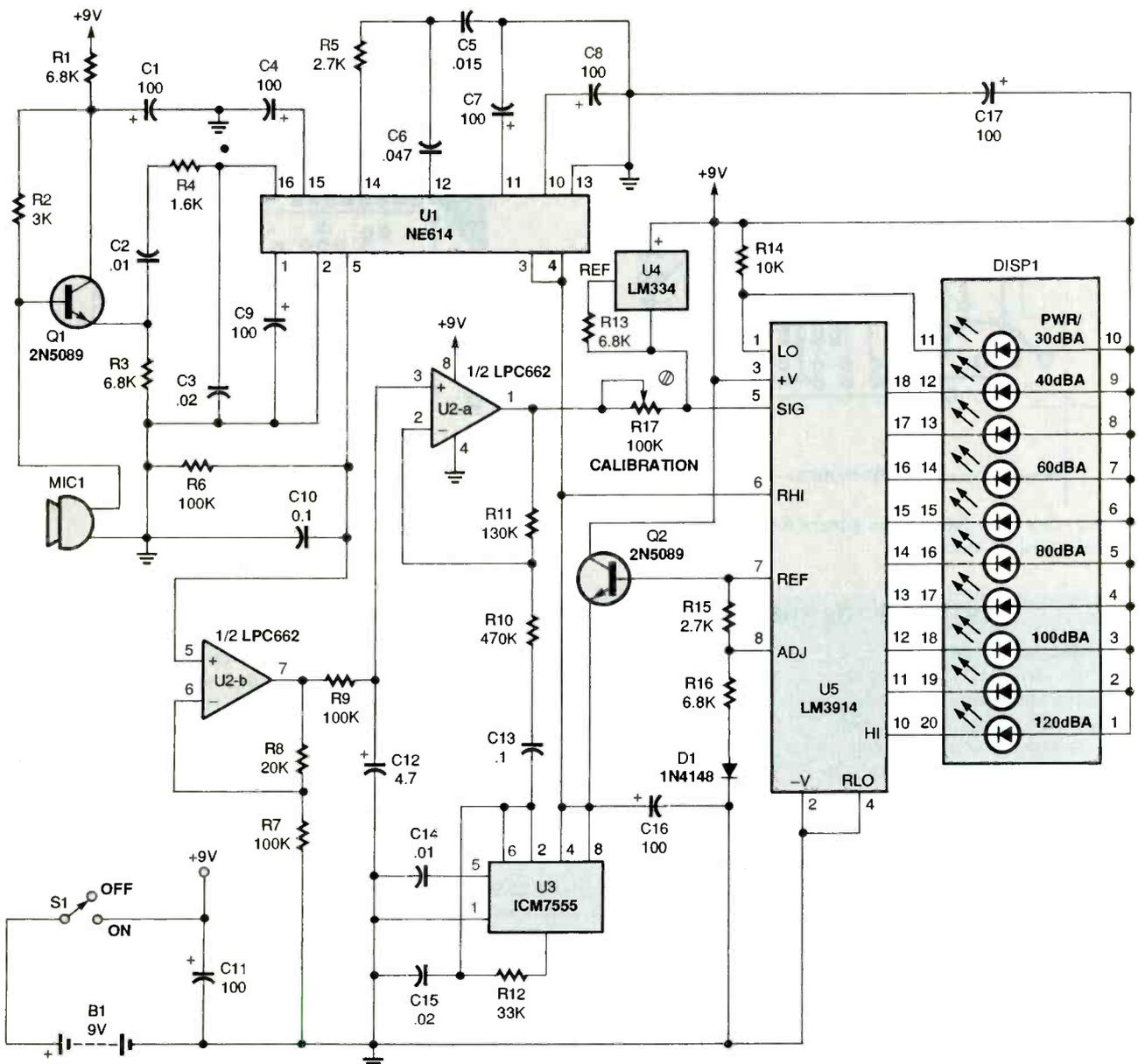
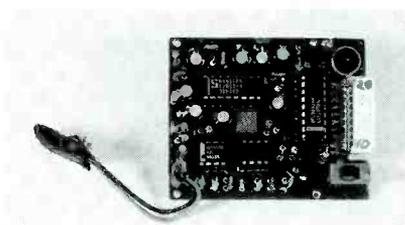


Fig. 1. Here's the schematic for the Sound-Level Meter. It uses an electret condenser microphone, MIC1, to pick up noise in a room. The unit then measures the level of that noise and displays it on DISP1, an LED bar-graph display.

ely with the RSSI signal slope of 0.1  $V_{cc}/10$  dB. Therefore, each segment of the display will increase by 10 dB, independent of the exact magnitude of  $V_{cc}$ .

While the slopes of the display driver and the RSSI signal are the same, they might not have the same offset. For that reason, an LM334, U4, is used to source a constant 10-microamp current through R17 to generate a fixed offset voltage on top of the composite RSSI voltage at the output of U2-a. By adjusting the value of potentiometer R17, differences in microphone sensitivity can be accommodated so that the display reads properly from 30 to 120 dB(A). The



This board shot shows how DISP1 looks when mounted properly.

proper readout of the display is also ensured by an ICM7555 timer, U4, which is configured as a self-excited, squarewave oscillator; the resulting peak-to-peak, 1-kHz signal of the timer is almost one step size of DISP1 (that's the equivalent of an LED bar).

**Construction.** The author's prototype for the Sound-Level Meter was built on a double-sided printed-circuit board. Building the Meter on a PC board with a good ground is strongly recommended because the NE614 is a high-frequency IC. If you would like to make your own PC board, you can use the solder- and component-side templates shown in Figs. 2 and 3, respectively. An etched and drilled board is also available from the source mentioned in the Parts List.

A parts-placement diagram is shown in Fig. 4. Cut the pins of the LED display to a length of approximately  $\frac{3}{16}$ -inch. Mount the LED display sideways with pins 11 through 20 lined up

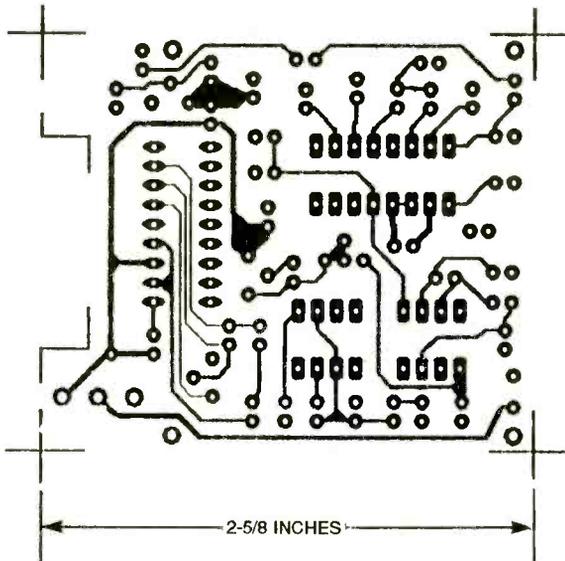


Fig. 2. This is the full-size foil pattern for the solder side of the double-sided PC board.

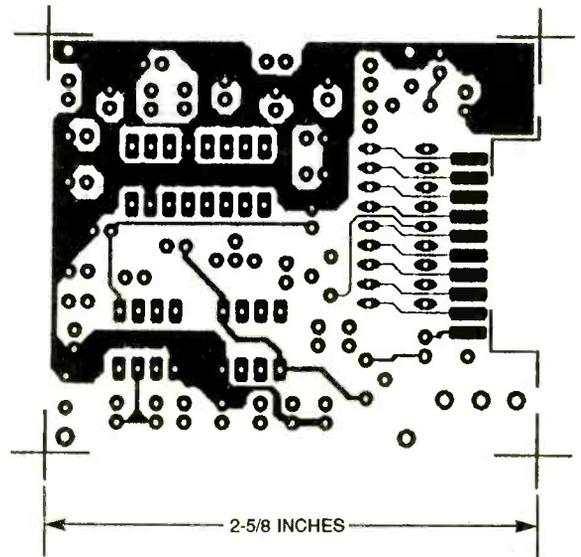


Fig. 3. Here's the component side of the board.

### PARTS LIST FOR THE SOUND-LEVEL METER

#### SEMICONDUCTORS

- U1—NE614 high-frequency IF amplifier, integrated circuit
- U2—LPC662 dual operational amplifier, integrated circuit
- U3—ICM7555 timer, integrated circuit
- U4—LM334 constant-current source, integrated circuit
- U5—LM3914 linear bar-graph driver, integrated circuit
- Q1, Q2—2N5089 NPN transistor
- D1—1N4148 silicon diode
- DISP1—Ten-LED bar graph

#### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

- R1, R3, R13, R16—6800-ohm
- R2—3000-ohm
- R4—1600-ohm
- R5, R15—2700-ohm
- R6, R7, R9—100,000-ohm
- R8—20,000-ohm
- R10—470,000-ohm
- R11—130,000-ohm
- R12—33,000-ohm
- R14—10,000-ohm
- R17—100,000-ohm trimmer potentiometer

#### CAPACITORS

- C1, C4, C7, C8, C9, C11, C16, C17—100- $\mu$ F, 10-WVDC, electrolytic
- C2, C10, C13—0.1- $\mu$ F ceramic-disc
- C3, C15—0.02- $\mu$ F ceramic-disc
- C5—0.015- $\mu$ F ceramic-disc
- C6—0.047- $\mu$ F ceramic-disc

- C12—4.7- $\mu$ F, 10-WVDC, electrolytic
- C14—0.01- $\mu$ F ceramic-disc

#### ADDITIONAL PARTS AND MATERIALS

- MIC1—Electret condenser element (Digi-Key part no. P9970-ND or equivalent)
- S1—SPST slide switch
- B1—9-volt battery
- Printed-circuit materials, project enclosure, battery snap with leads, IC sockets, wire, solder, hardware, etc.

**Note:** The following items are available from Vista (P.O. Box 1425, Bolingbrook, IL 60440; Tel. 708-378-5534): NE614 IF Amplifier—\$4.50 (plus \$3.00 shipping and handling); pre-etched PC board (NOISE-BRD)—\$10.00 (plus \$3.00 shipping and handling); kit of all parts including prepunched case with silk screen and battery (NOISE-KIT)—\$48.00 (plus \$5.00 shipping and handling); a fully assembled version is available with battery (NOISE-ASSEM)—\$59.00 (plus \$5.00 shipping and handling). Illinois residents please add 7.5% sales tax. Check, money order, and credit cards are accepted. For fast check verification, please provide street address (no P.O. boxes), telephone number, and driver's-license number and state of issue.

should be located above the component side of the board. Solder those free pins together with a wire and connect that wire to the solder pad closest to pin 11 of the LED display (see Fig. 4).

Next mount sockets for the U1–U4, making sure to observe proper orientation for each. The smaller, monolithic capacitors should be mounted next. Do not substitute other values for the capacitors, as most of the values tailor the bandwidth. Next, vertically mount the fixed resistors.

Mount the trimmer potentiometer, diodes, transistors, and the constant current source (U4). The electrolytic capacitors should be mounted next; make sure to match the proper polarity as shown in Fig. 4. Next install slide-switch S1 so that about 1/8 inch of the leads protrude through the PC board. That will give the switch the proper height and clearance for the SerPac M6 case that comes with the Sound-Level Meter kit.

Trim the battery-snap leads to approximately 2 1/2 inches, and solder them to the board, using the parts-placement diagram as a guide. You might want to apply silicone rubber to where the leads attach to the board to reduce the strain on the joint.

Clean the board of residual flux before installing the microphone (make sure that the component doesn't make contact with any cleaning solvents). The microphone used is a Panasonic WM-52BM (Digi-Key part

*(Continued on page 108)*

with the pads along the component side of the board. The face of the dis-

play should be pointing away from the board, and pins 1 through 10

**T**he Discone Antenna described here was designed to operate over a frequency range of 700 to 2000 MHz. It is a very small antenna, but very effective. It is vertically polarized, and has an omni-directional radiation pattern.

The antenna's principle elements are a flat conducting disc mounted horizontally atop but insulated from a conducting cone. The disc diameter is about 0.17 wavelength at the lowest desired operational frequency, and the cone has a length of 0.25 wavelength on the side. The discone's impedance is 50 ohms, so it can be fed by a 50-ohm coaxial cable. The outer (shield) conductor is connected to the cone, the center conductor is connected to the disc. The antenna's actual impedance varies depending on the cone's angle, frequency, and disc-to-cone spacing. Nevertheless, discone dimensions are not very critical for optimum performance.

Figure 1-a is an idealized sketch of a true discone antenna and its basic dimensions. It was determined that the disc diameter should be 3 inches and the length of a side element of the cone should be 4¼-inches. The angle  $\theta$  (Fig. 1-b) could be any angle between 25 to 40 degrees, so 30 degrees was selected for a practical reason. The space created by the insulating washer (S) will be ½ of the inside diameter of the brass tube (Fig. 2) or about ⅛ inch (thickness is not critical).

#### **Construction**

A piece of ⅝-inch brass tube is used to support the discone and is the outer conductor of the feedline (Figs. 1-b and 2). This tube has an inside diameter of 19/32 inch. With commonly available ¼-inch brass rod used for an inner conductor, the section of coaxial line that results has a 52-ohm impedance.

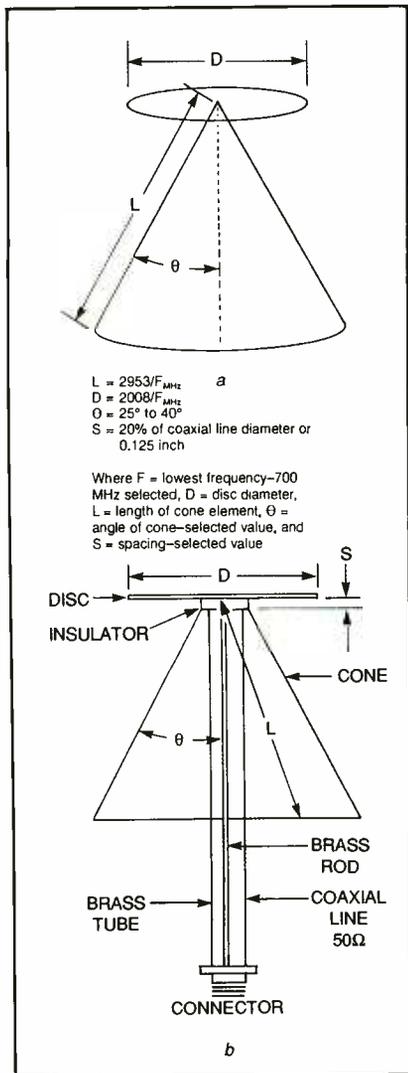
The exact impedance is not too critical and less than 10% variation in impedance should not cause reception problems. The length of the brass tube is up to the discretion of the builder. The loss the added length in-

# DISCONE VHF-UHF ANTENNA



***The discone is a popular wide-band antenna for VHF and UHF. This article shows you how to build a very efficient one for your UHF scanner.***

**WILLIAM SHEETS, K2MQJ and RUDOLF F GRAF, KA2CWL**



**FIG. 1—DISCONE ANTENNA DIMENSIONS:** a—view of idealized discone antenna and, b—view of assembled antenna specified in this article. Equations can be used for assembled antenna and provide excellent reception results.

roduces is negligible. A 5½-inch length of brass tube was used in the discone illustrated here, but up to about two feet of tubing should present no problems. Longer lengths will require some mechanical modifications in order to ensure that the line geometry remains concentric and reasonably rigid. This becomes a construction problem and should be avoided.

Theoretically the cone of the discone should come to a point. However, it can be truncated to allow the brass tube to be soldered to it. The disc is fastened to the brass rod (Fig. 3) by a screw which fits into a tapped

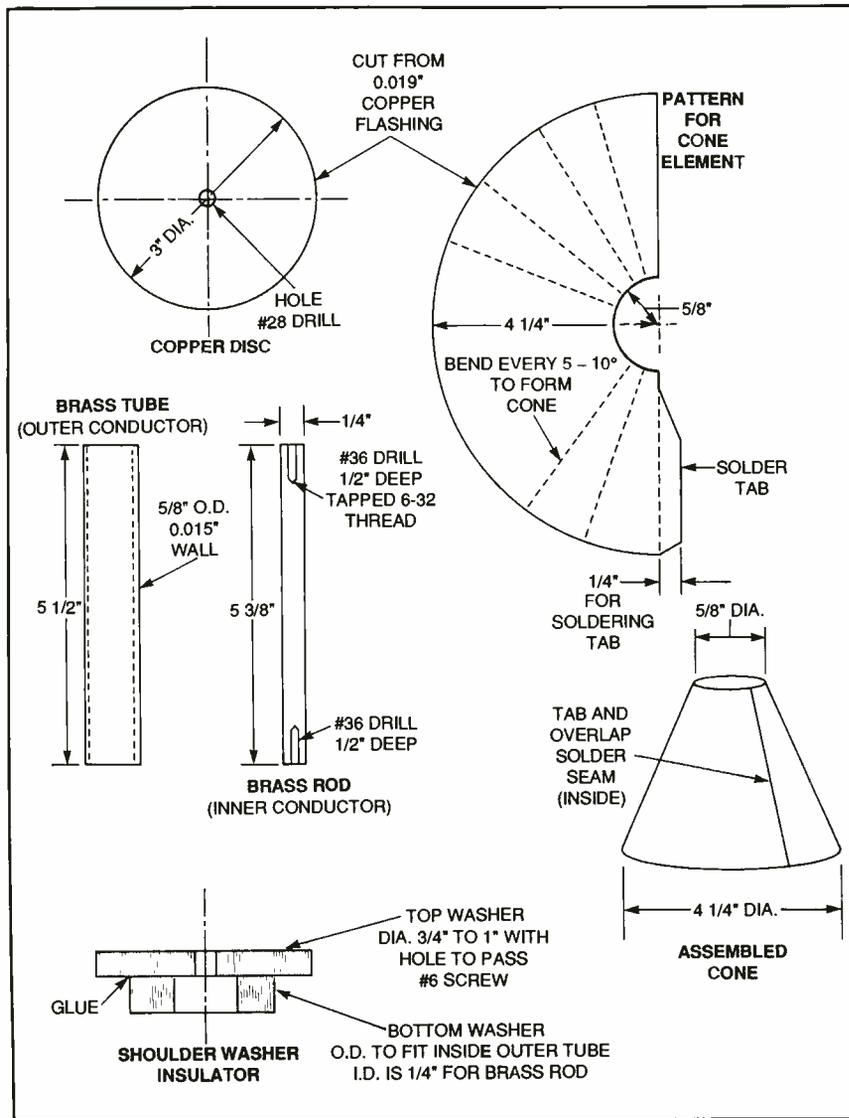
hole in the center conductor. A shoulder insulator made from plastic faucet washers keeps the brass rod concentric with the inner wall of the brass tube and provides a spacing between the disc and cone of about 0.125 inch. The bottom end of the line section is soldered to a type N UHF connector. A small clamp or U bolt can be used to mount the antenna to a mast.

### Sheet metal work

The disc and cone were cut from .019 gauge copper flashing stock (Fig. 2) purchased from a local plumbing supply house. Since the angle selected is 30 degrees, a half-circle pattern is needed to form the cone. Cut the cone and disc according to pattern. Allow a little overlap tab

as shown in Fig. 2 to allow for soldering. Use shears and wear heavy gloves as copper tends to cut with sharp razor-like edges. File all edges smooth.

The cone is formed by first drawing radial lines on the inside surface, bending the pattern a little at each line around a block of wood or steel, and repeating the process until the pattern edges meet. The cone should be a fairly good, even, circular shape. Make sure the hole at the top will fit the 5/8-inch brass tube snugly. Clean the edges and soldering surfaces with fine (No. 0) steel wool. Clamp the edges of the cone together with the tab underneath and solder using 60/40 solid-core solder and a liquid flux. Next, clean the brass tube with fine



**FIG. 2—CONSTRUCTION DETAILS** for a 700-2000-MHz UHF discone antenna.

steel wool and solder the cone to the brass tube as shown in Fig. 3. Make sure the brass tube is symmetrical and concentric in the cone. Carefully clean all flux residues using hot water and baking soda, followed by a final rinse in hot water.

Cut the brass rod to the same length as the brass tube. Drill a #36 hole in each end  $\frac{1}{2}$ -inch deep. Use a drill press if possible, and center punch each end to prevent the drill from "walking". The rod has to be held by a vise or clamp to do this. Tap one end of the brass rod for a 6-32 screw thread.

Make a shoulder-washer insulator as shown in Fig. 2 from two plastic washers. The top larger washer should be  $\frac{3}{4}$ -inch diameter by  $\frac{1}{8}$ -inch thick and the center hole should be large enough to pass a 6-32 screw (#28 drill hole), but not larger

## PARTS LIST

### LIST OF MATERIALS

1—Brass tube,  $\frac{5}{8}$ -in. (0.015-in. wall), 5 $\frac{1}{2}$ -in. long

1—Brass rod,  $\frac{1}{4}$ -in., 5 $\frac{3}{8}$ -in. long

1—Copper or brass sheet, .019 to .030-in. thick, approximately 5 × 12 in.

1—Type N UHF connector, UG58A/U, preferably silver plated

2—Plastic faucet washers ( $\frac{3}{4}$  to 1-in. dia.) with hole for #6 screw or smaller (drill and file to sizes in drawing)

1—6-32 ×  $\frac{1}{2}$ -in. brass machine screw, Philips or slotted head  
2—Pipe clamps to fit  $\frac{5}{8}$ -inch O.D. tube (plastic preferred) for mounting antenna.

Parts and materials not normally stocked by electronic parts stores can be obtained at hobby shops specializing in model aircraft and/or cars, plumbing supply outlets and hardware stores.

A catalog describing kits for ATV transmitters, ATV receiving converters and other projects usable with the antennas described in this article is available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804. Please include a #10 SASE and \$1.00 to cover handling and postage.

E-mail: Ncradio200@aol.com  
CompuServe 102033,1572

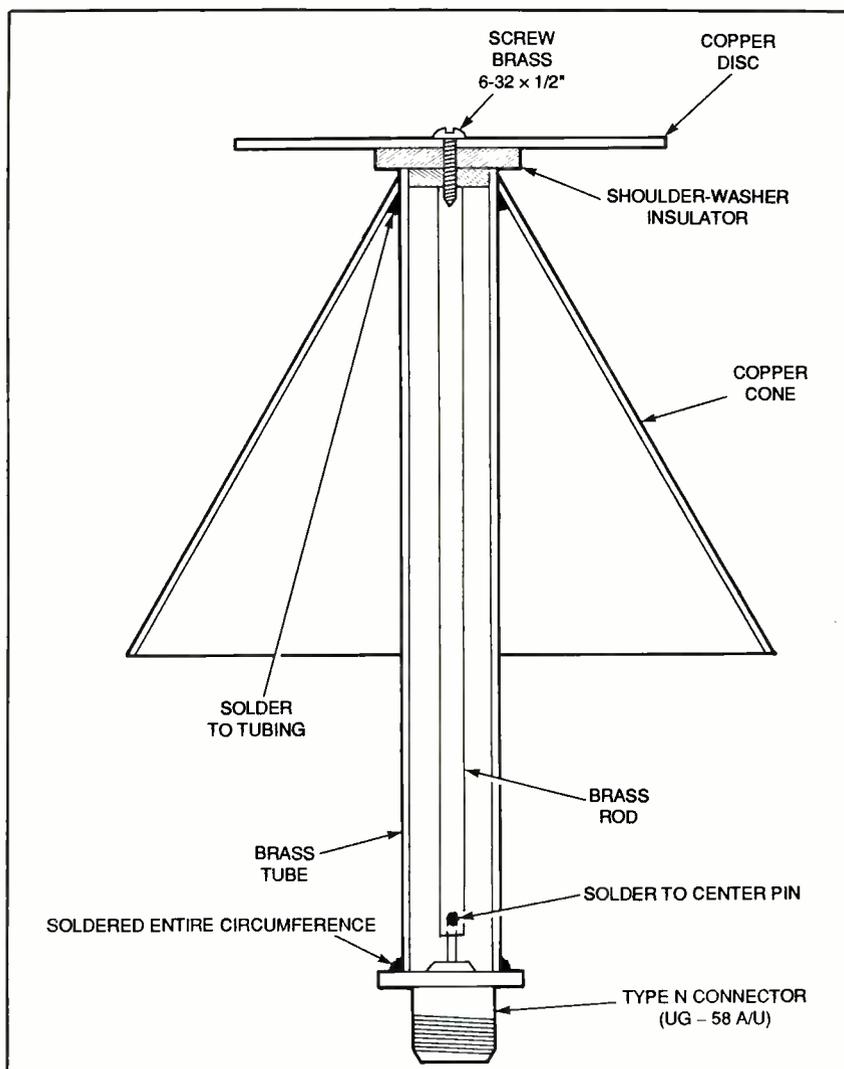


FIG. 3—ASSEMBLY VIEW of the discone antenna. Parts should fit firmly together before soldering is attempted. Clean surfaces to be soldered to a bright shine with #0 steel wool.

than  $\frac{3}{16}$  inch. The bottom washer should be press fit into the brass tube whose inside diameter is  $\frac{19}{32}$ -inch. The center hole should be  $\frac{1}{4}$ -inch diameter to pass the  $\frac{1}{4}$ -inch brass rod. Glue the washers together to form a shoulder washer. Now trial fit the entire discone assembly together. Trim the length of the center conductor so the top of the shoulder washer rests on the end of the brass tube. When the parts fit properly, you are ready to solder.

Clean the brass rod and the rear of connector flange with fine steel wool. The surfaces should be shiny. Using  $60/40$  rosin core solder, solder the untapped end of the brass rod to the N type UHF connector's center pin. Use at least a 100-watt

soldering iron. Next, insert this assembly into the lower end of the  $\frac{5}{8}$ -inch brass tube. Insert a 6-32 by  $\frac{1}{2}$ -inch long, brass, roundhead screw through the center of the copper disc, the insulator, and into the tapped hole in the end of the brass rod. Tighten the screw enough to hold the parts together and hold them in place for soldering. Make sure the brass tube is centered on the flange of the connector. Now, solder the connector's flange to the brass tube all around the seam. Use only enough solder to do the job.

Check for shorts with an ohmmeter. There should be an infinite resistance between the disc and cone, and the center terminal and flange of the type N

(Continued on page 109)

BY RICHARD PANOSH

**A**re you being lied to? For example, would you like to know if that politician on TV is really planning on lowering taxes? Let's face it, there are countless situations where knowing just who is telling the truth could come in handy. But how do you find out?

We've all heard of galvanic-skin-resistance (GSR) meters that attempt to measure a change in skin resistance that could be caused by nervousness. However, how many people would be willing to get "hooked up" to such a device? And even if they agreed to it, they would surely be insulted.

Now there's a better, less obtrusive method for finding out if you're being lied to. Simply use the *Voice-Stress Analyzer* described in this article. What's best about that device is that the suspected liar doesn't even have to be present—a tape recording of him or her will work just as well!

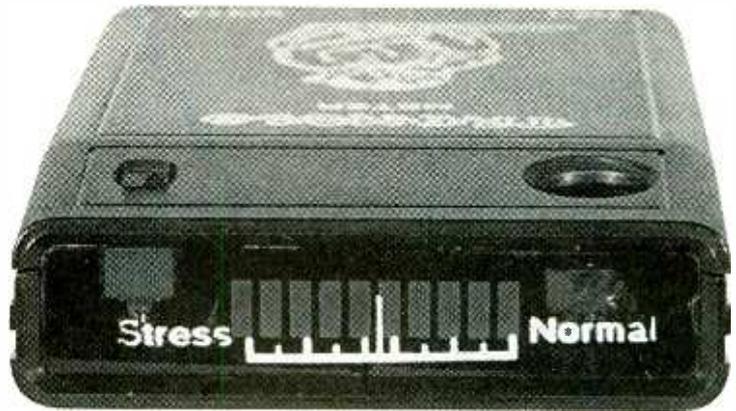
We'll get to how to build the Analyzer in a moment. But first, let's take a look at lie-detection methods of the past, and at how voice-stress analysis came about.

**The History of Lie Detection.** Since the earliest days of civilization, people have been faced with the problem of figuring out who's lying and who's telling the truth. To help determine that, truth seekers throughout the years have developed many methods to gauge a suspect's guilt or innocence. Most of those methods relied on physiological indicators such as sweating, rapid pulse rates, blushing, rapid breathing, trembling, or shifting gazes.

One of the earliest recorded examples of physiological lie detection is found in the Bible. That was when King Solomon stated he would divide a baby in half to determine by the reactions of two disputing women who the baby's real mother was.

In India, the guilt or innocence of a suspect was determined by forcing him or her to enter a dark room, alone, and grab an asp. Those that grabbed the asp and lived were innocent, while those that were bitten or failed to grab the asp were guilty (whether a suspect grabbed the asp was easy to determine, the snake was coated with a layer of black soot that would mark the suspect's hand).

# VOICE-STRESS ANALYZER



*See at a glance if you're being lied to with this innovative, truth-seeking circuit.*

Needless to say, few grabbed the asp and lived.

But in 1927, that all changed. Torturous and inaccurate methods of lie detection were replaced as science was finally applied to the task of gauging a suspect's guilt. The invention that resulted was the polygraph.

The polygraph detects chemical changes that occur in the body under the effects of stress. Stress causes the adrenal glands to increase their output, resulting in increased pulse rate, higher blood pressure, deeper breathing, and GSR changes.

During the 1960s, the American military sponsored research to develop a covert lie detector (a polygraph machine is quite noticeable). Methods ranged from using complex optical scanners to measure pupil dilation, infrared scanners to monitor skin temperature, microwave interferometers to measure breathing, and even odor detectors. Also during that period, some research was directed at detecting stress levels in the voice.

**Voice-Stress Analysis.** It seems that a person's voice changes under stress. In rare instances, a voice can even "crack." Such changes make voice-stress analysis possible. Best of all, as hinted at earlier, a test subject need not be present; conversations taken from a radio, television, telephone, or even tape recording can be used.

Now we'll examine just what causes a stressed individual's voice to change. It has been known for a long time that all working muscles in a relaxed human body produce micro vibrations with approximately 10-Hz cycles. More recently, research has indicated that those micro vibrations might diminish with stress.

Because muscles only exert force by contracting, movement of the body is produced by muscles that work in opposing pairs. In a relaxed state, it is believed that the muscles in the body are similarly relaxed and somewhat sluggish, which results in a dead zone in the control position of a

pair of opposing muscles. The body then alternately tenses opposing muscles to gain a sense of their position. Those vibrations occur at frequencies of 10 Hz.

You might have experienced a good analogy of that concept if you've ever driven an old car with a lot of play in the steering wheel. That play in the steering produces a dead zone around the control position that maintains a straight motion down the road. The dead zone can be handled in one of two ways: You can hold the steering steady, let the car wander off to one side until the error becomes excessive, and then jerk the wheel to correct your course. Or, you can rock the wheel back and forth through the dead zone, sensing the end control points and slowly controlling them to maintain a steady and straight path.

The latter method provides smoother control, and is akin to adding a small oscillation to a servo loop that exactly matches the amplitude of the dead zone. It should be mentioned that the frequency of that oscillation should be greater than the response time of the feedback loop to provide smooth control.

Now back to the muscle-pair example. Under stress and the action of adrenaline, the opposing muscles become more highly tuned and responsive. The dead zone of the muscle pairs is then reduced and the body becomes ready for fight or flight. Consequently, the micro vibrations of muscle pairs diminish with stress.

Because the membranes that form the vocal cord are controlled by three such muscle pairs, it is believed that the pitch of a person's voice will also experience a low-frequency modulation, and the level of that modulation should be inversely related to the level of stress. Those vocal tremors are found in the 7- to 15-Hz range, and are referred to as physiological or micro tremors.

It is believed that micro tremors produce both frequency modulation as well as amplitude modulation. Because micro tremors are small, they are usually inaudible and must be detected electronically. That type of detection is very difficult because human-voice frequencies are by nature quite variable.

In the mid seventies, Alan Bell, Charles McQuiston, and Wilson Ford

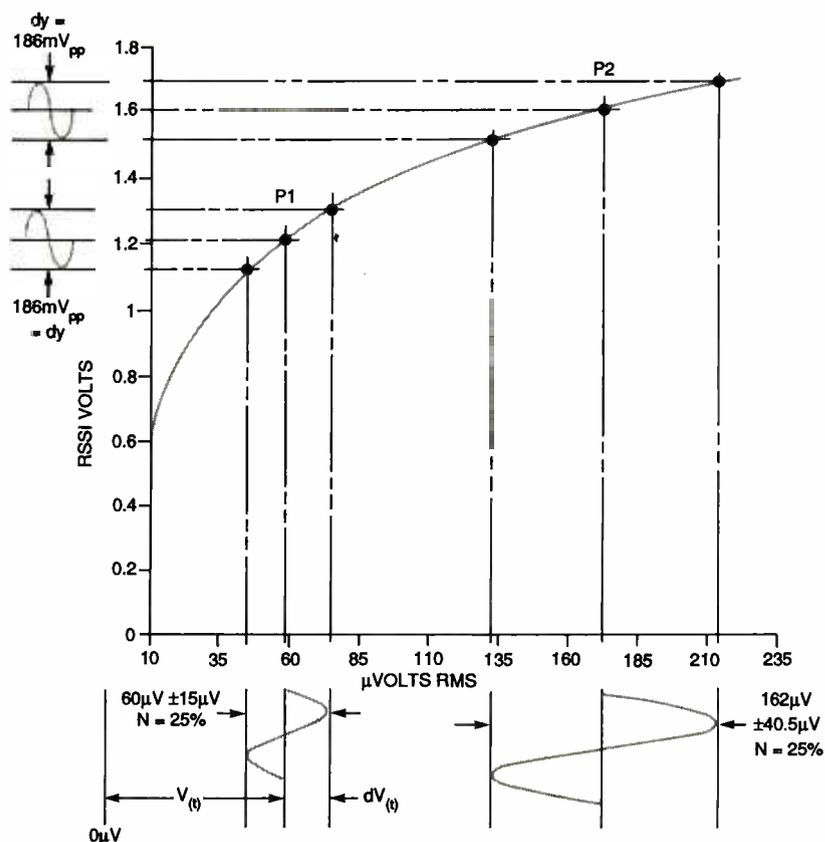


Fig. 1. Shown here is a small portion of a linear plot of Received Signal Strength Indicator (RSSI) response. Note that the slope or gain around small-input-signal-point P1 is high while the gain for a larger signal at a higher point, P2, is smaller.

received a patent on the Psychological Stress Evaluator (PSE). The PSE detects the resulting frequency modulation produced by micro tremors and produces a complicated output signal on a chart recorder. That chart is interpreted by a skilled examiner, as are polygraph results.

A few years after the introduction of the PSE, Fred Fuelleris invented the Vocal Stress Analyzer (VSA). The VSA works by detecting low-frequency amplitude vibrations in the subject's voice. Such amplitude modulation of the voice generates upper and lower sidebands. To determine the degree of stress, the VSA measures the amplitude of those sidebands.

To interpret the results of either a PSE or VSA machine, you must undergo extensive training. Who uses them? Mostly, the machines are bought by investigators, insurance claims adjusters, and law enforcement agencies. The machines are quite expensive, costing a couple-thousand dollars including training.

#### A Simpler Approach.

The Voice-

Stress Analyzer described here is based on a new detection scheme that directly measures the percentage of amplitude modulation in a voice. The chip that makes the Analyzer design possible is the Signetics NE614 high-performance FM-IF integrated circuit. While designed for cellular radio service, that 16-pin IC includes a complete successive-detection logarithmic amplifier with a dynamic range of over 90 dB, and a low frequency response due to its DC interstage coupling.

Pin 5 of the NE614 is the detected output and is called the RSSI (Received Signal Strength Indicator) line. The RSSI output level is a full-wave-rectified signal, which we'll refer to as  $y$ , that represents the logarithm of the signal input. That means that the level of amplitude modulation ( $dy$ ) on the RSSI output is a direct measure of the percentage modulation ( $N$ ) of the carrier ( $V(t)$ ) and is independent of its amplitude and frequency. That property of logarithmic response is of significant importance to the Voice-Stress Analyzer because the normal

voice energy during a conversation can vary by as much as 40 dB.

To better understand the logarithmic response just described, see Fig. 1. That figure illustrates a small portion of a linear plot of the RSSI response. Notice that the slope or gain around small-input-signal-point P1 is high while the gain for a larger signal at a higher point, P2, is smaller. The figure illustrates how two different amplitude signals with constant percentage modulation result in a constant output (dy).

**Circuit Description.** The schematic for the Voice-Stress Analyzer is shown in Fig. 2. Power for the circuit is supplied by a 9-volt battery, B1; S1 is the power switch.

Microphone MIC1 is coupled to the NE614 logarithmic amplifier, IC1. The

configuration allows voice frequencies ranging from 500-Hz to 10-kHz, where the human voice exhibits the greatest energy, to pass through. The RSSI output at pin 5 of IC1 is low-pass filtered by R6 and C10.

One section of an LM324M op-amp, IC3-c, buffers the RSSI signal to drive IC3-d, which is configured with a gain of two and a center frequency of  $12 \text{ Hz} \pm 6 \text{ Hz}$ . That results in a low Q value of one. The output at that point is a clean signal of the micro tremor and does not contain artifacts due to signal processing.

Op-amps IC3-a and IC3-b form a full-wave peak detector with an overall gain of 4.2; IC3-a operates on its own as a negative half-wave detector with a gain of 1. Low gain is required at that point because the non-inverting input of IC3-a is biased a bit

higher than +2.5 volts. The high gain occurs in IC3-b because its output swings positive during either cycle of the AC signal (the overall high gain is established by the ratio of R18 to R15, where  $R15 = 2 \times R17$ ).

When the output of IC3-b goes positive it is integrated by R10 and C16 for a fast response. During pauses in speech or under stress, the voltage developed on C16 bleeds off through the longer time constant caused by C16, R18, and R19. That allows the bar-graph display, DISP1, to show the signal quickly and with a fast attack time, and to hold the value with a slow release time during pauses in the speech process.

The display is controlled by IC4, an LM3914 bar-graph driver. Transistor Q2 is configured as an emitter-follower that buffers the output voltage refer-

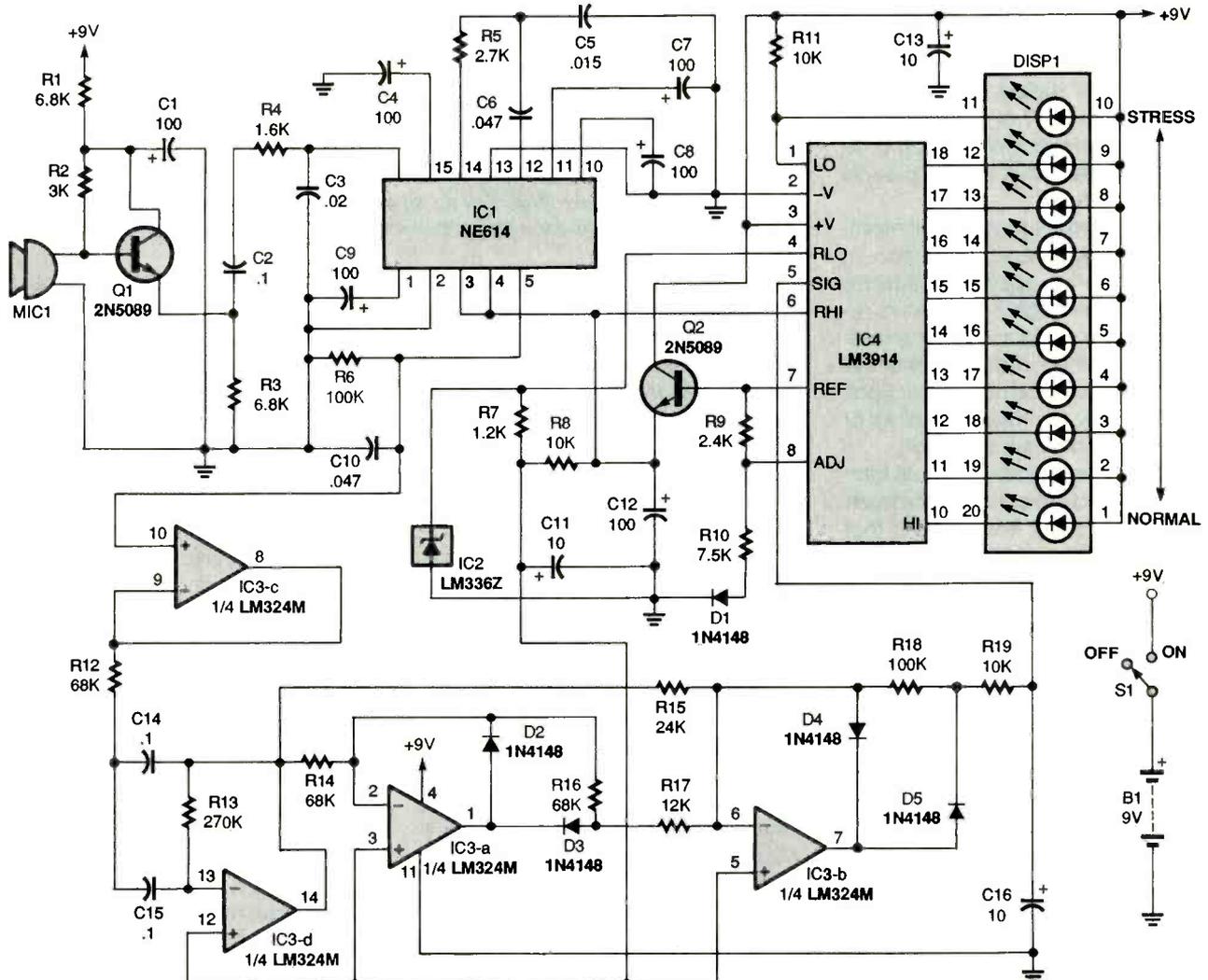


Fig. 2. Here's the schematic for the Voice-Stress Analyzer. At the heart of the circuit is IC1, an NE614 IF logarithmic amplifier, which allows the circuit to "interpret" the human-voice frequencies picked up by MIC1.

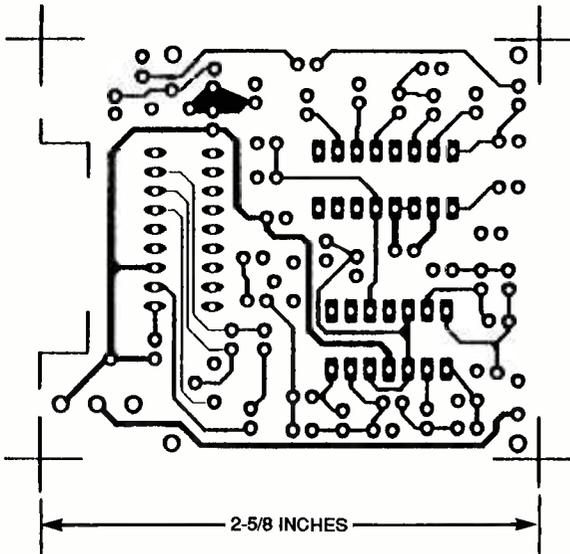


Fig. 3. The solder side of the Analyzer PC board is shown here.

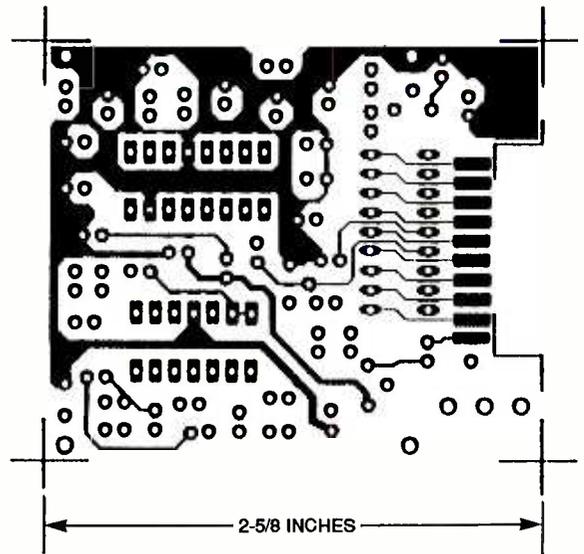


Fig. 4. Here's the component side of the board.

ence of IC4 to reduce power consumption. The transistor supplies a regulated voltage to U1 and the high end of the voltage divider that makes up the internal reference voltages for the comparators inside IC4. The low end of that voltage-divider string is referenced by IC2, an LM336Z, at +2.5 volts. That gives the bar graph a 2.5-volt, full-scale display.

Op-amps IC3-a, IC3-b, and IC3-d are biased from a voltage-divider string made up of R7 and R8. Resistor R7 biases the "quiet" operating point of those op-amps above the voltage level of the first bar-graph comparator so that the first bar will always be lit for a zero input. Because stress is inversely related to the percentage modulation, the first bar must remain lit for zero input to indicate maximum stress state. As stress is reduced and the percentage modulation increases, the signal drives DISP1 into the normal level. Even if the percentage modulation is unusually high, any level above the design value will still only light the tenth bar without going off range.

A swing of 0.3 volt on the RSSI signal will drive DISP1 to full scale. Because the slope of IC1's RSSI line is 0.414-volt/10-dB with a 5-volt supply, the full-scale display requires about a 7-dB swing, which corresponds to a 65% modulation. That value is approximately consistent with the example shown in Fig. 1, where a 25% modulation yields about a 200-mV peak-to-peak swing on the RSSI line. With the

### PARTS LIST FOR THE VOICE-STRESS ANALYZER

<p><b>SEMICONDUCTORS</b></p> <p>IC1—NE614 IF amplifier, integrated circuit</p> <p>IC2—LM336Z 2.5-volt reference diode, integrated circuit</p> <p>IC3—LM324M quad op-amp, integrated circuit</p> <p>IC4—LM3914 linear bar-graph driver, integrated circuit</p> <p>Q1, Q2—2N5089 NPN transistor</p> <p>D1—D5—1N4148 silicon diode</p> <p>DISP1—Ten-LED bar-graph display</p> <p><b>RESISTORS</b></p> <p>(All resistors are 1/4-watt, 5% units.)</p> <p>R1, R3—6800-ohm</p> <p>R2—3000-ohm</p> <p>R4—1600-ohm</p> <p>R5—2700-ohm</p> <p>R6, R18—100,000-ohm</p> <p>R7—1200-ohm</p> <p>R8, R11, R19—10,000-ohm</p> <p>R9—2400-ohm</p> <p>R10—7500-ohm</p> <p>R12, R14, R16—68,000-ohm</p> <p>R13—270,000-ohm</p> <p>R15—24,000-ohm</p> <p>R17—12,000-ohm</p> <p><b>CAPACITORS</b></p> <p>C1, C4, C7—C9, C12—100-<math>\mu</math>F, 10-WVDC, electrolytic</p> <p>C2, C14, C15—0.1-<math>\mu</math>F, polyester</p> <p>C3—0.02-<math>\mu</math>F, polyester</p> <p>C5—0.015-<math>\mu</math>F, polyester</p> <p>C6, C10—0.047-<math>\mu</math>F, polyester</p> <p>C11, C13, C16—10-<math>\mu</math>F, 16-WVDC, electrolytic</p>	<p><b>ADDITIONAL PARTS AND MATERIALS</b></p> <p>MIC1—Electret condenser element (Digi-Key part no. P9970-ND or equivalent)</p> <p>S1—SPDT switch</p> <p>B1—9-volt battery</p> <p>Printed circuit materials, project enclosure, battery snap with leads, IC sockets, wire, solder, hardware, etc.</p> <p><b>Note:</b> The following items are available from Vista (P.O. Box 1425, Bolingbrook, IL 60440; Tel. 708-378-5534): NE614 IF amplifier—\$4.50 (plus \$3.00 shipping and handling); pre-etched PC board (TREMOLLO-BRD)—\$10.00 (plus \$3.00 shipping and handling); kit of all parts including prepunched case with silk screen and battery (TREMOLLO-KIT)—\$48.00 (plus \$5.00 shipping and handling); fully assembled version is available with battery (TREMOLLO-ASSEM)—\$59.00 (plus \$5.00 shipping and handling). Illinois residents please add 7.5% sales tax. Check, money order, and credit cards are accepted. For fast check verification, please provide street address (no P.O. boxes), telephone number, and driver's-license number and state of issue.</p>
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ten-bar display used in the project, each bar represents about 6- or 7-percent AM modulation.

**Construction.** The author's prototype was built on a double-sided printed-circuit board. If you would like

to build your circuit the same way, you can etch your own board using the solder- and component-side templates shown in Figs. 3 and 4, respectively. Or, you can order a pre-etched board from the source mentioned in the Parts List. It is recommended that you use the PC board because the NE614 is a high-gain, high-frequency IF amplifier, and errors might result from stray capacitances caused by point-to-point wiring.

The PC board is compact and was designed to fit in a pocket-size SerPac M6 case, which is also available from the source mentioned in the Parts List. You can, of course, use any other suitable enclosure.

When building the circuit on the PC board, use the parts-placement diagram shown in Fig. 5 as a guide. Begin assembling the board by mounting DISP1. To do that, first cut the pins on the display to a length of between 1/8- and 3/16-inch. Mount the display with pins 11 through 20 lined up with the pads along the component side of the board. Solder pins 1 through 10 together using a wire; connect that common wire to the pad indicated in Fig. 5.

Mount IC sockets for IC1, IC3, and IC5, making sure they are oriented properly. Install the non-polarized capacitors next. Go on to mount the diodes and transistors and IC2, making sure all are oriented properly. You can then vertically mount all the resistors—that facet of the design helps keep the board compact.

Install the electrolytic capacitors next; note their polarity as indicated in Fig. 5. Then mount switch S1 so that about 1/16-inch of the leads protrude through the PC board. That should ensure the switch clears an opening in the case.

Trim the battery-connector leads to 2 1/2 inches overall and solder them to the board at the correct points. You might want to apply silicone rubber to the attachment point to reduce the strain at the joint.

At this point, clean the board of residual flux before installing the microphone. The microphone should not come in contact with cleaning solvents. Mount MIC1 with its leads just protruding through the board so that the microphone will have maximum height on the board. You can add a small bead of silicone rubber to the

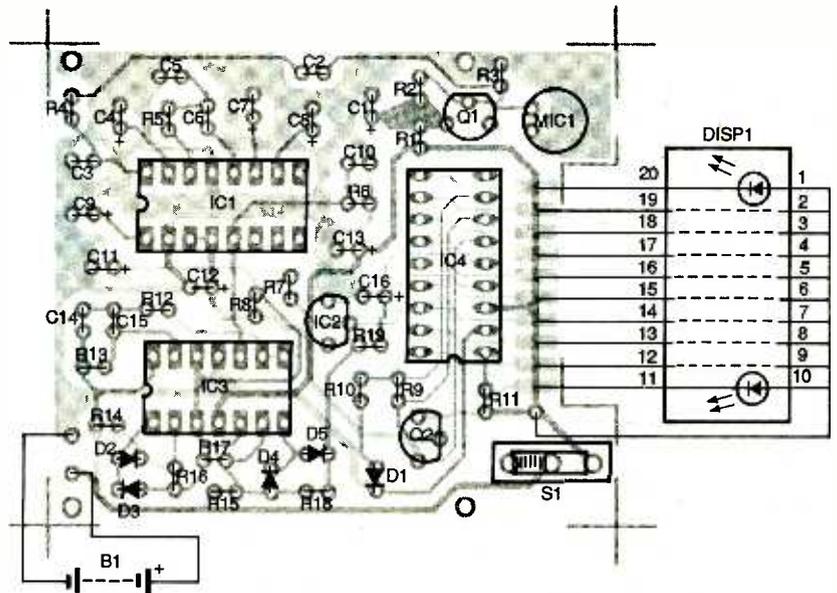


Fig. 5. Use this parts-placement diagram as a guide when assembling the circuit board. Note that pins 1-10 of DISP1 need to be connected together and to the indicated point on the board.

front edge of the microphone to support it more securely. Note: Be sure to use the microphone specified in the Parts List; do not substitute any other electret microphone that might have a different sensitivity, load, or frequency response.

You can now insert the three DIP-package ICs into their respective sockets. Complete the assembly of your Analyzer by mounting the circuit board into a case. If you use the Serpac M6 case mentioned earlier, the four holes at the edges of the board will match the four internal mounting posts of the case. Place a 1/8-inch spacer at the center of the back side of the case to support the board in place when the case is closed. The spacer can be made from foam tape or a rubber pad of suitable thickness.

**Checkout and Use.** When the unit is powered up, the emitter of Q2 should supply a nominal +5 volts. Also, the voltage across IC2 should read about +2.5 volts. At the junction of R7 and R8, the voltage should be larger than that across IC2 to light the first LED bar (in a quiet room). That bar is in the STRESS range, which corresponds to no modulation. It might be necessary to adjust the value of R7, depending upon component tolerances, to obtain that condition.

As you speak, higher LEDs should light in the display area marked NORMAL. Under stress, the modulation

level should fall and a bar in the STRESS half of the display will be lit.

The unit is small enough that you can carry it in a shirt pocket and glance down at the display while someone is speaking. It is best to evaluate a speaker in conversation because the Analyzer takes a moment to acquire the peak level of modulation and display it on the LEDs. If a source of white noise is introduced, such as the noise of running water or the hiss of a blank tape, the Analyzer output will remain in the STRESS region because the mixing of all possible frequencies will produce a zero swing on the RSSI signal. If music is playing, the Analyzer will remain in the STRESS range for the same reason.

You might find it interesting to analyze a taped conversation with the Voice-Stress Analyzer. You'll see that analysis is pretty much independent of the playback volume.

The results of voice-stress analysis are sometimes found in news stories that deal with political scandals and controversies. You can find a good source of stressful situations to evaluate your own Voice-Stress Analyzer by taping direct quotes of suspects from such news stories.

You can also use the Analyzer to measure the degree of stress in the voices of radio announcers or public speakers. As you can see, there are lots of entertaining applications for this fascinating project. ■



# TELEPHONE TRANSMITTER

BY MARC SPIWAK

*Receive telephone conversations on any FM radio with this neat little device.*

**W**ould you like to be able to amplify a phone call so everybody can hear it? Or perhaps you'd like a way to record a phone call to keep a record of it. If either idea sounds good to you, then you might want to build the *FM Telephone Transmitter* described in this article. It's a simple, yet ingenious device that connects in series with a phone line, "steals" power from the latter, and transmits both sides of a conversation to an FM radio tuned to between 90 and 95 MHz.

The circuit is built on a PC board that's so small it can easily be fitted inside the housing of a telephone, making it an instant pseudo-speakerphone. Keep in mind, though, that it is illegal to listen to or record a telephone conversation without informing all involved parties.

There are many legitimate reasons for wanting to broadcast a telephone call to an FM receiver. For one, maybe

you are calling one of those "900" information or entertainment lines, and everybody wants to hear the message. Or perhaps when someone calls long distance he or she doesn't have the time or can't afford to stay on long, but everybody at home still wants to hear his or her voice. Or perhaps you want to record a phone call so that you have a record of, say, some electronic banking you did or a deal you made.

Besides being small in size, the Telephone Transmitter is also small in price. Only a handful of parts are needed to build the Transmitter, and everything you need (including a PC board) can be purchased as a kit for only \$9.95. How's that for an inexpensive project?

**Circuit Description.** The schematic diagram for the Telephone Transmitter is shown in Fig. 1. That circuit connects in series with either the Tip or

Ring (green or red) telephone line. Power for the circuit is full-wave bridge rectified from the phone line by diodes D1 through D4.

Transistor Q1, capacitors C1 and C8, and inductor L3 form an FM oscillator that operates at a frequency of around 93 MHz. Variable-capacitor C8 allows the oscillator frequency to be adjusted between 90 and 95 MHz. To move the tuning area up to the 98- to 105-MHz range, C1 must be replaced with a 10-pF capacitor.

Audio from the phone line is coupled through R3 and C2 to the base of Q1 where it frequency modulates the oscillator. Transistor Q3, inductor L1, and capacitor C6 form a power amplifier. The signal tapped off L3 in the oscillator circuit is fed to the base of transistor Q2 and the FM signal is transmitted from Q2's collector. Inductor L2 is a radio-frequency shunt that decouples power and audio from the amplifier circuit.

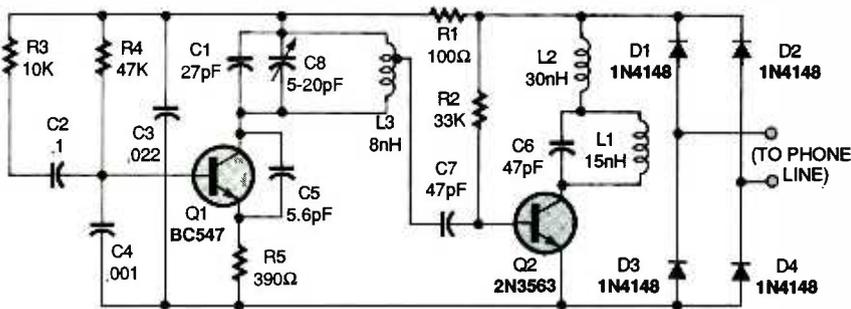


Fig. 1. Here's the FM Telephone Transmitter schematic. The circuit connects in series with a phone line, "steals" power from it, and transmits both sides of a conversation to an FM radio tuned to between 90 and 95 MHz.

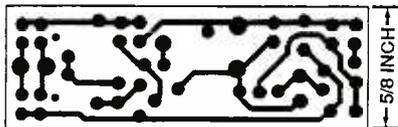


Fig. 2. If you'd like to etch your own board for the Transmitter, use this template.

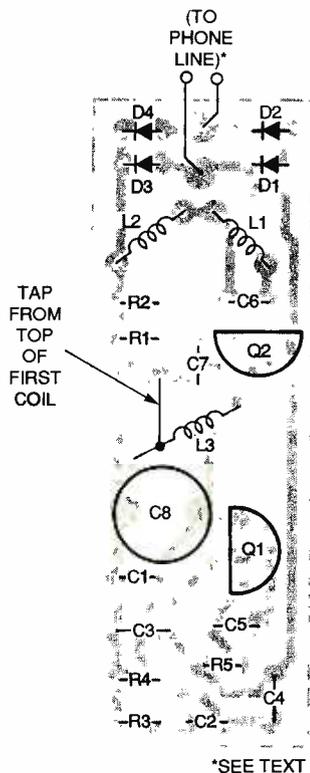


Fig. 3. Use this parts-placement diagram as a guide when mounting components to the board.

**Construction.** The circuit is simple enough to build on perforated construction board, but the tight design of the PC board shown in Fig. 2 is desirable. If you would like to use a PC board, you can either use the foil pattern provided in that figure to make your own PC board, or order a pre-etched and drilled board as part of a

complete parts kit available from the source mentioned in the Parts List.

When mounting parts to the PC board, use the parts-placement diagram shown in Fig. 3 as a guide. Begin by installing the resistors and diodes; the board is so tight that those components must be mounted vertically.

The next step is to install the inductors. Coils L1 and L2 are 6 and 8 turns, respectively, of enameled copper wire. If you are winding your own coils, use approximately 22-gauge wire and a 1/8-inch drill bit as your winding form. Any enamel on the leads where the coils are to be soldered must be sanded, scraped, or burned off with a soldering iron before solder will adhere to them properly. Coil L3 is 6 turns of tinned copper wire in which the coils must be spread out with about 1 millimeter between each of them—none of the turns should be touching each other. A tap must be connected between the top of the first turn of L3 and the PC board. Go on to install the fixed capacitors and the variable one. Then you can solder the two transistors to their appropriate places.

The kit mentioned in the Parts List includes alligator leads for connecting the Transmitter to the phone line. However, the author opted to modify a modular phone cord and install the board in series with it. The Transmitter can then easily be swapped between different phones. Be certain to inspect the board for errors before connecting it to the phone line.

The range of the Transmitter is less than 100 feet. That distance can be increased, however, by soldering a wire antenna (about 150 cm of 26-gauge wire) to the collector of Q2.

**Test And Tune.** Connect the Trans-

## PARTS LIST FOR THE FM TELEPHONE TRANSMITTER

### SEMICONDUCTORS

Q1—BC547, BC107, NTE 123A, or equivalent NPN transistor  
Q2—2N3563, ZTX320, NTE 108, or equivalent NPN transistor  
D1–D4—1N4148 silicon diode

### RESISTORS

(All resistors are 1/4-watt, 5% units.)  
R1—100-ohm  
R2—33,000-ohm  
R3—10,000-ohm  
R4—47,000-ohm  
R5—390-ohm

### CAPACITORS

C1—27-pF, ceramic-disc  
C2—0.1- $\mu$ F, ceramic-disc  
C3—0.022- $\mu$ F, ceramic-disc  
C4—0.001- $\mu$ F, ceramic-disc  
C5—5.6-pF, ceramic-disc  
C6, C7—47-pF, ceramic-disc  
C8—5- to 20-pF, trimmer

### ADDITIONAL PARTS AND MATERIALS

L1—15-nH, 6 turns of enameled copper wire (see text)  
L2—30-nH, 8 turns of enameled copper wire (see text)  
L3—8-nH, 6 turns of tinned copper wire (see text)  
Printed-circuit materials, alligator clips, wire, solder, hardware, etc.

**Note:** The following is available from Marlin P. Jones & Associates, Inc. (P.O. Box 12685, Lake Park, FL 33403-0685; Tel. 800-OK 2 ORDER or 407-848-8236; Fax: 407-844-8764): FM Telephone Transmitter Kit (#6016-KT—includes everything specified in the Parts List)—\$9.95 plus \$3.00 shipping and handling. Florida residents please add appropriate sales tax.

mitter to the phone line using whatever method you prefer. Turn on a nearby FM radio and tune to a quiet spot on the dial somewhere between 90 and 95 MHz. Pick up the phone; you should hear the dial tone right away on the FM radio. If that is not the case, adjust C8 until you do hear the dial tone. First adjust C8 for the best reception, and then fine tune the radio. If you have trouble finding a spot on the dial that is quiet enough, remember that the tuning area can be moved up to the 98- to 105-MHz range by replacing C1 with a 10-pF capacitor.

# Four-Mode Counter

*It's a great way to measure frequency and time.*

BY CLEMENT S. PEPPER



Most hobbyists would agree that a frequency counter having a range of 2 Hz to 1 MHz would make a useful addition to a collection of gadgets. But that device would be even more useful if it could also: measure the period of cyclic waveforms in the same range to a resolution of one microsecond; total randomly occurring events; and measure the width of singly occurring, positive-going pulses. If you agree that a device with those four modes could really come in handy, then the *Four-Mode Counter* described in this article is for you.

**Circuit Functions.** The circuit diagram for the Counter is shown in Fig. 1. Power for the circuit is supplied by a 9-volt DC source (see the Construction section for more details) to jack J2. An LM7805 regulator, U19, drops the 9 volts to 5 volts for use by the rest of the circuit (current drain is about 150 mA). Capacitors C4–C17 are bypass units.

Switch S1 is used to toggle between a TEST or MEASUREMENT input. When S1 is set to TEST, a timer-circuit test source—made up of U16 (a 7555 timer), R22R24, and C18—is activated. The output of that test-source section provides a convenient internal means of

verifying frequency count and period operation.

When S1 is switched to MEASUREMENT, a signal input to jack J1 is fed to the buffer section of the circuit. There, an LM339 comparator, U17, provides gain and waveform shaping. Diode D3 clips the negative-going half of sinusoidal inputs, D2 limits the inputs to 5 volts, and D4 provides a small input offset for the operation of U17. The CD4050 chip, U18, provides a buffer for the output of U17.

Rotary-switch S2 is used to select the desired Counter mode. The mode settings are: FREQUENCY, PERIOD, EVENT, and PULSE WIDTH (those settings correspond in order with the four modes introduced earlier). Two CD4503 three-state, non-inverting buffers (U10 and U13) are used to channel the input for the desired operating mode.

The measurements taken in the FREQUENCY and PERIOD modes use the one-second time base and the sequential-latch and sequential-reset pulses generated by it. Those pulses are switched out in the EVENT and PULSE modes where the counter latch input is held high.

When S2 is set to PERIOD, time measurement is limited to a single cycle in the following manner: The initial leading edge from pin 11 of U10 clocks U11-

a. A resulting high on pin 1 of D-type-flip-flop U11-a enables AND-gate U12-a, and 1-MHz clock pulses are then fed to OR-gate U14-a for counting. The next input leading edge toggles U11-b, locking U11-a in the reset mode, and shutting off the flow of clock pulses through U14-a. Gate U12-b inhibits further pulses to U11-b, and U12-d inhibits the period operation when S2 is in the FREQUENCY mode.

In the EVENT and PULSE WIDTH modes, U13 channels the inputs. For inputs in the PULSE WIDTH modes, pin 8 of AND-gate U12-c is held high to enable clock pulses to U13.

Another CD4503, U15, selects between the counter latch and reset functions of the modes. The counter latch is held high when the unit is in the EVENT or PULSE modes; reset is performed manually by pressing switch S3.

Two four-digit counters, U8, a 74C926, and U9, a 74C925, are used in the circuit. Both have internal output latching and multiplexed drivers for seven-segment displays. The multiplexing operations are performed internally, providing a "rotating" pulse sequence that drives switching-transistors Q1–Q6, which allow for the display of each digit in its turn through display-modules DISP1–DISP6. The Counter will display up to 999999. On a following input, the display would roll over to 000000, accompanied by a flash of LED1. Long pulse widths can

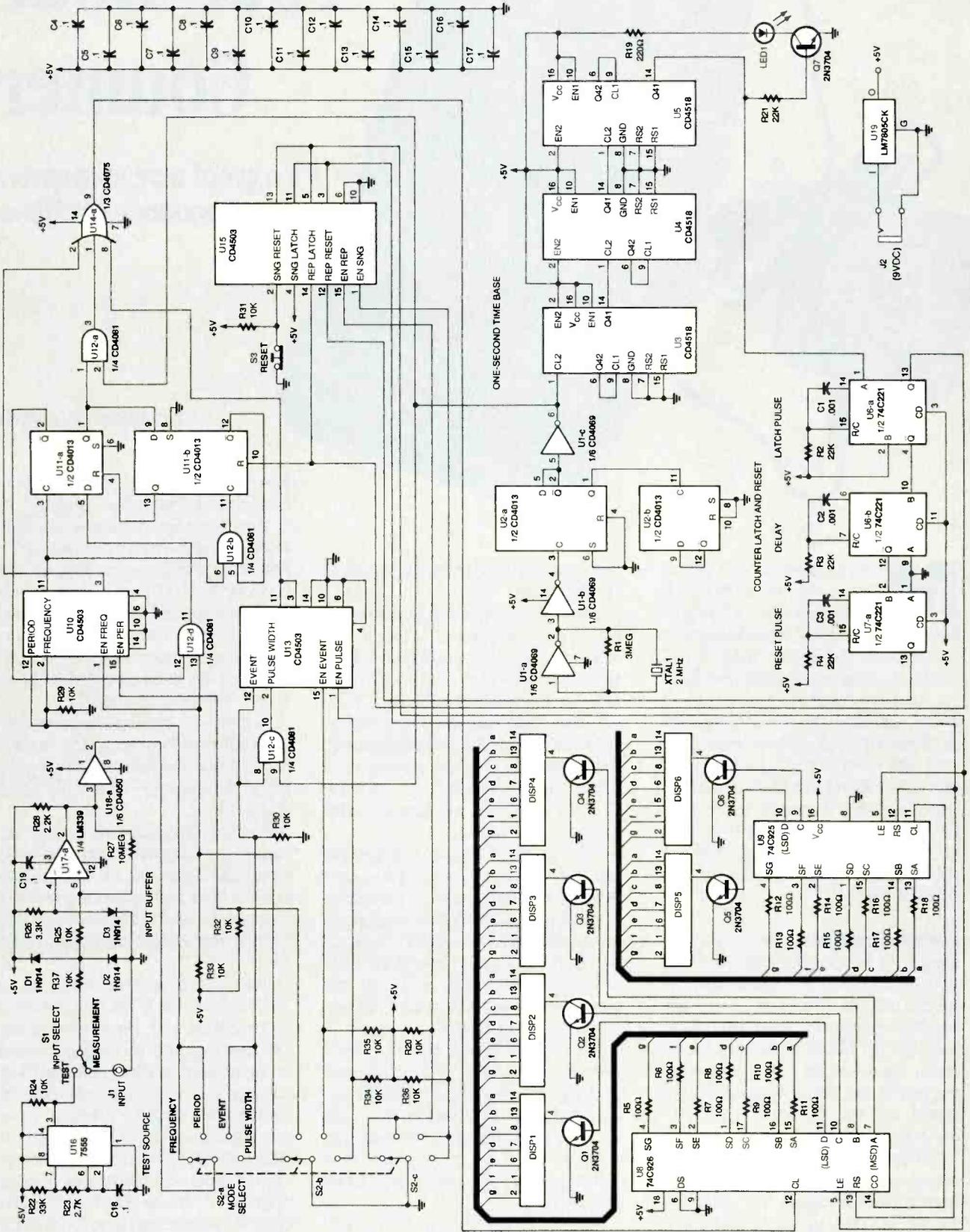


Fig. 1. As this circuit diagram shows, the Counter's display is made up of six individual modules, DISP1-DISP6. The digits are fed to those modules through U8 and U9.

## PARTS LIST FOR THE FOUR-MODE COUNTER

### SEMICONDUCTORS

U1—CD4069 hex inverter, integrated circuit  
 U2, U11—CD4013 dual D-type flip-flop, integrated circuit  
 U3—U5—CD4518 dual decade counter, integrated circuit  
 U6, U7—74C221 dual monostable multivibrator, integrated circuit  
 U8—74C926 4-digit counter with multiplexed 7-segment output driver, integrated circuit  
 U9—74C925 4-digit counter with multiplexed 7-segment output driver, integrated circuit  
 U10, U13, U15—CD4503 hex non-inverting three-state buffer, integrated circuit  
 U12—CD4081 quad 2-input AND gate, integrated circuit  
 U14—CD4075 triple 3-input OR gate, integrated circuit  
 U16—ICM7555 timer, integrated circuit  
 U17—LM339 quad analog

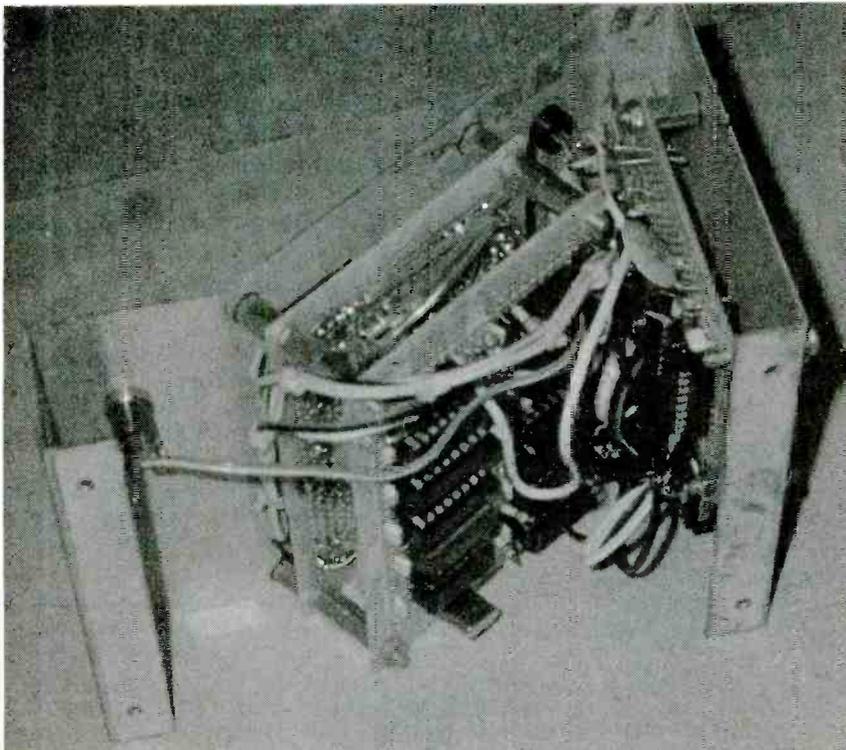
comparator, integrated circuit  
 U18—CD4050 hex buffer, integrated circuit  
 U19—LM7805CK 5-volt regulator, integrated circuit  
 DISP1—DISP6—7-segment display, orange, (MAN3640A or equivalent)  
 Q1—Q7—2N3704 NPN transistor  
 D1—D3—1N914 general-purpose silicon diode  
 LED1—Light-emitting diode, red

### RESISTORS

(All resistors are 1/4-watt, 5% units.)  
 R1—3-megohm  
 R2—R4, R21—22,000-ohm  
 R5—R18—100-ohm  
 R19—220-ohm  
 R20, R24, R25, R29—R37—10,000-ohm  
 R22—33,000-ohm  
 R23—2700-ohm  
 R26—3300-ohm  
 R27—10-megohm  
 R28—2200-ohm

### ADDITIONAL PARTS AND MATERIALS

C1—C3—0.001- $\mu$ F, ceramic-disc capacitor  
 C4—C19—0.1- $\mu$ F, ceramic-disc capacitor  
 XTAL1—2-MHz crystal  
 S1—SPDT switch, mini-toggle  
 S2—Rotary switch, 4-position, 3-pole (Digi-Key EG-1956-ND or equivalent)  
 S3—Pushbutton switch, normally closed  
 J1—Coaxial jack  
 J2—Power jack (should match power plug of adapter)  
 Perforated board, project enclosure, TO-220 heatsink for U19 (Jameco P/N 70771 or equivalent), wall transformer (120-volts AC to 9-volts DC, 1-amp; Jameco P/N 100888 or equivalent), round knob with dial, black transfer lettering, IC sockets, wire, solder, hardware, etc.



Here is an internal view of the author's prototype. As you can see, the circuit was built on three perforated boards.

be measured by keeping track of the flashes; the widths of repeated pulses are summed.

The one-second time base is derived from a 2-MHz crystal oscillator,

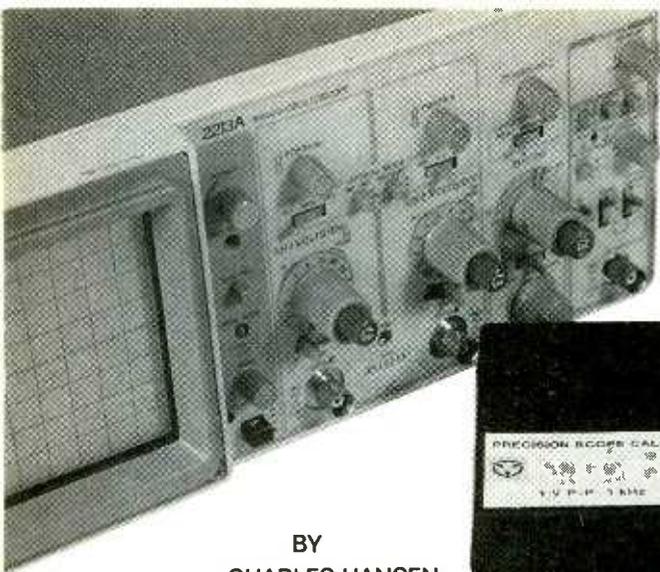
XTAL1. A 1-MHz divider input is taken from the first stage of U2-a. The 1-MHz input is further divided by six stages of decade frequency division; three CD4518 decade counters, U3, U4, and

U5, each provide two stages. Latch and reset pulses are derived from the 74C221 monostables, U6 and U7.

**Construction.** The author's prototype was built on three perforated circuit boards, using point-to-point wiring. All the components used in the Four-Mode Counter are standard stock, and are readily available from a variety of hobbyist sources. Some of the parts might even be in your junk box. Depending on what components you have on hand, and what sources you use to get the others, the cost of building the project will be approximately sixty dollars.

When you build the circuit, start by mounting the resistors and capacitors. Then go on to install the diodes and transistors. Next, mount sockets for all the ICs to protect them from damage; be sure to double-check the orientation of the sockets, and then insert the ICs.

Mount the display modules so that the digits will be in order (i.e. DISP1 goes first). You will have to cut an opening in whatever project case you use to allow the modules to be seen. You could make some kind of display bezel to cover the modules, if you wish; the author made one using  
*(Continued on page 107)*



# OSCILLOSCOPE CALIBRATOR

BY  
CHARLES HANSEN



*Use it to check your scope's vertical gain and horizontal time base.*

**M**any oscilloscopes do not have an internally generated calibration signal. Sure, some older models have 1-volt, peak-to-peak, 60-Hz calibrator outputs; however, those outputs are little more than clipped, 60-Hz sinewaves, and are not precise enough for calibration purposes. For that reason, you might want to build and use the *Oscilloscope Calibrator* described in this article. The unit provides an accurate squarewave of 1-volt-DC peak-to-peak, at a frequency of 1 kHz, which can be used to check the vertical gain and horizontal time base of your oscilloscope.

The Calibrator can also be used to adjust scope-probe compensation and can serve as a signal source for checking the transient response of audio equipment. It is battery powered for portability and is relatively insensitive to voltage fluctuation—the frequency output remains constant at a battery voltage of anywhere from 7.7- to 9.8-volts DC. Also, the minimal 2-mA current draw ensures long battery life.

**Circuit Description.** Figure 1 shows the schematic diagram for the Calibrator. The oscillator portion of the Calibrator consists of two sections of a 4049 CMOS hex inverter (U2-a and U2-b), and timing components C2, R2, R3, and R4. That portion of the circuit determines the output frequency. The exact frequency value can be found using the formula:

$$f = 2.2C2(R2 + R3)$$

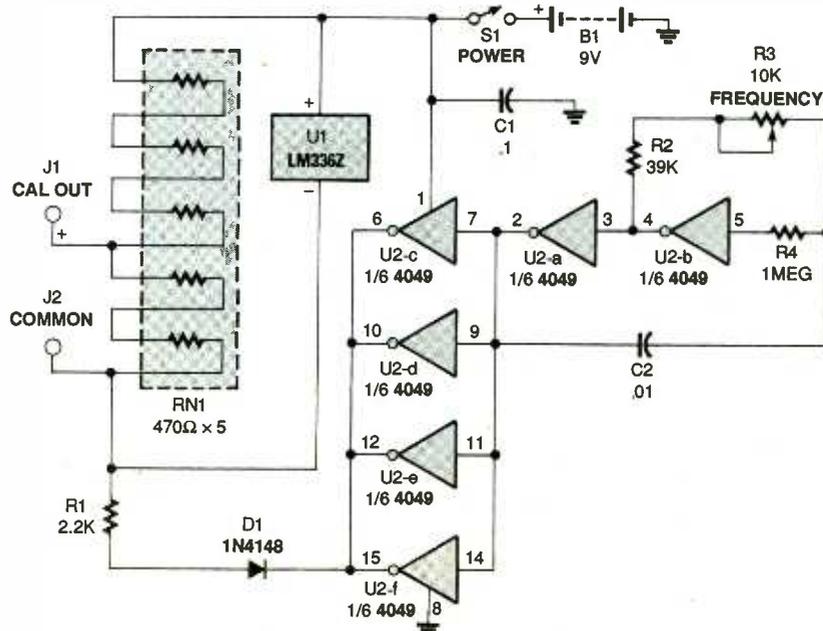
Assume that pin 5 of U2-b is initially low, causing the output at pin 4 of U2-

b to be high. Because the input at pin 3 of U2-a is also high, the output at pin 2 of U2-a is therefore low. The high output at pin 4 charges C2 through R2 and R3. When the voltage across C2 gets to the high input threshold at pin 6 of U2-c, the output at pin 4 and the input at pin 3 will go low. That causes the output of pin 2 to go high. Because the voltage across C2 cannot change instantly, the voltage at the input of U2-b is greatly increased to approximately 150% of battery voltage. That positive feedback reverses the logic level at the maximum rate that the CMOS gate is capable of achieving.

With the logic levels reversed on U2-

a and U2-b, C2 is charged in the other direction, with the voltage at pin 5 decreasing. When the C2 voltage gets to the low input threshold at pin 6, the output at pin 4 and the input at pin 3 will go high. That causes the output at pin 2 to go low. Again, the voltage across C2 cannot change instantly, and the voltage at the input of U2-b is reduced to about 50% of battery voltage. That once again reverses the logic level at the maximum rate.

Resistor R4 limits the input current to U2-b when the voltage across C2 exceeds that of the power-supply rails, thereby protecting the gate-input diodes. The resistor also prevents the RC-timing circuit from being loaded



*Fig. 1. Here's the schematic for the Oscilloscope Calibrator. To lower the long-term drift of the oscillator portion of the circuit, use a 2% metal-oxide resistor for R2, and a Mylar capacitor for C2.*

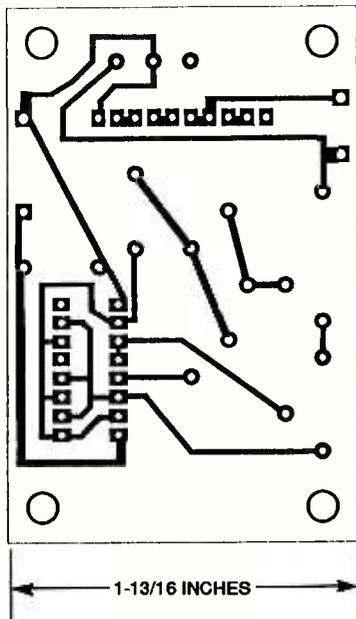


Fig. 2. Use this template to etch your own Calibrator PC board.

down by those internal diodes, which would tend to round off the edges of the squarewave. That results in a 50%-duty-cycle squarewave whose frequency is relatively independent of the battery voltage.

The squarewave output from pin 2 is connected to the parallel-connected inputs of the four remaining inverters in the 4049, whose outputs are also connected in parallel. When the squarewave output of the 4049 is low, U1, the LM336Z 2.5-volt DC reference (available from several hobbyist sources, including Digi-Key, P.O. Box

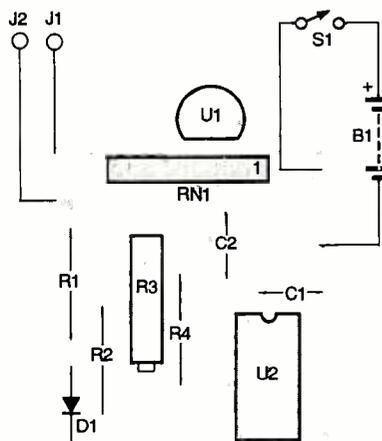


Fig. 3. When mounting the components on the board, use this parts-placement diagram as a guide.

677, Thief River Falls, MN 56701-0677; Tel. 800-344-4539), is turned on through R1 and D1. That causes the Calibrator's output squarewave to go high.

The combined current-sink capability of U2-c through U2-f is over 14 mA. Only 2 mA of that capability is used, assuring a very fast rise time for the output squarewave. In order to provide the 1-volt-DC, calibration output voltage, a 2% resistor network, RN1, is used. Each of the five elements in RN1 is rated at 470 ohms. The network is tapped at 40% of its overall resistance to provide the desired 1-volt-DC output at jack J1 (CAL OUT)—jack J2 is the COMMON.

When the squarewave output is high, the cathode of D1 is pulled to within 1/2-volt of the 9-volt DC supply. Therefore, no residual current flows through RN1 or U1, and the Calibrator output is a true zero. Waveform flatness is more than adequate due to both the 0.2-ohm, dynamic, "on" impedance of the LM336Z, and the complete turn-off of the drive current during a high output from the four drivers, U2-c-U2-f.

The voltage accuracy of the squarewave is maintained within 1% by U1. While the value of the network resistance is specified at 2%, the variations between each resistor element in the network are much smaller. That accurate voltage division provides a precise output-voltage level. Output impedance is approximately 1000 ohms.

The output squarewave depends greatly on the current through RN1, so a large filter capacitor is not required for the 9-volt battery, B1. Capacitor C1 is used to provide glitch filtering for U2 during logic transitions.

**Construction.** The author's prototype circuit was wire-wrapped on a perforated board. Layout of the parts is not critical, and for that reason, any standard project-building method can be used. However, for those who wish to build the Calibrator on a printed-circuit board, a foil pattern is shown in Fig. 2. Follow the parts-placement diagram shown in Fig. 3 if you choose to make your own PC board.

In keeping with good assembly practice, install the least-sensitive parts first, followed by the more-sen-

## PARTS LIST FOR THE OSCILLOSCOPE CALIBRATOR

### SEMICONDUCTORS

- U1—LM336Z precision 2.5-volt DC reference, integrated circuit (Jameco 23771 or equivalent)
- U2—4049 CMOS hex-inverter, integrated circuit
- D1—1N4148 silicon diode

### RESISTORS

- (All fixed resistors are 1/4-watt, 5% units, unless otherwise noted.)
- R1—2200-ohm
  - R2—39,000-ohm, metal-oxide, 1%
  - R3—10,000-ohm trimmer potentiometer (see text)
  - R4—1-megohm
  - RN1—470-ohm  $\times$  5, 2% resistor network

### ADDITIONAL PARTS AND MATERIALS

- C1—0.1- $\mu$ F ceramic-disc capacitor
- C2—0.01- $\mu$ F Mylar capacitor
- S1—SPST mini toggle switch
- J1, J2—Binding post
- B1—9-volt battery
- Printed-circuit materials, project enclosure, battery snap with leads, wire, solder, hardware, etc.

sitive parts. Install the battery connector, an IC socket for U2, and the switch, followed by the potentiometers and jacks. Next, mount the other passive parts—resistors first, then capacitors. To keep long-term drift in the oscillator portion of the circuit to a minimum, C2 should be a Mylar capacitor, R2 should be a 2% metal-oxide timing resistor, and R3 should be a wire-wound multi-turn trimmer potentiometer. Finally, install D1, U1, and U2. Double check the orientation of the polarized components, and if you aren't using a PC board, double check your wiring.

Depending on the sensitivity of your scope, you might need a higher reference voltage for the Calibrator. If that is the case, keep the following possible customization in mind when building the unit. Connect two LM336Zs in series, and use a reduced value resistor for R1 to maintain 1 mA in the divider and the LM336Zs. That will provide a reference based on 5-volts DC.

**Checkout and Calibration.** The output voltage of the Calibrator can be  
(Continued on page 101)

**M**any people like listening to a cricket's song. Some believe it induces a feeling of well-being that can aid in getting a better night's sleep. Others like to have a natural sound in their homes during the winter months, possibly to prevent cabin fever. And a few hold to the belief that the song can bring good luck to a person. If you'd like to bring the song of a cricket into your home, but not the insect itself, build the *Chirrup* described in this article. It's a compact, realistic-sounding device that can easily be built in an evening.

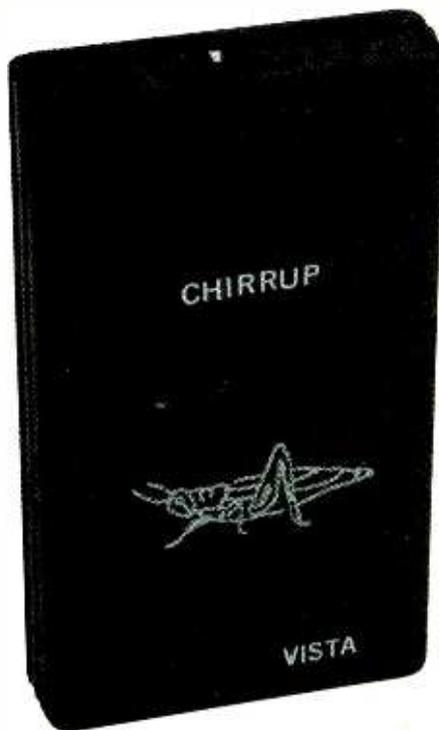
**Cricket Folklore.** Due to the cricket's long relationship with humans, much folklore surrounds the creature. In Europe, legend has it that if a cricket abandons a house, those living there can expect the coming of bad luck. Moving to the east, we find that the Chinese kept crickets that were selectively bred for musical sounds in bamboo cages, while others were bred specifically for fighting. Wagers were placed on those fighting crickets for entertainment.

Popular fiction has also contributed to the popularity of the cricket in the past couple of centuries. Most notably, Charles Dickens immortalized the cricket in his story "The Cricket on the Hearth," which was written in three "chirps" instead of chapters. More recently, everyone of course remembers the lovable Walt Disney character, Jiminy Cricket.

One final bit of cricket lore surrounds the fact that crickets are cold blooded and seek warm places to live. For that reason, the insects are known to many as "poor men's thermometers." Supposedly, if you count the number of chirps a cricket makes in 15 seconds and add 39 to that number, the result is the approximate temperature in degrees Fahrenheit.

**Cricket Song.** While crickets have no sound-producing organs, they do interact and communicate with each other through sounds they make by rubbing their forewings together (it seems those wings evolved just for the production of sound). One wing has a serrated ridge, called the "file," which is dragged across the opposite wing's "scraper." That excites a clear area on the left wing, causing it to resonate.

The sound produced as a result of



# Chirrup

*Let the summer song of the cricket bring you good luck and peace of mind all year long.*

BY RICHARD PANOSH

that seemingly simple process, however, is anything but simple. The natural resonant frequency of a cricket wing is near 2 kHz, and is excited by the file to produce a nearly 100% amplitude modulation of the carrier, which contains about seven beats within a duration of 0.22 seconds. After producing the chirp, the wings reset in about 0.35 seconds to begin the next chirp. A complex waveform is generated due to the intermittent impulse of the file and its subsequent damping. Superimposed on that waveform is the pulse frequency dur-

ing the time the wings are reset. In addition, some distortion of the resonant frequency of the wing is produced by the appendage's complex structure.

The cricket's song is an insect version of the "siren's love call" from mythology. However, unlike the alluring female sirens, it is the male cricket that calls the wandering female to his lair with his song. In fact, the sound of the song itself is sufficient to excite the female. The female (and male) cricket hears with auditory organs that are located on the front legs just below the knee; each organ is highly directional (similar to a directional microphone). Those sound receptors are very sensitive to ultrasonic sounds and can respond to frequencies as high as 100 kHz.

**Circuit Description.** The schematic for the Chirrup is shown in Fig. 1. Power is supplied from a 9-volt battery, B1; current drain is a little under 2 mA, so an alkaline battery should last over 250 hours. Switch S1, the power switch, is part of potentiometer R10, which also acts as a volume control.

A duty cycle is generated by op-amp U1-a, which is configured as a pulse generator. Diode D1 establishes a fast charging rate that generates a 0.22-second period, which matches the duration of a cricket's seven-beat chirp. The discharge rate is established by R2 to generate a reset time of 0.35 seconds, which is the exact reset time of a cricket's wing.

One half of an ICM7556 CMOS timer, U2-a, is used to simulate the amplitude modulation of a chirp (do not substitute another bipolar timer IC, because it will adversely affect the timing and also increase power consumption). The pulse output of the chip is not directly used, but rather the alternate charge and discharge voltage across C2. During the charge time, diodes D2-D4 are reverse biased. The timer then operates in a conventional manner, charging C2 through R6 and R7 to  $\frac{2}{3}$  of the supply voltage.

During the discharge time, when the output goes low, the control voltage at pin 3 of U2-a is pulled down by diodes D2 through D4. Because the lower comparator threshold voltage is internally biased to  $\frac{1}{2}$  the control voltage, the lower trip point has been

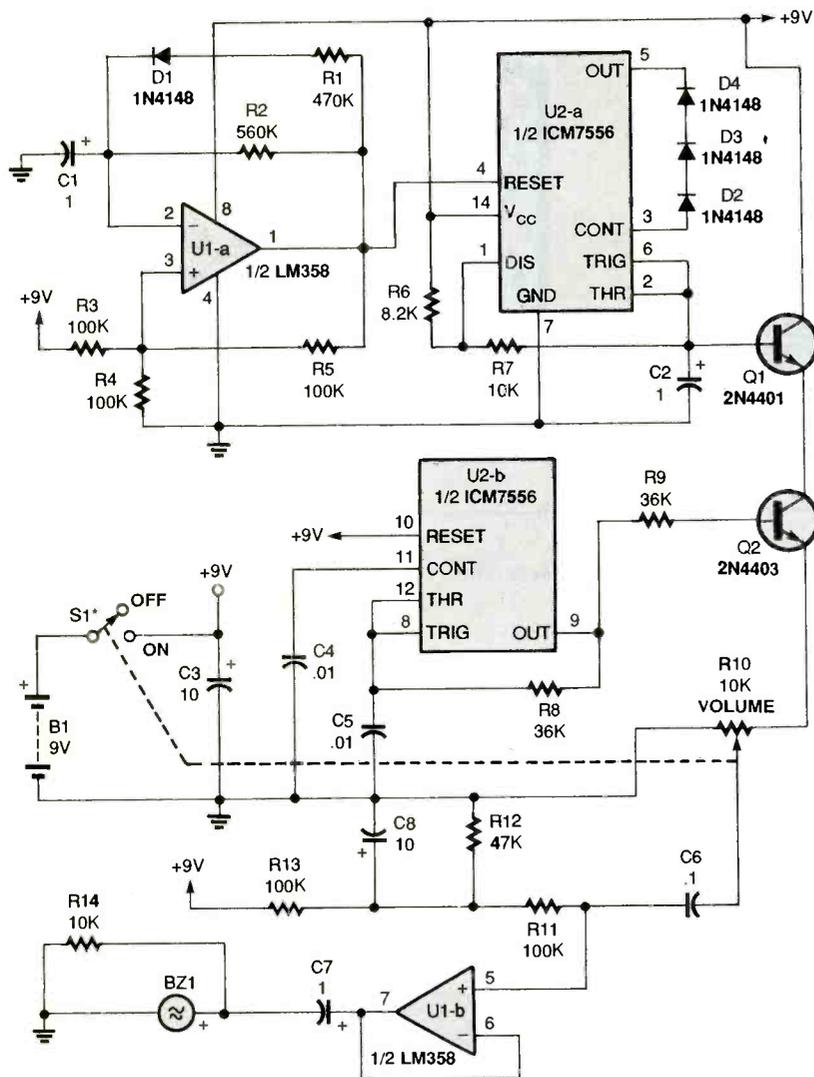


Fig. 1. This circuit matches the 0.22-second period of a cricket's seven-beat chirp, and the 0.35-second time of a cricket's wing. Potentiometer R10 is used as both a power switch (S1) and a volume control.

modified to  $\frac{1}{2}$  the voltage drop across the three diodes (about 1 volt). The longer discharge time that results is offset by resistors R6 and R7, which cause the first charge time to be very close to the subsequent timing cycles.

The lower voltage across C2 is just below the cutoff voltage of transistors Q1 and Q2, thereby ensuring that both transistors will be turned off at the very bottom of each discharge cycle. The cut-off time has been established to allow the piezoelectric element, BZ1, to ring down to zero in order to achieve 100% amplitude modulation. The resulting voltage across C2 produces the amplitude modulation envelope and is buffered by Q1.

Timer U2-b is configured as a conventional pulse generator with a symmetrical duty cycle and an output

frequency of 2 kHz. The output of U2-b is used to switch Q2 on and off, which produces a voltage across volume-control R10 that has the magnitude of the instantaneous voltage across C2 with a 2-kHz sampling rate. A portion of that voltage is applied to U1-b, which is configured as a unity-gain, non-inverting buffer that drives the piezo element, BZ1. A suitable piezo device is Radio Shack catalog no. 273-073, which has a center frequency of 500 to 2500 Hz. That piezo element comes in a Helmholtz resonator cavity that attenuates higher-frequency components of the square-wave to produce a sinewave, which more closely resembles the sound produced by a cricket.

**Construction.** To make the unit por-

## PARTS LIST FOR THE CHIRRUP

### SEMICONDUCTORS

- U1—LM358 dual op-amp, integrated circuit
- U2—ICM7556 dual CMOS timer, integrated circuit
- Q1—2N4401 NPN transistor
- Q2—2N4403 PNP transistor
- D1-D4—1N4148 general-purpose silicon diode

### RESISTORS

(All fixed resistors are  $\frac{1}{4}$ -watt, 5% units.)

- R1—470,000-ohm
- R2—560,000-ohm
- R3-R5, R11, R13—100,000-ohm
- R6—8200-ohm
- R7, R14—10,000-ohm
- R8, R9—36,000-ohm
- R10—10,000-ohm audio-taper potentiometer with switch (Mouser 31TV401 or equivalent)
- R12—47,000-ohm

### CAPACITORS

- C1, C2, C7—1- $\mu$ F, 16-WVDC, electrolytic
- C3, C8—10- $\mu$ F, 16-WVDC, electrolytic
- C4, C5—0.01- $\mu$ F, ceramic-disc
- C6—0.1- $\mu$ F, ceramic-disc

### ADDITIONAL PARTS AND MATERIALS

- BZ1—Piezo element (Radio Shack 273-073 or equivalent)
- S1—SPDT switch (part of R10)
- B1—9-volt battery

Printed-circuit materials, project enclosure, battery snap with leads, IC sockets for U1 and U2, machine screws and nuts, water-soluble flux, wire, solder, hardware, etc.

**Note:** The following items are available from Vista (P.O. Box 1425, Bolingbrook, IL 60440; Tel. 708-378-5534): double-sided PC board (CHIRRUP-BRD)—\$10.00; kit of all parts including prepunched case with silk screen and battery (CHIRRUP-KIT)—\$38.00; fully assembled Chirrup with battery (CHIRRUP-ASSEM)—\$48.00. Add \$5.00 shipping and handling on all orders. Illinois residents please add appropriate sales tax. Check, money order, and credit cards are accepted. For fast check verification, please provide street address (no P.O. box), telephone number, and driver's license number with state of issue.

table, the author's prototype was built on a double-sided printed-circuit

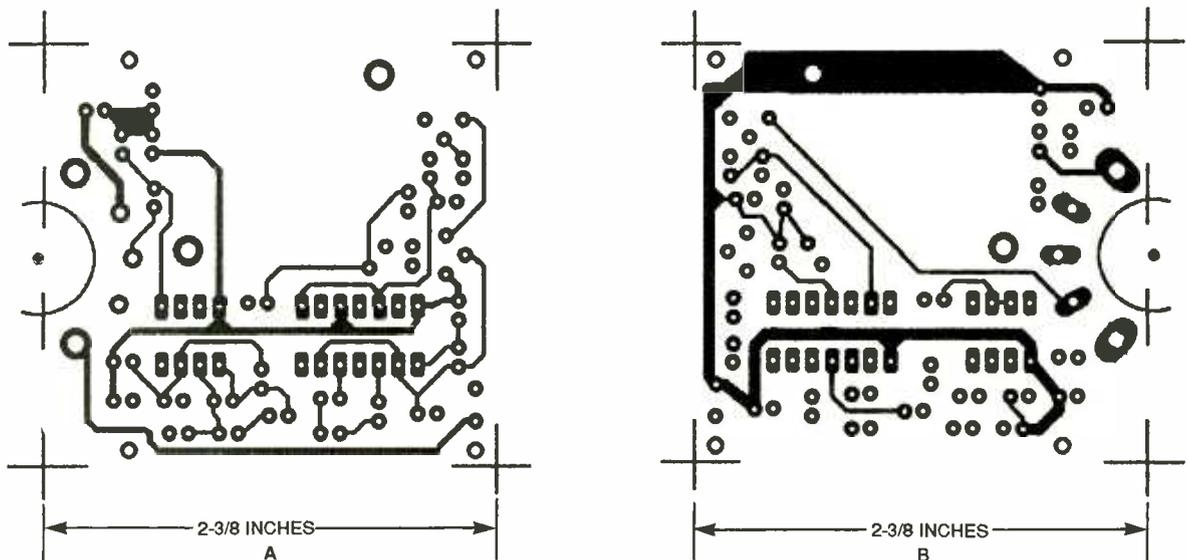


Fig. 2. The template for the solder side of the board is shown in A; the component side of the board is shown in B.

board. However, any standard project-building method can be used. If you do want to build the circuit on the PC board, you can either etch your own using the solder- and component-side foil patterns shown in Figs. 2A and 2B, respectively, or you could order the board from the source mentioned in the Parts List. Use the parts-placement diagram shown in Fig. 3 as a guide if you do use the printed-circuit board.

Mount potentiometer R10 so that its terminals are on the component side of the circuit board, with the knob shaft facing upward. Next, mount IC sockets for U1 and U2, being careful to observe the proper orientation. Working outward from the center of the board, install the resistors standing upright, followed by the capacitors. Double-check the orientation of the electrolytic capacitors. Then install the diodes and transistors, and insert the ICs.

Cut the battery-snap connector leads to a length of approximately 2½ inches, and solder them to the board. The leads should be positioned along the side of the board and routed to the battery compartment in a way that allows a little slack when installing batteries. A little silicone rubber can also be applied at the connection point to reduce the strain.

To prevent foreign material from entering the piezo element housing, clean the residual flux off the board before installing the unit. Trim the leads of element BZ1 to a 1 inch length and solder them to the appropriate

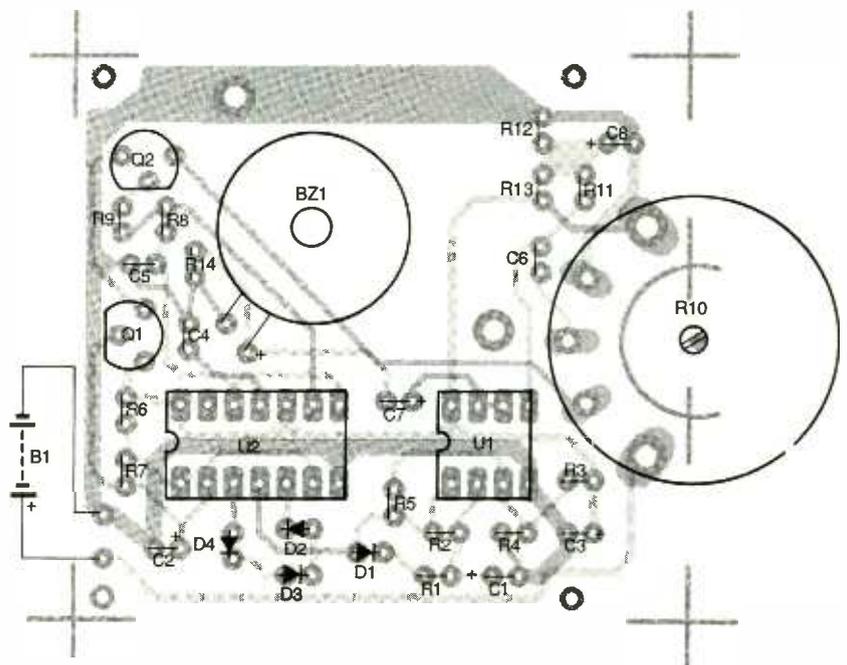


Fig. 3. When mounting components to the double-sided board, use this parts-placement diagram as a guide.

points (again, see Fig. 3). The piezo element can be glued to the board or secured with machine screws and nuts. Be careful how you mount it though, as placing the element near structures that obscure the opening can alter its audio characteristics. For best results, speaker cloth or acoustically transparent speaker foam can be used in front of BZ1 to cover a sound hole on the enclosure's surface.

The author's prototype board was placed in a Serpac M6-style case, which is available as part of a kit from the source mentioned in the Parts List.

Of course, any case that the board fits in can be used. How you mount the board depends on the case you use; for the Serpac case, four plastic mounting posts are provided (a bit of ¼-inch-thick foam tape will keep the board firmly held between the two halves of that case).

When your Chirrup is assembled, connect a fresh 9-volt battery to the snap, and turn on the power by turning potentiometer R10 (which closes the built-in switch, S1). Then sit back and enjoy your very own "Cricket on the Hearth."

# DTMF Decoder/Logger

If you've ever wanted to keep a running log of all the activity on your phone line, then the *DTMF Decoder/Logger* described in this article is for you. It can decode all 16 DTMF tones that are used by standard, touch-tone telephones, and automatically log the numbers. The Decoder can also be wired directly to the speaker terminals of any radio receiver to decode repeater codes, control codes, or any other touch tones that are broadcast.

The Decoder's nonvolatile memory will continually hold the last 240 characters entered, which can then be viewed on a 16-character LCD display by using a pair of pushbutton switches to scroll through the contents of memory. A "space" is automatically inserted between groups of numbers that are received more than ten seconds apart for ease of viewing.

**Circuit Description.** The schematic diagram for the DTMF Decoder/Logger is shown in Fig. 1. The circuit is powered by a 9-volt battery, B1; a 78L05 regulator, U4, drops the voltage to the 5 volts required for the circuit. To stabilize the operation of the regulator, capacitors C9 and C10 are used.

Capacitors C1 and C2, and transformer T1, isolate the circuit from the phone line and couple the DTMF tones to pin 7 of U1. That MC145436 DTMF receiver converts the tones generated by your phone into 4-bit TTL-level data.

The circuit is protected from high-voltage spikes on the line by MOV1, a metal-oxide varistor. Zener diodes D1 and D2 clamp the ringer voltages.

At the heart of the circuit is microcontroller U2, a PIC16C55. That microcontroller receives the 4-bit DTMF identification data from U1's output pins, converts it to ASCII characters, then stores that information in the



*Keep track of phone numbers that were called from your phone, or "catch" the tones you hear in broadcasts.*

BY TERRY J. WEEDER

93LC56 EEPROM, U3. Microcontroller U2 also monitors switches S2 through S4, and manages the LCD display module, DISP1. (The microcontroller, EEPROM, and display module will all be looked at more closely later.)

In order to scan the switches for activity, U2 sets bit 3 of port A (pin 9) low to provide a corresponding low through R1 on any switch that is closed. When bit 3 is set high, U1 is enabled (that occurs when you check for a DTMF tone). The 3.58-MHz crystal, XTAL1, generates the clock pulse that is shared by both U1 and U2. Trimmer-potentiometer R6 is used to adjust the contrast of the LCD display.

**The Microcontroller and EEPROM.** The PIC16C55 is an 8-bit CMOS microcontroller (manufactured by Microchip) that has two 8-bit I/O ports, one 4-bit I/O port, 512 × 12 bits of on-chip EPROM for storing the operating program, and 32 × 8 bits of data RAM. Each pin of each I/O port can be configured individually as either an input or output through software commands.

The instruction set for the PIC consists of 33 single-word operations, most of which require one cycle (four clock pulses) for execution. Those instructions that force a program branch require two cycles.

One of the other ICs used in the Decoder, U3, is also manufactured by Microchip. That chip is a 93LC56 2K serial EEPROM. In our application, four pins of the 93LC56 interface with three pins of U2: the chip select (cs) pin of U3 connects to pin 6 of U2, the clock (clk) pin of U3 connects to pin 7 of U2, and both the data in (di) and data out (do) pins of U3 connect to pin 8 of U2. Because the di and do pins share the same line, R7 limits current flow during those transition times between read and write when there are conflicting logic levels.

Microcontroller U2 communicates with the 93LC56 by placing a high on the CS pin. Data is then transferred serially to and from the 93LC56 on the positive transition of the clk pin. Each read or write function is preceded by a start bit, an opcode (that identifies the function to be performed), then an 8-bit address, followed by the 8 bits of data that is being written to, or read from that address. Immediately preceding and following all write operations, the microcontroller sends instructions to the 93LC56 that enables/disables the write function, protecting the data thereafter.

**LCD Display Module.** The component used for DISP1 is a 1-line, 16-character, LCD module. It has its own built-in controller designed to display both numbers and letters by receiving the standard ASCII code equivalent on its 8-bit port. Data, including the ASCII codes, are sent to the display via port C (pins 18–25) of microcontroller U2. The last three bits of U2's port B (pins 15–17) are used as control lines for the display.

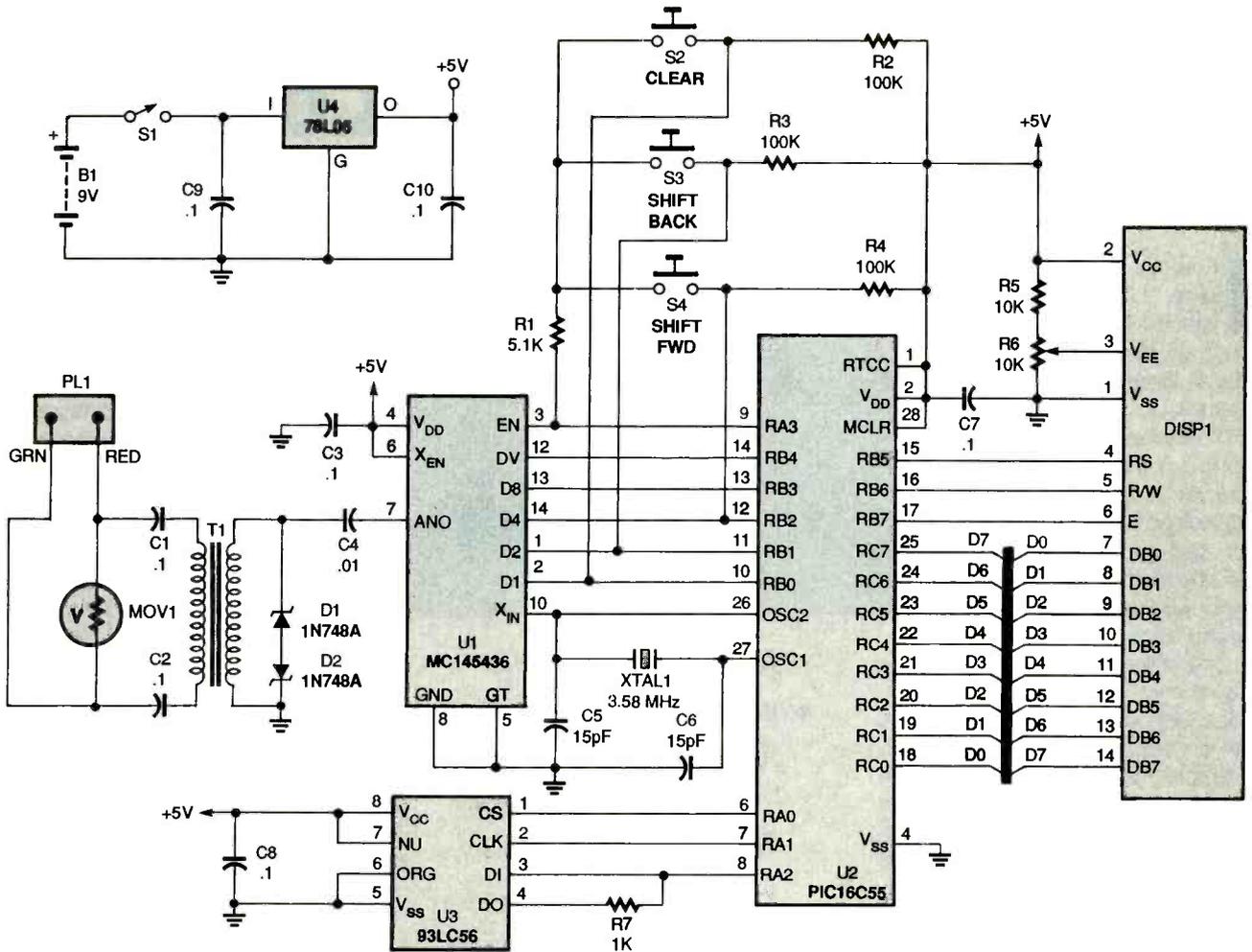


Fig. 1. Here's the schematic for the DTMF Decoder/Logger. The preprogrammed microcontroller, U2, monitors switches S2-S4, takes the decoded DTMF data from U1, and stores the data in U3, the EEPROM. Microcontroller U2 also manages the LCD display module, DISP1, which allows viewing of the DTMF digits stored in U3.

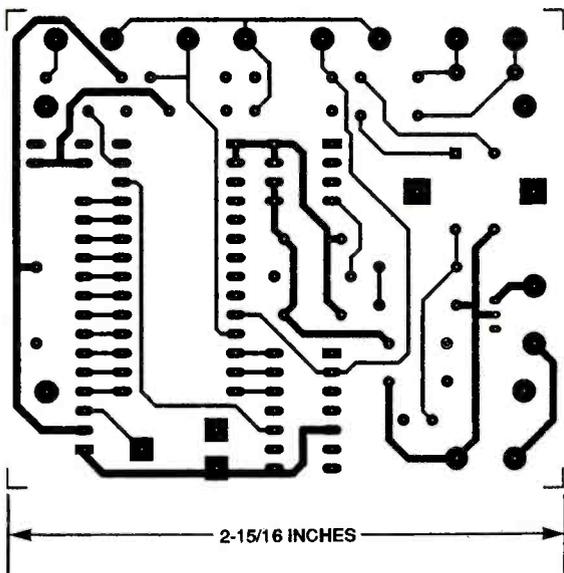


Fig. 2. This is the full-size template for the solder side of the double-sided circuit board.

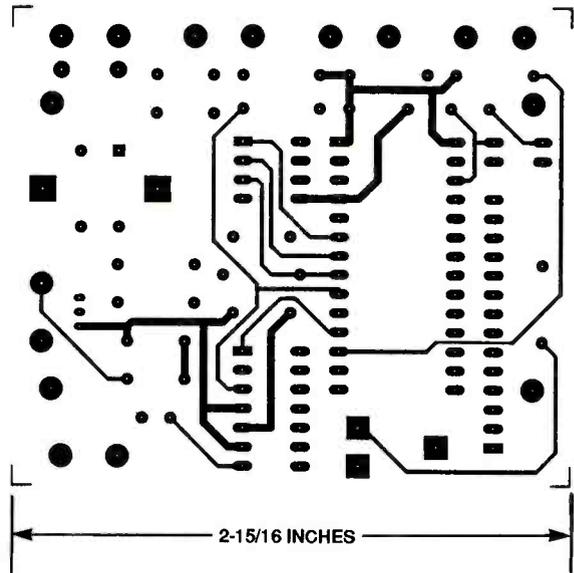


Fig. 3. Here's the component side of the DTMF Decoder/Logger's PC board.

## PARTS LIST FOR THE DTMF DECODER/LOGGER

### SEMICONDUCTORS

- U1—MC145436 DTMF receiver, integrated circuit  
 U2—PIC16C55 (preprogrammed) 8-bit microcontroller, integrated circuit  
 U3—93LC56 serial EEPROM, integrated circuit  
 U4—78L05 5-volt regulator, integrated circuit  
 DISP1—16 × 1-character LCD module (Optrex DMC16117 or equivalent)  
 D1, D2—1N748A 3.9-volt Zener diode  
 MOV1—130 VRMS, metal-oxide varistor

### RESISTORS

- (All fixed resistors are 1/4-watt, 5% units.)  
 R1—5100-ohm  
 R2—R4—100,000-ohm  
 R5—10,000-ohm  
 R6—10,000-ohm, trimmer potentiometer  
 R7—1000-ohm

### CAPACITORS

- C1—C3, C7—C10—0.1- $\mu$ F, Mylar  
 C4—0.01- $\mu$ F, Mylar  
 C5, C6—15-pF, ceramic-disc

### ADDITIONAL PARTS AND MATERIALS

- T1—600-ohm primary, 600-ohm secondary, audio transformer  
 XTAL1—3.58-MHz, TV colorburst crystal  
 PL1—Modular telephone plug  
 S1—SPST toggle switch  
 S2—S4—SPST pushbutton switch, momentary contact, normally open  
 B1—9-volt battery  
 Printed-circuit materials, project enclosure, IC sockets, battery snap with leads, ribbon cable, telephone cable, RTV adhesive, wire, solder, hardware, etc.

**Note:** The following items are available from Weeder Technologies (P.O. Box 421, Batavia, OH 45103; Tel. 513-752-0279): Double-sided etched and drilled PC board (WTTDL-B)—\$9.50; all board-mounted components, including a pre-programmed PIC16C55 (WTTDL-C)—\$26.50; LCD display module (DISP16X1)—\$18.50; pre-programmed PIC16C55 (PIC-TDL)—\$18.00. All orders must include an additional \$4.00 for shipping and handling. Ohio residents please add 6% sales tax. VISA, MC welcome.

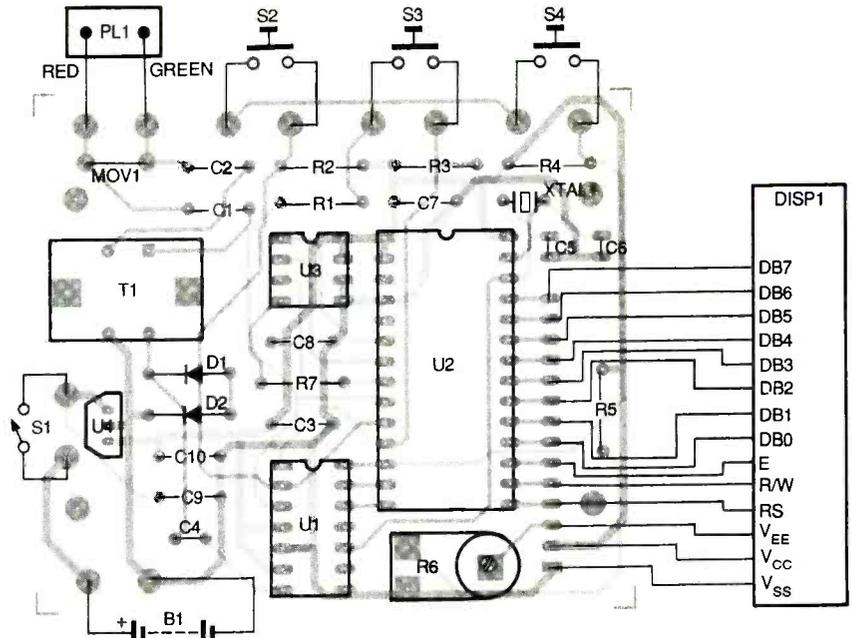


Fig. 4. Use this parts-placement diagram when mounting components to the component side of the PC board. Ribbon cable can be used to connect the display module to the main board.

The process of writing a character to the display consists of first placing the character's 8-bit address, or location, on port C, thereby setting the correct status on the control lines while strobing the enable line. Then, the actual ASCII character code is placed on port C, while again strobing the enable line with the correct status on the control lines. The microprocessor then changes port C to an input, sets the status lines to read the busy flag from DISP1, and strobes the enable line until the busy flag indicates that DISP1's internal operation has finished writing the character to the screen. All of those operations take less than 100 microseconds to complete.

**The Program.** For the microcontroller to perform all the functions described in this article, it needs to be programmed with the DTMF Decoder/Logger firmware. A PIC16C55 microcontroller pre-programmed with the firmware is available from the source mentioned in the Parts List. For those who have the equipment and wish to program their own microcontroller, the source and object code files for the PIC16C55 are available on the **Popular Electronics** bulletin board (516-293-2283).

Here's how the PIC16C55 microcontroller works when programmed

with the firmware. Upon power-up, the microcontroller sends a series of commands to the LCD module to initialize it; a logo is then printed across the display and remains there for a few seconds before clearing. The microcontroller goes on to read the 93LC56 EEPROM and determines whether any characters have been previously stored there, and if so, the microcontroller sets the EEPROM address pointer to the end of memory. If the 93LC56 is found to be blank, the microcontroller branches to a subroutine that writes a space (in ASCII format) to all locations in the EEPROM and then sets the EEPROM address pointer to the beginning.

The PIC16C55 constantly monitors switches S2—S4 and the DTMF receiver, U1. When a high is detected on the data-valid (dv) pin of U1 (indicating that a valid DTMF tone pair is sensed and decoded at U1's output), the PIC reads that decoded value through port B, converts it to its ASCII character equivalent, and stores it in the next available memory location in the EEPROM, using port A. Starting from the EEPROM address pointer, U2 reads the next 16 characters from the EEPROM and writes them across the display from left to right. Because the DTMF digit was placed in the next available memory location and all unused areas of memory were initially

set to spaces, the character appears at the leftmost position of the display with all other locations showing a blank space.

Each additional DTMF digit that is received is stored in a subsequent memory location, and the display is again rewritten starting from the EEPROM address pointer that has not been changed. That causes each new character to be shown immediately to the right of the last one. When more than 16 characters have been received, the EEPROM address pointer increments prior to a display rewrite. As a result, when reading the EEPROM and writing the characters to the display, it appears that all characters have shifted to the left and that they continue to do so as each new digit is received.

If a time period of more than 10 seconds elapses between the reception of DTMF tones, the microcontroller inserts a space in memory, and sets the address pointer to the end. When the next group of DTMF tones are received, the screen appears to be cleared, and the new characters start printing on the left-hand side of the display as if the DTMF Decode/Logger was just powered up or cleared.

When the microcontroller detects a

high from any one of pushbutton switches S2–S4, one of the following occurs:

**Switch S2 (CLEAR) is Pressed:** The microcontroller writes a space to all locations in the EEPROM, sets the address pointer to the beginning of memory, then writes the next 16 characters in the EEPROM to the display.

**Switch S3 (SHIFT BACK) is Pressed:** The microcontroller decrements the address pointer, then writes the next 16 characters in the EEPROM to the display. That action is continuously repeated while the switch is held down.

**Switch S4 (SHIFT FWD) is Pressed:** The microcontroller increments the address pointer, then writes the next 16 characters in the EEPROM to the display. That action is repeated for as long as the switch is held down.

**Construction.** The author's prototype for the DTMF Decoder/Logger was built on a double-sided printed-circuit board measuring just  $2\frac{1}{2} \times 3$  inches. A pre-etched and drilled PC board can be obtained from the source mentioned in the Parts List, or you could make your own using the templates shown in Fig. 2 and Fig. 3. Of course, the circuit can also be built

on a perforated board, using point-to-point wiring. But if you do use a PC board, the parts-placement diagram shown in Fig. 4 should make building the board a lot easier.

Identify the component side of the board (it has the pattern shown in Fig. 3), and start by soldering in IC sockets for U1, U2, and U3 (but don't insert the ICs yet). Mount U4 directly to the board, being very careful to avoid solder bridges between the pads, which are very close together.

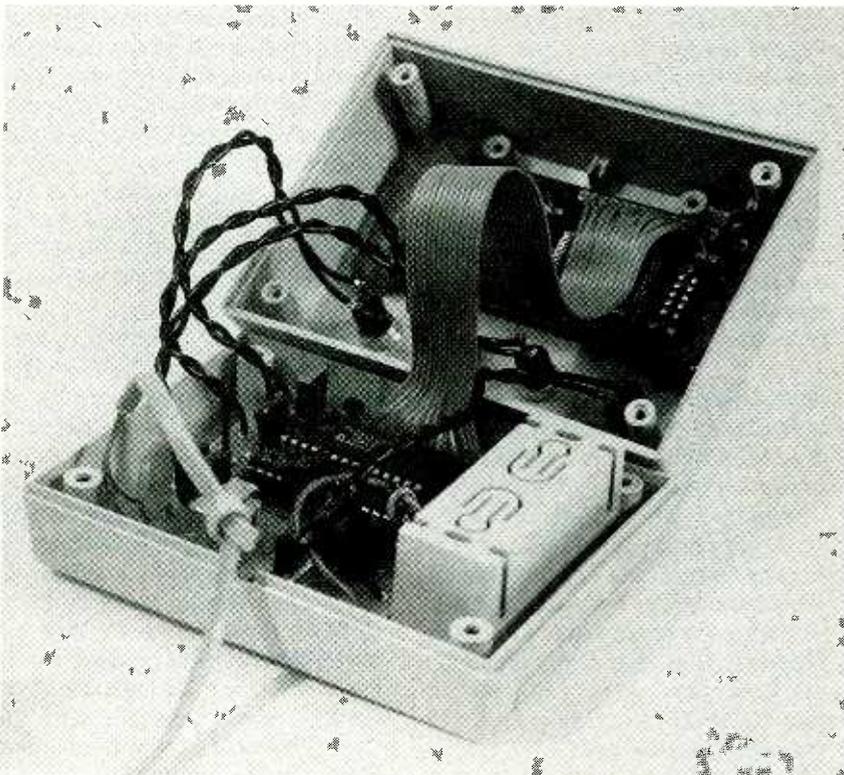
Next, mount the resistors, capacitors, and diodes, paying attention to the orientation of the latter. When soldering crystal XTAL1, leave a small space between the bottom of the crystal and the PC board. There is a chance that the metal case of the crystal could short the two solder pads together if it is mounted flush against the board. Next, install transformer T1 and varistor MOV1.

Use a piece of 14-conductor ribbon cable to connect the display module, DISP1, to the board. If you can't find that type of cable, 25-conductor ribbon cable, which is readily available from Radio Shack (catalog no. 278-772), will work fine. Simply peel off the 11 excess wires. Separate the conductors on each end of the cable by a length of about 1 inch to make it easier to solder to the PC board and the display module. On the PC board, the pad for pin 1 is rectangular instead of oval; be sure to match that pad with the pad labeled "1" on the display module.

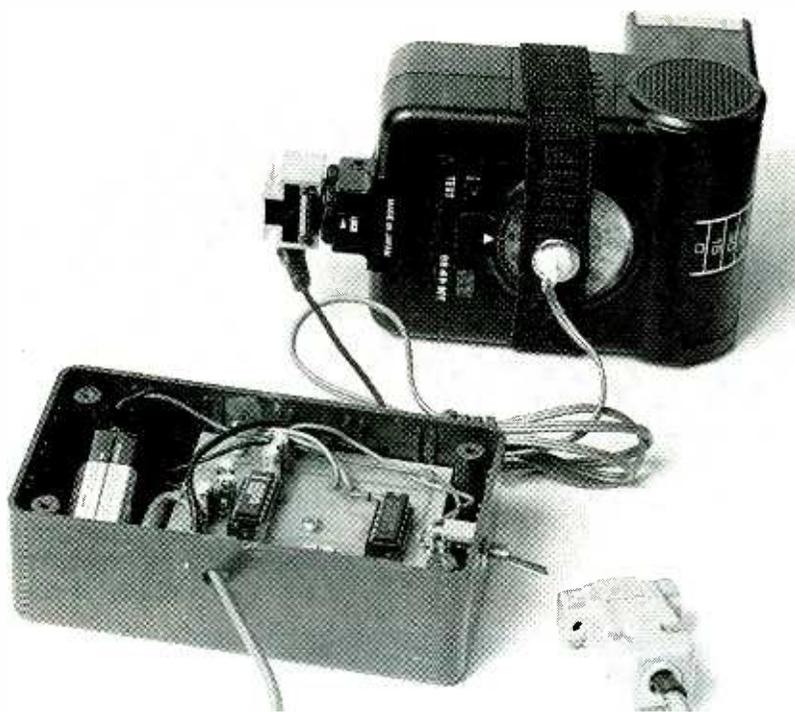
Switches S1–S4 are mounted on the enclosure. Cut eight 6-inch pieces of insulated hook-up wire and twist them into pairs. You will use those wires to connect the switches to the board. Solder a battery snap to the terminals as shown in Fig. 4, making sure that the red wire goes to the "+" terminal and the black wire goes to the "-" one.

Solder the red and green leads of a phone cord to their appropriate connection points on the board, and attach the other ends of those leads to the proper positions in a modular plug. If you're not sure of how to do so, use a modular plug that comes with a phone cord already attached. The yellow and black leads are not used and can be cut off.

After soldering all components and wires to the PC board, carefully check  
(Continued on page 102)



This internal view shows how the display module and main PC board are connected. Ribbon cable keeps the assembly neat.



BY JAMES BAILEY

# Flash-Battery Tester

*Just how good are the batteries you're using in your flash? Use this project and your PC to find out.*

**W**ant to know exactly how a particular brand or type of battery performs in your electronic flash? Well, if you have a PC, you can use it and the *Flash-Battery Tester* described in this article to evaluate different batteries in your flash and get a permanent record of how well they did.

With the Tester, there's no need to invest in or build an expensive analog-to-digital converter or data-acquisition system. Neither will you need to write several pages of complex code to do the testing. Just enter into your PC the short BASIC program listed within this article, plug the Tester into the computer's serial port, and you're all set.

**Battery Differences?** We'll get to how the Tester works in a moment. But first, let's just take a brief look at how different types of batteries behave in

different ways when used with a camera flash.

Figure 1 contains a graph showing how one brand of "AA" alkaline batteries compares with "AA" lithium ones. As you can see, lithium batteries maintain a shorter recycle time for a greater number of flashes. After 150 flashes, an alkaline battery takes almost 29 seconds to recycle the flash, while a lithium battery only takes 10 seconds to recycle after the same number of flashes.

But the differences don't end with types of batteries. Different brands of the same type of battery can perform significantly better or worse than each other as well. So, as you can see, there are lots of tests to perform with the Flash-Battery Tester.

**Circuit Description.** The schematic for the Flash-Battery Tester is shown in Fig. 2. Power from a 9-volt battery, B1, is

fed to a 78L05 regulator, U3. The IC then produces a regulated 5 volts to power the rest of the circuit.

A cadmium-sulfide photocell, PC1, conducts when a connected flash's ready light comes on and illuminates it. When current flows through PC1, U1-a and U1-b, two sections of a 74HC132 quad Schmitt trigger NAND gate, produce a sharp-edged TTL high. A MAX232, U2, converts the high to an RS232 low that is compatible with the PC's serial port. The MAX232 also takes an incoming serial-port pulse and converts it to TTL levels to fire the flash via SCR1, a C106D2 silicon-controlled rectifier.

As mentioned earlier, the circuit works with a BASIC program (see Listing 1). That program fires the flash by sending a brief pulse through plug PL1 to the serial port's DTR pin. The program then starts timing how long it takes for the flash to recycle. In other words, the program "looks" at the CTS pin over and over until it sees that it went low. That happens when the photocell is lit by the flash's ready light. The program records the elapsed time and then continues counting until one minute elapses.

At that time the DTR pin is cycled again to fire the flash and the process is repeated. The test concludes when the recycle time exceeds 45 seconds.

**Construction.** There is nothing critical about the layout of the Tester, so any project-building method can be used. For those who would like to etch a PC board, however, a full-size template is shown in Fig. 3.

If you use a PC board, refer to the parts-placement diagram in Fig. 4 when installing the components. Begin by mounting IC sockets for U1 and U2. Make sure they are oriented properly. Then, go on to install the resistors and capacitors, making sure to match the polarity of the latter with what's shown in Fig. 4.

Next go on to solder U3 and SCR1 to the board. Make sure to follow the orientation shown for the components in the parts-placement diagram.

Now we get to a slightly more tricky part, the photocell assembly. Cut an elastic strap to a length of approximately 7 inches. Sew the strap so that it makes a band or loop, and then cut a hole in it.

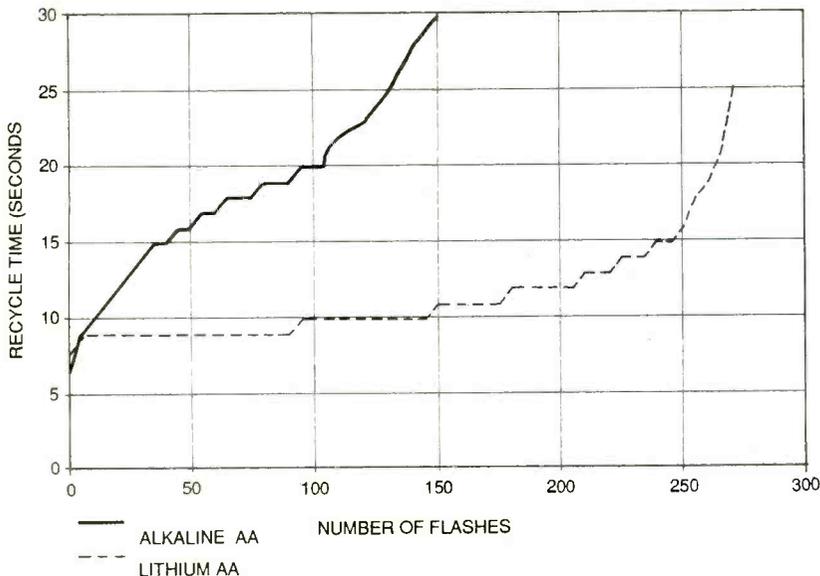


Fig. 1. As this comparison chart shows, typical lithium batteries keep shorter flash recycle times for a greater number of flashes than do alkaline ones.

using a large center punch.

Solder two-conductor wire to the photocell's leads. Unless the photocell's leads are very short, insulate the connections with shrink tubing. Center the photocell in the eyelet so that the sensor points into the band, and epoxy the photocell in place. When the epoxy is cured, you might want to reinforce the leads with more epoxy or silicone caulk.

When the photocell assembly is ready, take the loose ends of the wire and attach the conductors to their appropriate points on the board (see the parts-placement diagram). The elastic band should easily slip over your flash.

Use one end of a flash sync cord to connect the Tester to your flash (sync cords are available at any photo

#### LISTING 1

```

10 ***** RECYCLE TEST *****
20 KEY OFF
30 C$=""
80 '
90 '
100 ***** ESTABLISH DISK FILE *****
105 '
110 '
115 CLS: LOCATE 1,1:INPUT"ENTER DATA FILENAME
";FILENAME$
120 FILENAME$="A:"+ FILENAME$+".PRN"
130 OPEN FILENAME$ FOR APPEND AS #1
140 N%=0
150 INPUT "ENTER SAMPLE DESCRIPTION
";SAMPLE$
160 PRINT #1, SAMPLE$
170 PRINT #1,"FLASH #";",";","SECONDS"
180 '
190 '
200 ***** ARE YOU READY? *****
205 '
210 '
215 CLS:LOCATE 1,1:PRINT "PRESS ANY KEY TO
START TEST"
220 A$=INKEY$:IF A$="" THEN GOTO 220
230 CLS
240 '
250 '
260 ***** FIRST SHOT *****
270 '
280 '
310 F=TIMER
320 OUT &H3FC,(&H1 OR INP(&H3FC))
330 FOR I%=1 TO 10 :NEXT I%
340 OUT &H3FC,(&HFE AND INP(&H3FC))
350 FOR I%=1 TO 1000: NEXT I%
360 '
370 '
380 ***** CHECK FOR READY *****
390 '
400 '
405 LOCATE 1,1:PRINT C$:LOCATE 1,1:PRINT
"FLASH IS CHARGING"
410 T%=(INP(&H3FE)AND &HFF)
415 IF T%>5 THEN GOTO 420
417 LOCATE 1,1:PRINT C$:LOCATE 1,1:PRINT"READY
LIGHT IS ON"
420 LOCATE 2,1:PRINT C$:LOCATE 2,1:PRINT USING
"##.##";TIMER-F
430 IF T%>5 THEN GOTO 405
440 B=TIMER-F
450 N%=N%+1
460 GOSUB 1000: ***** SAVE READING TO
DISK *****
465 ***** IF RECYCLE TIME IS >45 SEC, THEN
TERMINATE TEST *****
470 IF B>=45 THEN GOTO 9000
500 ***** NEXT CYCLE
*****
515 LOCATE 5,1:PRINT"ELAPSED TIME="
520 LOCATE 5,17:PRINT USING "##";TIMER-F
530 IF TIMER-F>=60 THEN GOTO 550
540 GOTO 520
550 CLS:GOTO 310
995 '
1000 ***** DISK DATA STORAGE
*****
1005 '
1010 PRINT #1,N%,"";B
1020 RETURN
8990 '
8900 ***** CLOSE DISK FILE AND END TEST
*****
8910 '
9000 CLOSE #1
10000 END

```

Pass one half of a brass eyelet through the hole in the band, and put a few drops of white glue around the edges of the hole to keep the edges

from fraying. Slip the other half of the eyelet through the first half's opening. Secure the halves together using a swagging tool or by hammering them

store). Cut off the end that doesn't go to the flash, strip the exposed leads, and solder them across SCR1 as shown in Fig. 4.

## PARTS LIST FOR THE FLASH-BATTERY TESTER

### SEMICONDUCTORS

U1—74HC134 quad Schmitt trigger NAND gate  
 U2—MAX232 RS232 interface  
 U3—LM78L05 5-volt regulator  
 Q1—2N3906 PNP transistor  
 SCR1—C106D2 silicon-controlled rectifier

### RESISTORS

(All resistors are 1/2-watt, 5% units.)  
 R1—51,000-ohm  
 R2—15,000-ohm  
 R3—1200-ohm  
 R4—470-ohm

### ADDITIONAL PARTS AND MATERIALS

C1—C5—10- $\mu$ F, 16-VVDC, electrolytic capacitor  
 PC1—Cadmium-sulfide photocell  
 S1—SPST miniature toggle switch  
 PL1—9-pin D plug and shell  
 Printed-circuit materials, project enclosure (Radio Shack 270-222 or equivalent), electronic flash-sync cord (should fit your flash), IC sockets, 9-volt battery and connector, two-conductor wire (such as speaker wire) for photocell, four-conductor wire (such as telephone wire) for D plug, elastic strap, brass eyelet, epoxy, wire, solder, hardware, etc.

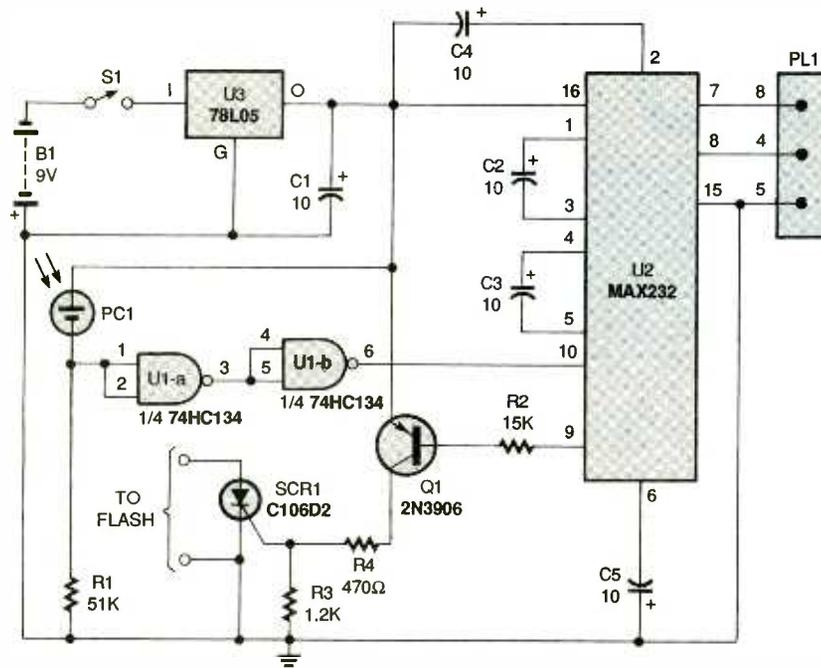


Fig. 2. This is the schematic for the Flash-Battery Tester. A MAX232 (U2) and a 9-pin D plug (PL1) provide a simple interface to a PC.

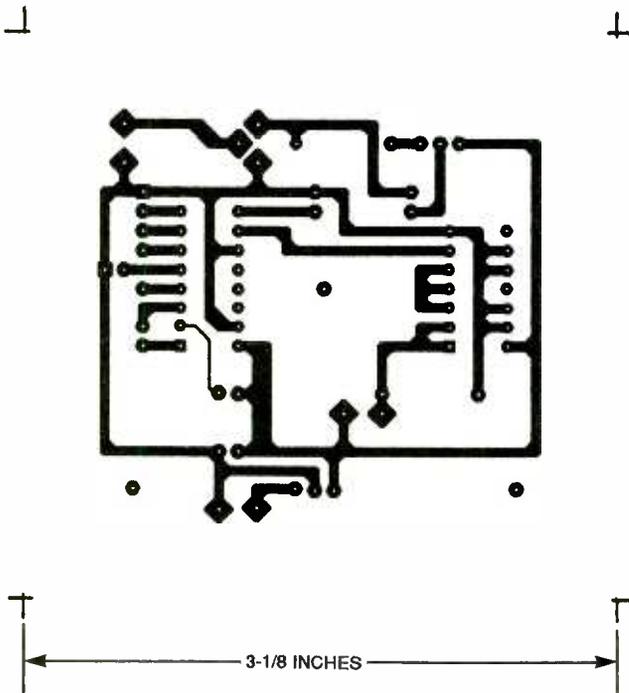


Fig. 3. Layout of the Tester is not critical, but if you'd like to build the project on a PC board, use this template to etch your own.

Mount the board in a suitable project enclosure. Using the parts-placement diagram as a guide, attach a battery snap and leads for switch S1 to the appropriate points. Mount the switch to the enclosure and connect that component to the leads you just mounted.

The last step is to attach the proper pins of PL1, the 9-pin D plug and shell,

to their proper points on the board. Use a four-conductor wire to accomplish that.

**Checkout.** Install a 9-volt battery and turn S1 on. Connect a voltmeter between pins 5 and 8 of PL1. Be sure that the photocell is somehow kept dark. The voltmeter should read between 8 and 10 volts, and pin 8 should

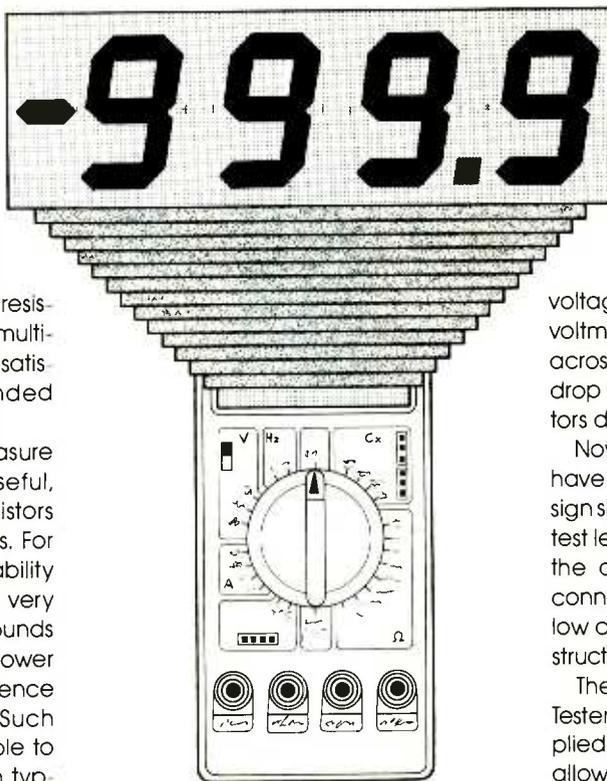
be positive. Shine a flashlight at the photocell; the voltmeter should now read the same voltage, but pin 8 should be negative.

Strap the photocell around your flash so the photocell sits directly over the ready light. Turn on the flash. When the ready light comes on, pin 8 of PL1 should again switch from positive to negative.

Temporarily connect pin 8 of PL1 to pin 4. Keep the photocell dark. Connect your flash to the sync cord, and turn on the flash. Measure the voltage across SCR1; it will be between 5 and 250 volts, depending on the type of synchronizing interface the flash has, but the actual voltage is not important. What is important is that the anode of SCR1 must be positive with respect to its cathode. If not, disconnect the flash, turn off S1, and reverse the wires from the sync cord to SCR1.

Reconnect the flash, if necessary, and turn on S1 and the flash. After the flash's ready light comes on, shine the

(Continued on page 106)



**F**or most applications, the resistance ranges on digital multimeters (DMMs) are usually satisfactory. But sometimes, extended ranges are needed as well.

First of all, the ability to measure smaller resistances can be useful, both to measure low-value resistors and to locate poor connections. For example, the author found the ability to read resistance to 0.001 ohm very helpful in finding the poor grounds that were causing an audio power amplifier to have severe interference from AM broadcast stations. Such measurements can be impossible to do using standard DMMs, which typically can measure and display resistances only as low as 0.1 ohm.

Now, the upper reading of many DMMs is 20, 30, or 40 megohms. But there are also some units that only read up to 2 or 3 megohms, and there are instances when higher ranges are desirable.

So what do you do to add the extra ranges? Build the *Low-Ohms Tester* and the *Megohm Tester* described in this article. They can be used with nearly any DMM to extend the resistance ranges down to 0.001 ohm and up to hundreds of megohms. The Low-Ohms Tester lets you take a direct reading from your DMM's display and simply multiply the reading by 10 or 100. The Megohm Tester requires a two- or three-step calculation with a pocket calculator to determine the resistance.

**How they Work.** Two basic methods of resistance measurement are used in these circuits: the constant-current four-wire method in the Low-Ohms Tester, and the constant-voltage method in the Megohm Tester. Both circuits use a three-terminal voltage regulator to improve accuracy and take advantage of the high sensitivity of the DC voltage ranges of DMMs (usually the lowest readout is 0.1 millivolt, even on low-priced DMMs).

In the four-wire constant-current method shown in Fig. 1, the voltage drop across the resistance being

## Expanded Resistance Ranges for your DMM

BY BILL STILES

*With the help of these two simple devices your DMM can take readings on much lower or higher ranges.*

measured is directly proportional to the resistance. Therefore, by choosing a current of 10 or 100 mA, the calculation is reduced to multiplying the voltage reading by 100 or 10. An advantage of the four-wire method eliminates the effect of test-lead and contact resistance by using four test leads, two to carry the constant current to the resistance being measured, and two for measuring the

voltage across the resistance. Thus the voltmeter reads only the voltage drop across the test resistance; the voltage drop in the current-carrying conductors does not affect the reading.

Now, because it is inconvenient to have four test leads, the type of design shown in Fig. 1 is used. There, each test lead is a two-wire cable. To make the circuit work properly, test clips connected to the leads should have low contact resistance (see the Construction section for more on that).

The actual circuit for the Low-Ohms Tester is shown in Fig. 2. Power is supplied by a 9-volt battery, B1. Switch S1 allows the selection between a current of 10 or 100 mA. As mentioned earlier, that means you would either multiply the voltage reading by 100 or 10, respectively, to find the resistance being measured. The remaining components make up the constant-current circuitry represented in Fig. 1.

Now let's look at the constant-voltage method. There, the resistance being measured is proportional to the current flowing through it. To measure high resistances, a sensitive current meter and/or a high test voltage is needed. The Megohm Tester uses a modified constant-voltage method (shown in Fig. 3), which lets you determine current by measuring the voltage ( $V_x$ ) across a resistor ( $R$ ) in series with another resistance being measured ( $R_x$ ). Resistor  $R$ , shown as a value of 1 megohm, is actually the parallel combination of the DMM's input resistance and a calibration resistor in the Tester.

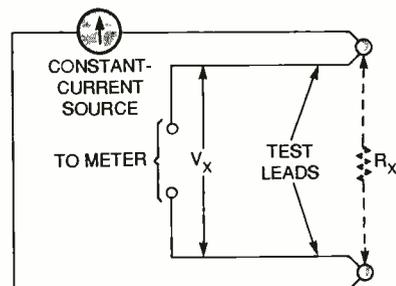


Fig. 1. Shown here is the four-wire constant-current method of measuring resistance.

Now, it's not possible to directly measure  $V_x$  because the input resistance of the meter (10 megohms for many DMMs) would be in parallel. However, because  $V_{in}$  is constant and  $V$  can be measured,  $V_x$  can be calculated by subtracting  $V$  from  $V_{in}$ .

For two resistors in series, the voltage drop across each is directly proportional to its resistance. A formula for the ratio is:

$$R_x/R = V_x/V$$

In this case, with resistances in megohms,  $R$  equals one and the formula becomes:

$$R_x = V_x/V$$

Because  $V_x = V_{in} - V$ , the final formula is:

$$R_x = (V_{in} - V)/V$$

where  $V_{in}$  is the regulated input voltage and  $V$  is the measured voltage (in either volts or millivolts, if they are both the same units), and  $R_x$  will be the resistance being measured (in megohms). For resistances over 100 megohms, the simplified formula:

$$R_x = V_{in}/V$$

can be used with an error of less than one percent. The error does increase at low resistances, though. An error of one percent in  $V_{in}$  or  $V$  gives an error of two percent in  $R_x$  at 1 megohm, three percent at 0.5 megohm, and six percent at 0.2 megohm.

Voltage  $V_{in}$  must be high enough to produce a readable voltage across  $R$ . For a  $V_{in}$  of 6 volts (using a 9-volt battery and a 6-volt regulator) and a DMM whose lowest valid measure-

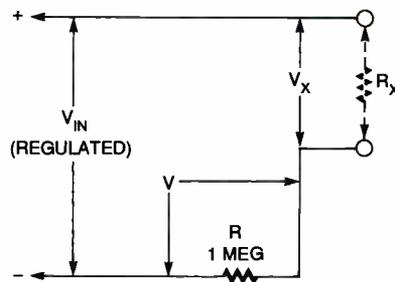


Fig. 3. This is the modified constant-voltage method of measuring resistance. It lets you determine current by measuring the voltage ( $V_x$ ) across a resistor ( $R$ ) in series with another resistance being measured ( $R_x$ ).

ment is 0.1 millivolt, a maximum of 600 megohms can be measured before  $V$  becomes less than three digits. By using two 9-volt batteries in series and a 15-volt regulator, the maximum becomes 1500 megohms.

The actual circuit for the Megohm Tester is shown in Fig. 4. Power is supplied by a 9-volt battery, and switch  $S1$  is a power switch.

As just mentioned, different  $V_{in}$  voltages can be used, so a number of different regulators can be used for  $U1$ . The component chosen for  $U1$  determines the values used for  $R1$  and  $R2$  (see the Construction section and the Parts List for more on that).

Potentiometers  $R2$  and  $R4$  are used to calibrate the circuit. Resistor  $R3$  takes the place of the  $R$  value mentioned in the earlier calculations.

**Construction.** The two circuits should be built on separate circuit boards, using any standard project-building method; layout is not critical.

## PARTS LIST FOR THE LOW-OHMS TESTER (Fig. 2)

### SEMICONDUCTORS

- U1—LM317T adjustable-voltage regulator, integrated circuit
- Q1—2N3906 PNP transistor
- LED1—Low-current light-emitting diode (see text)

### RESISTORS

(All resistors are 1/4-watt, 5% units, unless otherwise noted.)

- R1—135-ohm (see text)
- R2—10,000-ohm
- R3—2200-ohm
- R4—3300-ohm
- R5—12.4-ohm, 1%

### ADDITIONAL PARTS AND MATERIALS

- S1—SPDT miniature toggle or slide switch
- B1—9-volt alkaline battery
- Perforated board (see text), enclosure, 9-volt battery snap with leads, zip cord (18 or 20 gauge), alligator clips (see text), tip jacks or banana plugs, wire, solder, hardware, etc.

You could then mount the two completed boards in the same case and, if you wish, power them from the same 9-volt battery.

When building the Low-Ohms Tester, start by mounting the resistors. Then install  $Q1$  and  $U1$ , making sure to observe proper orientation for each. Switch  $S1$  and  $LED1$  can be mounted to the case.

To make test leads, you can use zip cord (18 or 20 gauge). For the test connectors at the end of the leads, don't use ordinary plated-steel alligator clips because their contact resistance is too high. Kelvin Clips, which are designed for four-wire resistance measurement, are recommended. The jaws of those clips are insulated from each other, and you can connect one wire of a test lead to each jaw. The drawback to Kelvin Clips is that they are rather expensive; contact Hosfelt Electronics, Inc. (2700 Sunset Blvd., Steubenville, OH 43952-1158; Tel. 800-534-6464; Fax: 800-524-5414) for more information.

An alternative to the Kelvin Clips are large, solid-copper alligator clips, which work almost as well and are much cheaper. They could have contact resistances of less than 0.001 ohm, but you could have to move them slightly, after clipping them on

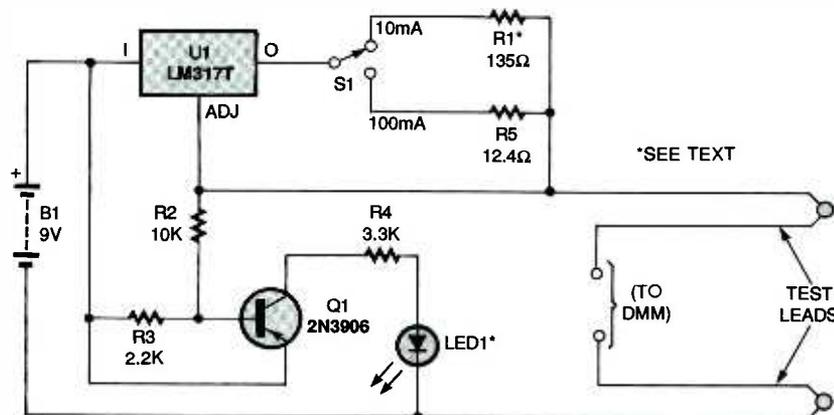


Fig. 2. Here's the schematic for the Low-Ohms Tester. Switch  $S1$  allows the selection between a current of 10 or 100 mA, which means you would either multiply the voltage reading by 100 or 10, respectively, to find the resistance being measured.

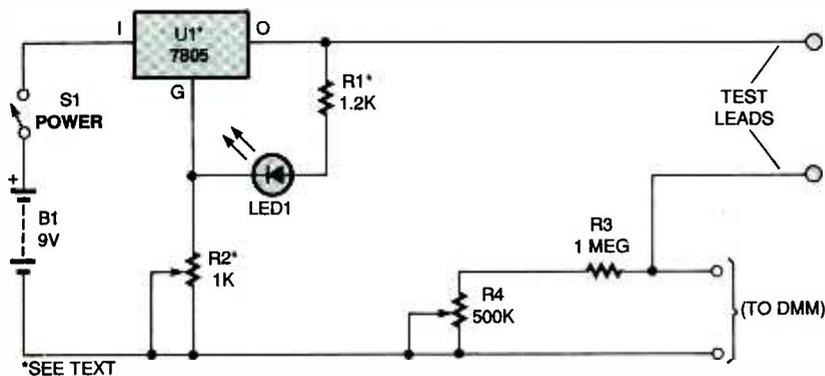


Fig. 4. Here's the schematic for the Megohm Tester. Because different  $V_{in}$  voltages can be used, U1 can be either a 7805, 7806, 78L05, or 78L06. However, the regulator used determines the values used for R1 and R2.

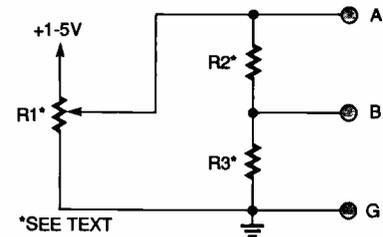


Fig. 5. To determine which LM317T regulator is the best to use in the Low-Ohms Meter, temporarily connect each available LM317T to this circuit. Choose the one whose output voltage is nearest to 1.24 volts.

er is a low-current type, needing a current of only 2 to 2.5 mA, which extends the life of B1. Radio Shack offers a low-current LED (stock number 276-044). Another source is Digi-Key Corp. (P.O. Box 677, Thief River Falls, MN 56701-0677; Tel. 800-344-4539; Fax: 218-681-3380); they have red (stock number HLMP-4700QT-ND) and yellow (HLMP-4719QT-ND) LEDs available.

The one-percent resistor, R5, can be obtained from Digi-Key, Mouser Electronics, or numerous other sources. No power switch was used in the prototype, as the current is extremely low when the test clips are not connected. The original battery used for B1 has lasted for several months and is still working.

Note that the value necessary for R1 is not a standard value. You can either use two resistors in series (for example, a 120-ohm and 15-ohm) to get the correct value, or use a 200-ohm multi-turn trimmer potentiometer and adjust it to the correct resistance.

If an accurate voltmeter and more than one LM317T are available, slightly higher accuracy can be ob-

Fig. 6. The circuit shown here can be used to check for a change in input resistance between the lowest DC voltage ranges of a DMM.

tained on the 100-mA range. To determine which regulator to use, temporarily connect each available LM317T to the circuit of Fig. 5, and choose the one whose output voltage is nearest to 1.24 volts. That output will match the standard one-percent resistor value for R5: 12.4 ohms. Any source of 5- to 20-volts DC can be used.

When building the Megohm Tester, you have the option of not using a circuit board at all. The regulator, switch, potentiometers, and LED can all be mounted to the case. The leads of R2, R4, and U1 can be used as tie points for the fixed resistors.

Note that a 7806 or 78L06 that has an output slightly below 6 volts can also be used for U1. However, you will have to replace R1 with an 1800-ohm resistor, and R2 with a 100- or 200-ohm unit. The current through R1, LED1, and R2 is about 2.5 mA. That is less than the recommended 5 mA, but it works fine.

Again, tip jacks or banana plugs can be used to connect the Megohm tester to the DMM. Just make sure you label which leads connect the meter to which of the circuits.

**Calibration and Use.** The 10-mA range of the Low-Ohms Tester has to be calibrated for the circuit to be accurate. There are two ways of doing that: One way is to connect a milliammeter to the test leads and adjust R1 for a reading of 10 mA. Or, you can attach one or more precision resistors (with values of 1 to 10 ohms) to the leads and adjust R1 for a correct reading.

There are two calibration adjustments that need to be made to the Megohm Tester. For starters, connect your DMM to the Megohm Tester. Short the test leads (of the Megohm Tester), and adjust R2 for a reading of 6 volts.

(Continued on page 106)

### PARTS LIST FOR THE MEGOHM TESTER (Fig. 4)

#### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

R1—1200-ohm (see text)

R2—1000-ohm multi-turn trimmer potentiometer (Bourns 3006P series, Spectrol 43P series, or equivalent; see text)

R3—1-megohm

R4—500,000-ohm multi-turn trimmer potentiometer (Spectrol 43P504, Bourns 3006P-504, or equivalent)

#### ADDITIONAL PARTS AND MATERIALS

U1—7805, 7806, 78L05, or 78L06 voltage regulator (see text)

LED1—Low-current light-emitting diode (see text)

S1—SPST, miniature toggle or slide switch

B1—9-volt alkaline battery

Perforated board (optional, see text), enclosure, 9-volt battery snap with leads, tip jacks or banana plugs, wire, solder, hardware, etc.

the object to be measured, to get the lowest resistance. The alligator clips are available from any supplier carrying Mueller clips. Hosfelt Electronics has them, as does Mouser Electronics (2401 Highway 287 North, Mansfield, TX 76063-4827; Tel. 800-346-6873; Fax: 817-483-0931).

Tip jacks can be used to connect the circuit to the DMM (the meter test prods plug into them). Or you can attach wires, ending in banana plugs, to the circuit and simply plug them into the DMM test-lead jacks.

The LED used in the Low-Ohms Test-

BY RONALD A. REIS

Something's out there—on the porch, in the driveway, or behind the shed. Or maybe it's inside—in the garage, basement, or den. Whatever it is, human or beast, it's moving. Perhaps it's just your teenager sneaking in from a late night out. Possibly it is only the neighborhood cat. Or, more ominously, it could be a prowler bent on theft or physical harm. Whatever is going on, you know something is up because you just installed the *Ultrasonic Motion Detector* described in this article.

Depending on what parts you have available, or if you buy the complete kit from the source mentioned in the Parts List, the Motion Detector can be built for less than \$30. It contains a complete ultrasonic (40-kHz) crystal-controlled transmitter and a super-sensitive receiver on a printed-circuit board that measures only 1½ × 3 inches.

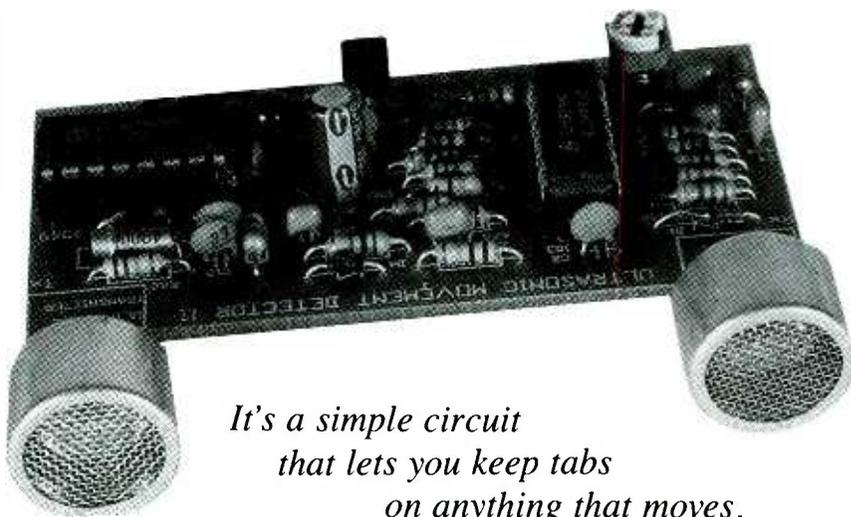
The project detects motion from 4- to 7-meters away. Once that occurs, a red LED lights. But with additional circuitry attached to the output, the detector can turn on lights, sound buzzers, trip a recording device, or even call the police. Also, the circuit can be made to sound off with a message when anyone moves within its field of detection. Using various voice recording and playback circuits (see "Circuit Circus" in the July and August 1995 issues of this magazine) you might even have the Ultrasonic Motion Detector provide a pleasant greeting or snarl with a barking dog sound when someone approaches the front door.

As you can see, your Ultrasonic Motion Detector project can be put to work in a variety of ways. Let's now look at how it works.

**Circuit Description.** The schematic for the Ultrasonic Motion Detector is shown in Fig. 1. A 9-volt battery, B1, directly provides power for some sections of the circuit. The battery is also connected to a 78L05 regulator, IC3, which provides a 5-volt-DC power source for other sections of the circuit.

The transmitter section of the Detector is basically a crystal-controlled relaxation oscillator built around a 4049 hex inverter, IC2. One of the 4049 sections, IC2-c, along with re-

# ULTRASONIC MOTION DETECTOR



*It's a simple circuit  
that lets you keep tabs  
on anything that moves.*

sistors R21 and R22, and capacitors C11 and C12, "pings" the 40-kHz crystal into sustained oscillation. The remaining 4049 sections act as linear buffers to drive a 40-kHz, ultrasonic transmitting transducer, BZ2. (For an in-depth review of crystal-oscillator circuits, see Joseph J. Carr's excellent article, "All About Crystal-Oscillator Circuits," in the August 1995 issue of **Popular Electronics**.)

The receiver section of the circuit is made up of four AC-coupled stages, each built around one of four sections of an LM324 op-amp, IC1. In the first stage, the input voltage developed across R1 and R2 is modulated by a 40-kHz, ultrasonic receiving transducer, BZ1, and is then fed to IC1-a, where it is amplified. The receiving transducer detects any reflected sound produced by the transmitting transducer, BZ2. If there is no movement, the resulting envelope signal is just a straight line; diode D1 and resistor R8 operate as a negative peak detector to recover the envelope signal.

In the second stage, which is built around IC1-b, the recovered signal is again amplified. The time constant of IC1-b is quite slow so that the envelope can be followed; the output of the second stage is a DC level that represents the strength of the envelope. If there is movement, the envelope will reflect it in the form of a positive or negative signal.

At the input to the third stage—a differential amplifier built around IC1-c—there are two diodes, D2 and D3. They detect both positive and negative pulses. When there is no movement, the voltage at pin 7 of IC1-b is half the supply voltage and neither D2 or D3 can conduct. The voltage at pin 8 of IC1-c is then low. If the signal rises above +0.7 volt (a silicon diode's breakdown voltage), D3 conducts causing the output on pin 8 to go high. If the signal falls below -0.7 volt, D2 conducts, which also causes the output to go high. Thus we have a window detector. It detects voltages that move both below and above a given range.

The fourth stage, built around IC1-d, is set up as a monostable flip-flop. That stage converts any signal that gets through the filter into a pulse substantial enough to turn on transistor Q1. When Q1 conducts, LED1 turns on and an output signal is provided to drive a separate relay or any other device connected to the circuit (more on that later). The time constant of the monostable flip-flop is about half a second and is set by C8 and R18. Diode D4 is used to separate the charge- and discharge-time constants. It lets the circuit switch on immediately when movement is detected but allows about a half-second delay for the reset.

**Construction.** The author built the Ultrasonic Motion Detector from a complete kit of parts, which includes a pre-etched and drilled PC board. That kit is available from the source mentioned in the Parts List. If you

choose to round up your own components, it is still recommended that you use a PC board. You can use the foil pattern shown in Fig. 2 to make your own.

Refer to the parts-placement diagram shown in Fig. 3 while assembling your circuit. Begin by soldering all resistors flush to the PC board. Then install the five diodes, making sure to orient them properly. Next, install the capacitors. Be sure to double check the polarity of C9

Go on to install crystal XTAL1. Bend the crystal's leads so that the component rests flat on the board. Note the two unused holes next to the two for the crystal. You can bend a resistor lead around the crystal in a "U" shape and solder the lead ends to the unused holes. That should hold the crystal in place.

Install the potentiometer. Then continue by mounting the 78L05 voltage regulator and the BC639 transistor;

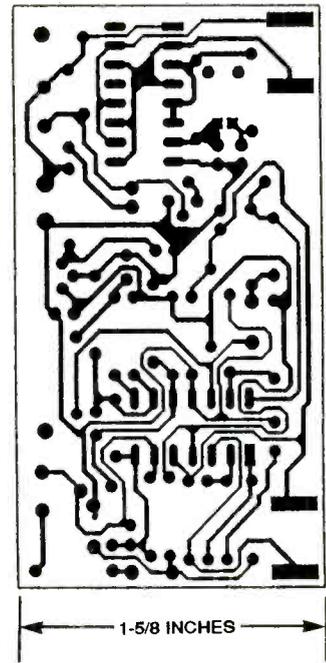
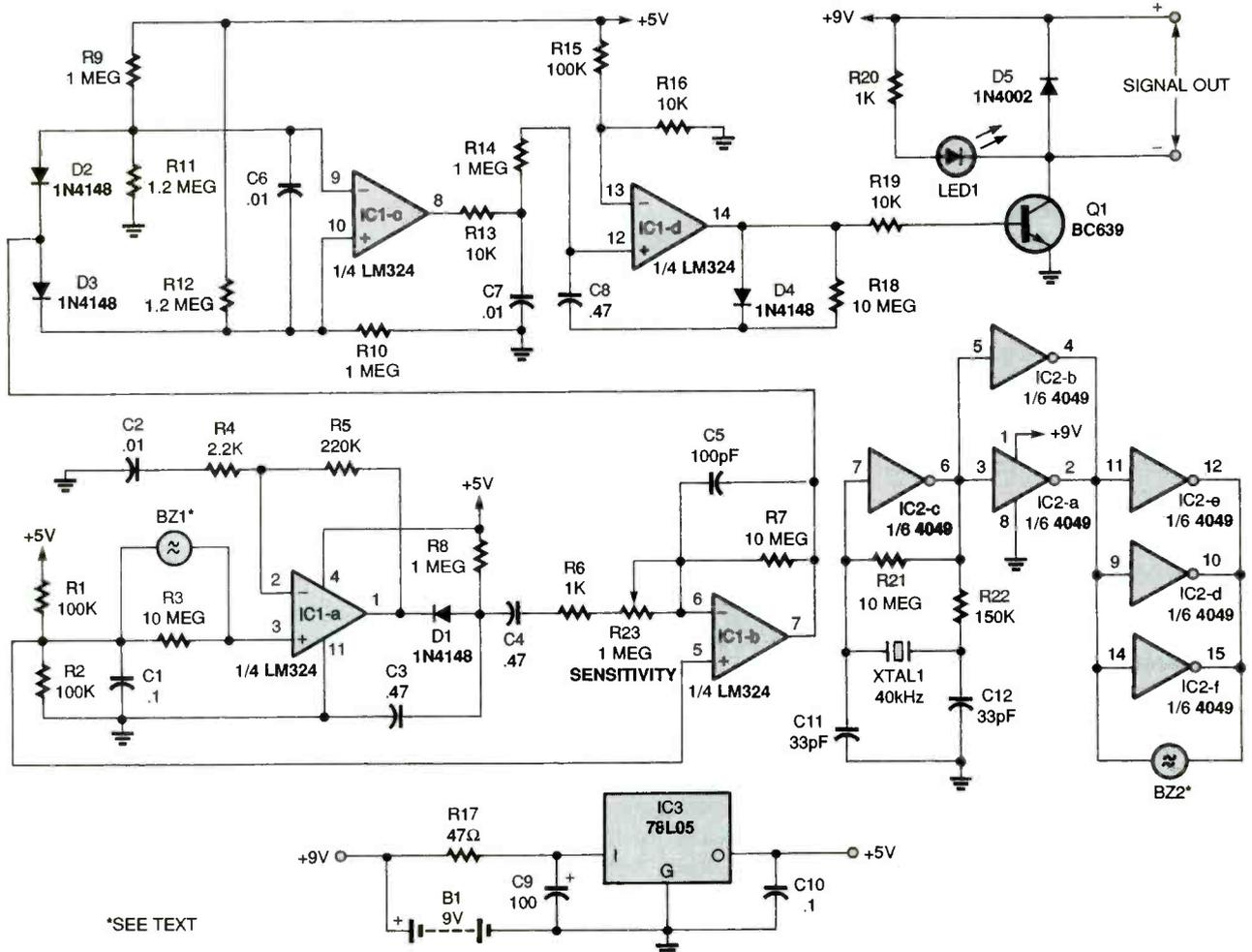


Fig. 2. If you'd like to etch your own board, use this full-size template.



\*SEE TEXT

Fig. 1. This is the schematic for the Ultrasonic Motion Detector. When movement is sensed, transistor Q1 switches on, lighting LED1.

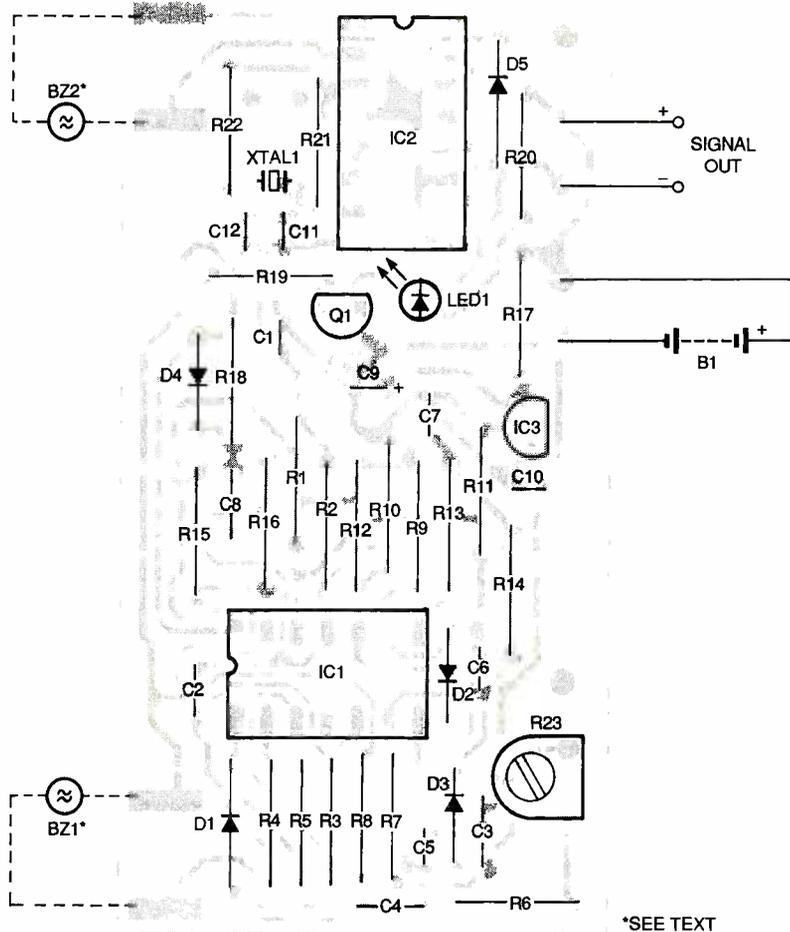


Fig. 3. When assembling the circuit, use this parts-placement diagram as a guide. Note that BZ1 and BZ2 surface-mount on the foil side of the board.

### PARTS LIST FOR THE ALARM CIRCUIT (Fig. 4)

#### SEMICONDUCTORS

IC1-IC3—555 timer, integrated circuit  
 Q1—2N3055 NPN transistor  
 D1—1N4148 silicon diode  
 D2-D4—1N4001 silicon rectifier diode

#### RESISTORS

(All resistors are 1/4-watt, 5% units.)  
 R1—2.2-megohm  
 R2, R6—10,000-ohm  
 R3—12,000-ohm  
 R4, R7—100,000-ohm  
 R5—1000-ohm  
 R8—120-ohm

#### CAPACITORS

C1—470- $\mu$ F, 16-WVDC, electrolytic  
 C2—47- $\mu$ F, 16-WVDC, electrolytic  
 C3, C5-C7—0.01- $\mu$ F, ceramic-disc  
 C4—10- $\mu$ F, 16-WVDC, electrolytic

#### ADDITIONAL PARTS AND MATERIALS

RY1—9-volt relay, normally open contacts  
 SPKR1—8-ohm speaker  
 Perforated board, IC sockets, wire, solder, hardware, etc.

ect you have to replace the battery regularly. As the battery voltage decreases, the circuit's sensitivity will change; that is particularly true if the unit is triggered often. To avoid the

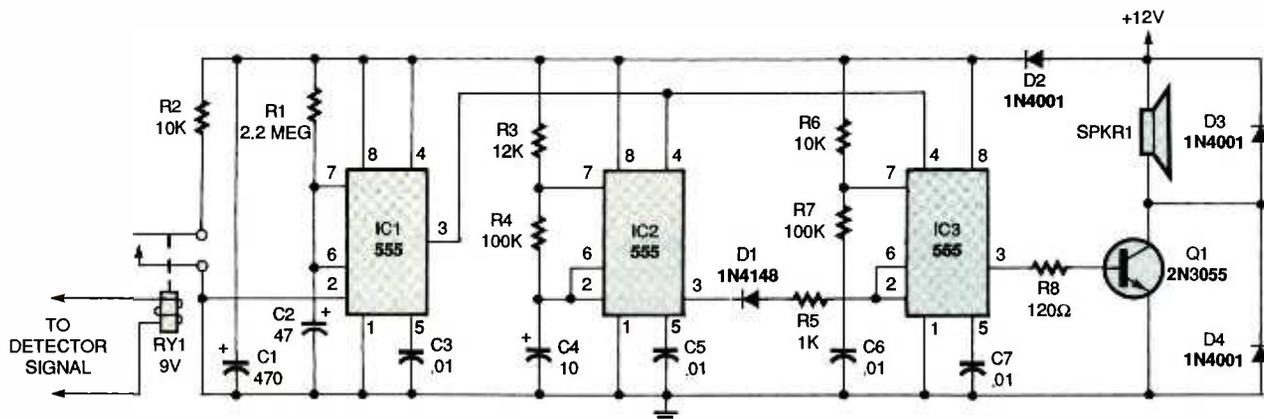


Fig. 4. This simple circuit can be used with the Motion Detector to provide a two-minute alarm tone when motion is detected.

those two parts look alike, so be careful not to confuse them. Also install the LED. Make sure all those parts are oriented as shown in the parts-placement diagram.

Now solder IC sockets for IC1 and IC2 to the board, noting the proper

placement of the notches indicated in Fig. 3. Insert the ICs into their respective sockets.

Connect the leads of the 9-volt battery clip to the board next. Now is a good time to note that if you do plan on using a battery to power the proj-

extra expense of replacing batteries, you might want to replace the battery clip with two wires (red and black) can be used to indicate polarity) so that you can hook up a 9-volt power supply.

Now you can install the ultrasonic

transducer pair. If you are not building the project from the kit, you should make sure you are using a matched pair of 40-kHz transducers or the proj-

## PARTS LIST FOR THE ULTRASONIC MOTION DETECTOR (Fig. 1)

### SEMICONDUCTORS

IC1—LM324 quad op-amp, integrated circuit  
 IC2—4049 hex inverter, integrated circuit  
 IC3—78L05 5-volt regulator, integrated circuit  
 Q1—BC639 NPN transistor  
 D1-D4—1N4148 silicon diode  
 D5—1N4002 silicon rectifier diode  
 LED1—Light-emitting diode, red

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

R1, R2, R15—100,000-ohm  
 R3, R7, R18, R21—10-megohm  
 R4—2200-ohm  
 R5—220,000-ohm  
 R6, R20—1000-ohm  
 R8-R10, R14—1-megohm  
 R11, R12—1.2-megohm  
 R13, R16, R19—10,000-ohm  
 R17—47-ohm  
 R22—150,000-ohm  
 R23—1-megohm potentiometer

### CAPACITORS

C1, C10—0.1- $\mu$ F, ceramic-disc  
 C2, C6, C7—0.01- $\mu$ F, ceramic-disc  
 C3, C4, C8—0.47- $\mu$ F, ceramic-disc  
 C5—100-pF, ceramic-disc  
 C9—100- $\mu$ F, 16-WVDC, electrolytic  
 C11, C12—33-pF, ceramic-disc

### ADDITIONAL PARTS AND MATERIALS

XTAL1—40-kHz crystal  
 BZ1—40-kHz ultrasonic receiving transducer (part of matched pair, see text)  
 BZ2—40-kHz ultrasonic transmitting transducer (part of matched pair, see text)  
 B1—9-volt battery (see text)  
 Printed-circuit materials, IC sockets, battery connector with leads, wire, solder, hardware, etc.

**Note:** The following is available from Marlin P. Jones & Assoc., Inc. (P.O. Box 12685, Lake Park, FL 33403-0685; Tel. 407-848-8236; Fax: 800-4FAXYES): complete kit of parts, including printed-circuit board (6049-KT)—\$27.95 plus \$5.00 shipping and handling. Florida residents please add 6% sales tax.

ect will not work. You can get the "Transmitter/Receiver Pair" from Electronic Goldmine (P.O. Box 5408, Scottsdale, AZ 85261; Tel. 602-451-7454) as part-number G5721. Contact them for more information.

The transmitting transducer, BZ2, has a T suffix on the number stamped underneath it. The receiving transducer, BZ1, has an R suffix. Neither part is polarized. Tag-solder each transducer on its proper pads directly on the foil side of the PC board. The leads should rest flat on the pads and the fronts of the transducers should point away from the PC board.

Finally, install two wires to provide a signal-out connection for attaching various output transducers and circuits. You might want to use one red and one black wire, as the signal is polarized.

**Checkout.** Power up your circuit with either a battery or fixed power source. Set up the Motion Detector in a quiet room with no one moving about. Even air moving (hot air rising, wind blowing, and, believe it or not, someone talking) will trigger the device when set to its greatest sensitivity.

After you connect the power, let the unit stand for at least 20 seconds so the whole circuit will settle down electrically. Set the 1-megohm trimmer potentiometer to about 400,000 ohms by eye (in other words, imagine that the potentiometer has settings for zero through ten, and set it at four). Below about 300,000 ohms, the Detector is often too sensitive and will self-trigger. Trial and error will show the best setting for your particular requirements.

**Some Applications.** Referring back to Fig. 1, note that transistor Q1 turns on and delivers a continuous unregulated 9 volts to a suitable load as long as something is moving within the Detector's range. If the load is a 9-volt relay, virtually any electronic device can be turned on in response to motion. That might be good enough for many applications—lights can be made to flash, horns to blare, etc. (If you have trouble driving the coil of a 9-volt relay, you might need to reduce the value of R19 in Q1's base circuit.)

However, there are times when you will want an output device to remain activated after motion has stopped.

For example, if a prowler quickly crosses the field of "view," you wouldn't want a speaker to sound or a light to flash for just an instant. A continuous signaling, perhaps for many minutes, would be desirable.

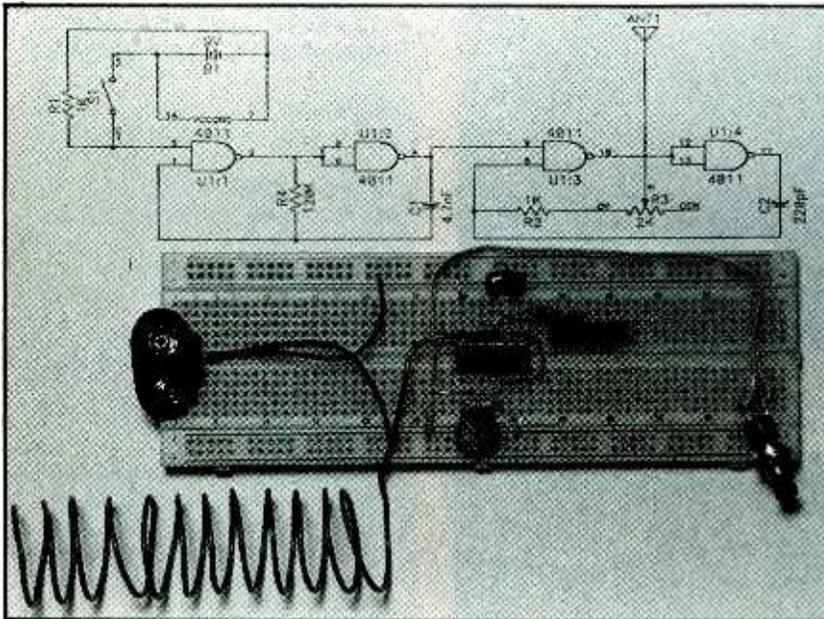
The alarm circuit shown in Fig. 4 will provide just such a warning. It consists of three 555 timer ICs, IC1-IC3, where IC1 is operated in a monostable mode, and IC2 and IC3 are in astable configurations.

The trigger input to IC1 (pin 2) is connected to the normally open contacts of a 9-volt relay. The coil of the relay should be connected to the signal output terminals on the PC board. When the Detector senses motion, even for a brief moment, the relay is energized, and pin 2 of IC1 (all part designations given from here on are found in Fig. 4) is brought to ground, thus triggering the monostable circuit, or timer. Pin 3 of IC1 then goes high. The length of time it remains high is determined by the values of R1 and C2. With the components shown, the output pulse is approximately 2 minutes. To increase that time, use a higher-value capacitor for C2, to decrease the time, use a lower-value capacitor.

When the output of IC1 goes high, IC2 and IC3 are activated. The latter timer, IC3, is connected to produce a 500-Hz tone; IC2 is a 1-Hz oscillator. Thus IC2 is used to trigger IC3 on and off once per second, generating a pulse-tone alarm. Note that the alarm circuit is run off a separate power supply from that used by the Detector.

Of course, using an alarm circuit with your Motion Detector is only one application. Let your imagination fly; think of all the devices you can turn on (or off) when movement is sensed. Consider your project as the heart of a wide range of fun and practical applications. ■





# Poor-Man's Transmitter

*It's a simple, inexpensive transmitter that demonstrates the basic principles of amplitude modulation.*

BY JAMES CICON

**Y**ou are shipwrecked on a deserted tropical island. All you have are oranges (there are lots of them on a tropical island), and your Nintendo *Gameboy*. At first you think your situation is heaven, but then the batteries go dead in the *Gameboy*, and you start thinking that if you only had a phone, maybe you could get some pizza delivered. What to do?

Well, they didn't call you "kid McGyver" for nothing in high school, so you take out half a dozen oranges and make a battery. You then rip open your *Gameboy* and use the guts to make an emergency radio beacon. In no time at all, you are back at home telling every one about wrestling great-white sharks and battling with marauding cannibals.

Now, this article isn't going to tell you how to make batteries out of oranges (if you are *really* interested, see the article "Experiments in Galvanism" in the November 1991 issue of **Popular Electronics** for information on how to do that). Nor will it recommend that you take your *Gameboy* apart. But it is going to show you how to build a *Poor-Man's Transmitter* that makes for a great little radio beacon. Best of all, it can be built for just a few dollars.

The project is a simple AM transmitter that you can use to transmit tones into your AM or FM Radio, TV set, CB radio, police scanner, ham radio, or anything else that you happen to have lying around that picks up radio

waves (later in the article, we'll get to why the AM transmissions can be picked up by so many different types of devices). To avoid annoying your neighbors, the range on the Transmitter as shown is just about enough to reach across an average-size room, provided no one is standing in the way.

**AM-Transmitter Basics.** The Poor-Man's Transmitter is basically a simple amplitude-modulated (AM) radio transmitter. The dictionary defines modulation as "an inflection of the tone or pitch of the voice" (to convey meaning). It also defines modulate: "to vary the amplitude, frequency, or phase of a carrier wave for the transmission of intelligence."

Amplitude modulation, as the name implies, changes the loudness or amplitude of a carrier to transmit intelligence. In order to build an AM

transmitter, three things are needed: a carrier wave, another wave to modulate it, and some way of transferring an intelligent message into the system. The Poor-Man's Transmitter works by supplying all three of those.

**Circuit Description.** The schematic diagram for the Transmitter is shown in Fig. 1. Power for the circuit is supplied by B1, a 9-volt battery.

Two sections of a 4011 NAND gate, U1-c and U1-d, are used as part of a radio-frequency (RF) oscillator (carrier). The other two sections, U1-a and U1-b, are used in an audio frequency (AF) oscillator (modulator). Switch S1 enables and disables the modulation to allow the transfer of an intelligent message with the Transmitter.

When you press S1, the AF oscillator composed of U1-a, U1-b, R4, and C1 starts generating an audio signal (see Fig. 2). That signal gates the RF os-

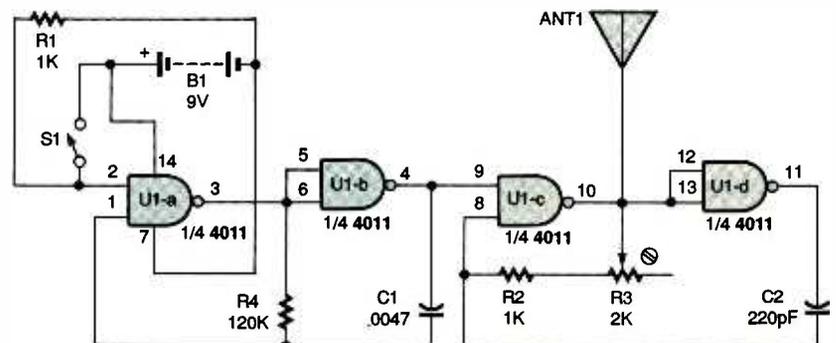


Fig. 1. This is the schematic for the Poor-Man's Transmitter. The circuit gets its name because of the extremely low parts count (and the low prices of those parts).

cillator composed of U1-c, U1-d, R2, R3, and C2 on and off. When on, the RF oscillator runs at 1 MHz. The resulting output is sent out ANT1 as an AM signal (see Fig. 3). Note that except for R3, the AF and RF circuits are laid out exactly the same. The purpose of R3 is to tune the RF oscillator.

When momentary-contact, push-button-switch S1 is released, the AF oscillator is turned off. Resistor R1 pulls the voltage on pin 2 of U1-a low, disabling the circuit. When S1 is pressed again, pin 2 goes high. That causes the circuit to once again start flipping between its two stable states. The first of those states is when the output of U1-a is high and the output of U1-b is low. The second state is when the output of U1-a is low and the output of U1-b is high.

Capacitor C1 is included in the circuit to control the speed of the transitions between the two states. If the capacitor weren't used, the circuit would oscillate at an unpredictable, and extremely rapid rate. The frequency would be affected by the temperature of the room, the shape of the wires connecting the circuit together, and even the nearness of your hand to the IC. Here's how C1 controls the frequency of the changing states:

When U1-a flips and tries to change the circuit from the first state to the second one, C1 keeps the circuit in the first state for a little while, thereby slowing down the frequency. The capacitor does that because it is connected to the input of U1-a, just as R4 is. As long as C1 is charged up, it can "overpower" R4, preventing it from changing the input of U1-a. Gradually, C1 loses enough charge through R4 and allows U1-a to flip to the second state.

Figure 4 shows the waveform of the voltage appearing across C1; the curving sloping region occurs when C1 is keeping the circuit from flipping to the next state. Figure 5 shows the waveform of the voltage at the output of U1-c; remember, U1-c is part of the RF oscillator. Notice the bumps on the leading edge of the squarewave in Fig. 5 and on both edges of the sawtooth wave in Fig. 4. The bumps are there because the electrical circuit is behaving in a similar manner to a mechanical switch. When the circuit switches rapidly from off to on, it bounces a bit.

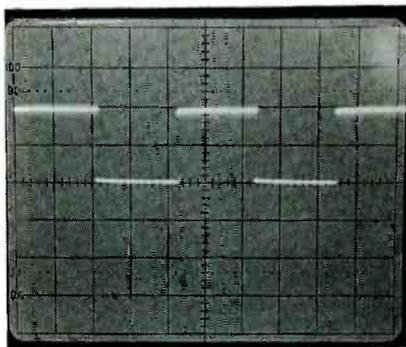


Fig. 2. When you press S1, the AF oscillator in the Transmitter generates an audio signal; here's the waveform.

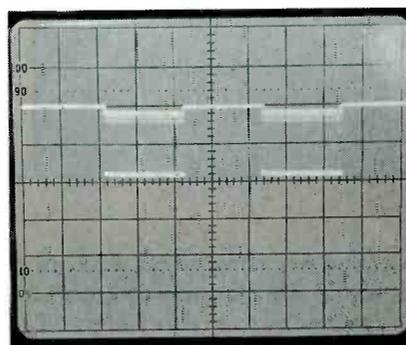


Fig. 3. Shown here is the waveform of the Transmitter's output AM signal.

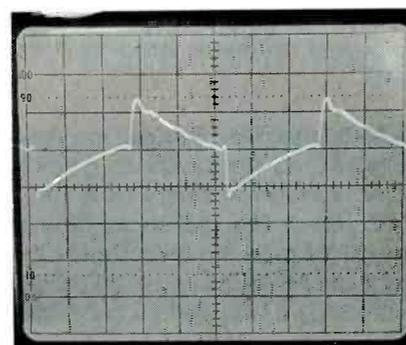


Fig. 4. Here's the waveform of the voltage appearing across capacitor C1. The curving sloping region occurs when C1 is keeping gates U1-a and U1-b from switching between two states (see text).

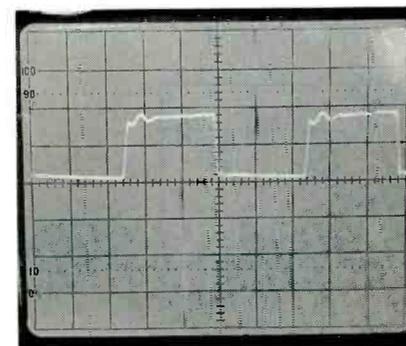


Fig. 5. This shot shows the waveform of the voltage at the output of gate U1-c, which is part of the Transmitter's RF oscillator.

## PARTS LIST FOR THE POOR-MAN'S TRANSMITTER

### RESISTORS

(All fixed resistors are ¼-watt, 5% units.)

R1, R2—1000-ohm

R3—2000-ohm, 15-turn trimmer potentiometer

R4—120,000-ohm

### ADDITIONAL PARTS AND MATERIALS

U1—4011 quad 2-input NAND gate, integrated circuit

C1—0.0047-μF, ceramic-disc capacitor

C2—220-pF, ceramic-disc capacitor

ANT1—Four feet of stiff, 22-gauge wire (see text)

S1—SPST, momentary-contact, normally open pushbutton switch

B1—9-volt alkaline battery

Modular IC breadboard (Radio Shack 276-175 or equivalent), 22-gauge solid wire, 24-gauge stranded cable (2-conductor), battery snap with leads, solder, hardware, etc.

**Construction.** Building the Transmitter is a very simple task. As you can see in the photo at the beginning of this article, the author's prototype was built on a breadboard. The components were simply pressed directly onto the breadboard, and small jumper wires were used to make connections between components.

If you want a more permanent circuit, you can assemble the circuit on a perforated board. If you decide to go that route, use an IC socket for U1 to make sure that it doesn't get damaged. Also, install the resistors, the potentiometer, and the capacitors before you insert the IC into its socket.

Solder long leads of stranded, small-gauge wire to switch S1. That will allow you to hold it in your hand when keying the Transmitter on and off. Stranded wire is flexible, so you can move the switch easily.

Next install the battery-snap leads. Both the snap and the switch have stranded-wire leads. If you are using a breadboard to build the project, you will have to first tin the ends of the wire to stiffen them. That makes it easier to insert the wires into their holes.

For those who don't know, tinning a wire is pretty simple. Strip the insulation of the wires back about ¼ inch and twist the strands together. Then

(Continued on page 109)

If you want to add some scary sound effects to this year's Halloween fun, try building the *Vocal Sound-Effects Generator* described in this article. With it, you can add both reverb and echo to make yourself sound like a creepy ghost, shift the pitch of your voice higher to sound like a shrieking banshee, or shift the pitch lower to create a ghoulish monster voice. Plus, a warbling vibrato can be combined with any of the previous effects to create even stranger effects!

The battery-powered project, including its small microphone and remote speaker, is very portable. You can easily incorporate it into any costume or use your imagination and have a talking pumpkin greet the trick-or-treaters at your front door. However it is used, the Effects Generator will provide hours of fun and entertainment!

**Circuit Description.** The schematic diagram for the Vocal Sound-Effects Generator is shown in Figure 1. Four AA batteries supply 6 volts to the LM386 audio amplifier, U2. Resistor R4 and Zener-diode D1 convert and regulate the battery voltage to 3.6 volts to power the HT8950 signal-processor chip, U1. The power switch, S1, is part of the volume-control potentiometer, R5. Capacitors C8 and C5 provide power filtering for the circuit.

During operation, the user's voice is picked up by electret-microphone MIC1 and the signal is AC coupled by C1 to pin 6 of U1 (which is the input of the chip's preamplifier stage). Resistors R8 and R9 set the gain of the internal preamplifier at approximately 8, which is figured out by:

$$V_{out} = (R9/R8) \times V_{in}$$

The output of the HT8950's preamplifier stage is buffered and fed into the chip's internal, 8-bit, analog-to-digital converter. That A/D converter samples the speech signal at 8 kHz under the control of a time-base generator, and the 8-bit digital values are stored in internal SRAM memory. Simultaneously, the chip's control circuit clocks the SRAM data out to a digital-to-analog converter (DAC) that restores the analog signal and outputs it at pin 9. The signal then passes through a low-pass filter formed by R2 and C2. Amplifier U2 provides the final



# Vocal Sound-Effects Generator

BY DAVID WILLIAMS

*Create a truly ghoulish voice for yourself and get into the spirit of Halloween with this fun project.*

amplification and drives speaker SPKR1; potentiometer R5 controls the volume.

If the speech data is clocked in and out of U1's SRAM at the exact same rate, the original signal gets reproduced with no changes. But if the digital data is manipulated before it passes through the DAC, some pretty weird effects can be created! The four-position DIP switch, S2, is used to set the operating modes of the HT8950 (see Table 1).

The HT8950 can be set for NORMAL

VOICE, ROBOT VOICE, and several pitch-shift-up and pitch-shift-down modes; vibrato can be added to each of those modes. The normal setting requires no explanation. As for the ROBOT VOICE mode, that adds echo and reverb effects by delaying part of the digitized audio then adding the delayed signal to the original. The pitch-shifting modes are analogous to speeding up or slowing down a tape recording during playback. Voice pitch is shifted by changing the clocking ratio of the internal time-base generator. Vibrato is created when the HT8950 automatically shifts the pitch of the input signal up and down alternatively at a rate of 8 Hz.

**Construction.** The simplest way to build your own Vocal Sound-Effects Generator is to use a printed-circuit board. A template for that is shown in Fig. 2. If you don't want to fabricate your own board, a pre-etched and drilled board can be purchased from the source mentioned in the Parts List (you can also purchase other parts, and even a complete kit, from the same source). Of course, the circuit can also be built on perforated board. Most of the parts for the project are fairly easy to find. The one exception is the HT8950 (U1); if you can't find it locally, it can be purchased from the source given in the Parts List or from Alltronics (2300-D Zanker Road, San Jose, CA 95131; Tel. 408-943-9773).

If you do build the circuit on a PC board, use the parts-placement diagram in Fig. 3 as a guide. First, install

TABLE 1

DIP-SWITCH SETTINGS				MODE
S2-a	S2-b	S2-c	S2-d	
*	X	X	0	NORMAL VOICE
*	0	0	X	PITCH-SHIFT UP1
*	X	0	X	PITCH-SHIFT UP2
*	0	X	X	PITCH-SHIFT UP3
*	0	X	0	PITCH-SHIFT DOWN1
*	X	0	0	PITCH-SHIFT DOWN2
*	0	0	0	PITCH-SHIFT DOWN3
*	X	X	X	ROBOT VOICE

\*SW1 Toggles VIBRATO mode ON & OFF in combination with all other modes.  
Note: X=OFF, 0=ON



**W**hen most hobbyists buy a number of similar-valued components, they keep them together. But what if they get mixed in with other parts? Well, in the case of resistors, you can use a multi-meter or the color code to quickly determine their value. With capacitors, however, it isn't so easy. The big electrolytics are usually well labeled, but ceramic, Mylar, and old mystery types are frequently labeled with what appears to be random letters and numbers. When you separate those units from their labeled drawer or packaging, the only way to tell what they are is to use a capacitance meter that can determine the appropriate range on its own.

The *Auto-Ranging Digital Capacitance Meter* described in this article does just that. To use it, you simply insert the mystery capacitor's leads into the unit's test socket and wait about a second. The Meter automatically determines the range and displays the capacitance with the correct unit. That's all there is to it. There are no controls of any type, other than the power switch.

In addition to being extremely easy to use, the Meter is very accurate too. From 1 pF to 10  $\mu$ F, the author's prototype differed less than 1% from its calibration unit. Typically, the Meter can measure up to about 1000  $\mu$ F at a 5- to 10-percent error, and can estimate the value of capacitors up to approximately 5000  $\mu$ F.

Another great feature of the Meter is its automatic compensation for stray capacitance. You see, before you connect a capacitor to the circuit, there is already as much as 35 pF present. When the meter is turned on, it measures and records that stray capacitance, and subtracts it from all subsequent readings. That feature allows you to measure very-small-value (1 or 2 pF) capacitors accurately.

**Circuit Description.** The schematic for the Meter is shown in Fig. 1. When switch S1 is closed, a 9-volt battery, B1, supplies power to a 78L05 regulator, U2, and to filter-capacitors C7 and C8. The result is a 5-volt DC supply for the rest of the circuit. Because the current draw is low, the 9-volt battery will provide close to 40 hours of usage.

A Microchip PIC16C57, U1, is at the heart of the circuit. That micro-

controller has 2K of internal EPROM, which is programmed with the Meter's rather complex program (more on that later).

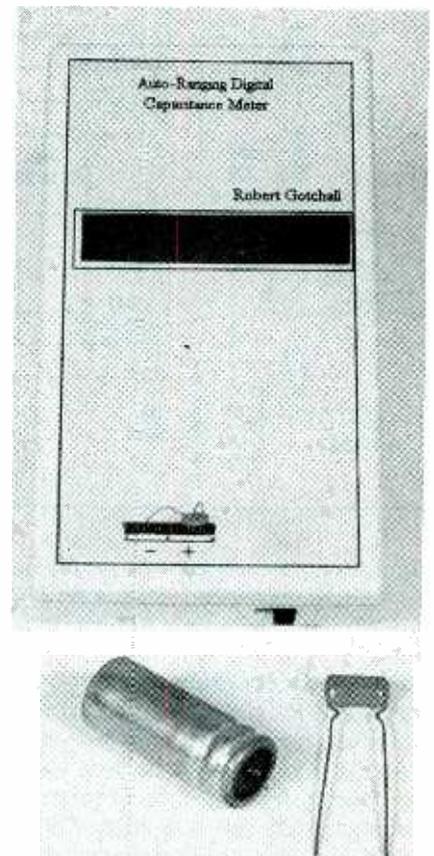
The circuit uses one of three 7555 CMOS timers, U3–U5, to generate a pulse train; the frequency of that pulse train has a strong linear dependence on the capacitor under test. That capacitor is inserted between ground and three relays, K1–K3. Microcontroller U1 turns on one of those relays to connect the capacitor to one of the three timing circuits.

The timer circuit made up of J5, R3, R4, R5, and C1 has the lowest resistance and impedance, while U4 and its surrounding components has a medium resistance and impedance, and U3's circuit has the highest. All the timer circuits have two nominally equal resistors; one of them is the series combination of a fixed resistor and a trimmer potentiometer. That variable combination is for calibration (which we'll look at later). The high-impedance (1-megohm) circuit is the default, and is used for small-valued capacitors, the medium-impedance (10,000-ohm) circuit is for medium-valued capacitors, and the low-impedance (100-ohm) circuit is for high-valued capacitors.

In other words, three timer circuits with low, medium, and high resistances are used to widen the effective measurement range and to allow the microcontroller to measure a frequency within certain easily managed limits (except at large capacitances). For instance, a 10- $\mu$ F capacitor with the high-impedance circuit would oscillate imperceptibly slowly, while a 10-pF capacitor would cause the low-impedance circuit to oscillate far too high, and with a large amount of non-linear error.

When the capacitor under test is connected to the appropriate circuit, the microcontroller measures the frequency. Here's how that's accomplished: A 4-MHz crystal, XTAL1, gives U1 a 1-MHz internal-clock frequency. The microcontroller can therefore count the number of pulses from the appropriate timer circuit in a known period of time. It then goes on to convert the frequency to capacitance using 32-bit, floating-point arithmetic, and displays the results on a 16  $\times$  1 LCD, DISP1, with the correct unit and decimal point.

# AUTO RANGING CAPACITANCE METER



*It's an accurate and useful addition to any hobbyist's workbench.*

BY ROBERT GOTCHALL

Capacitor C9 is connected in parallel to the capacitor under test to aid in final calibration and for stability. Diodes D1–D3 protect the microprocessor from the back EMF of the relays' coils.

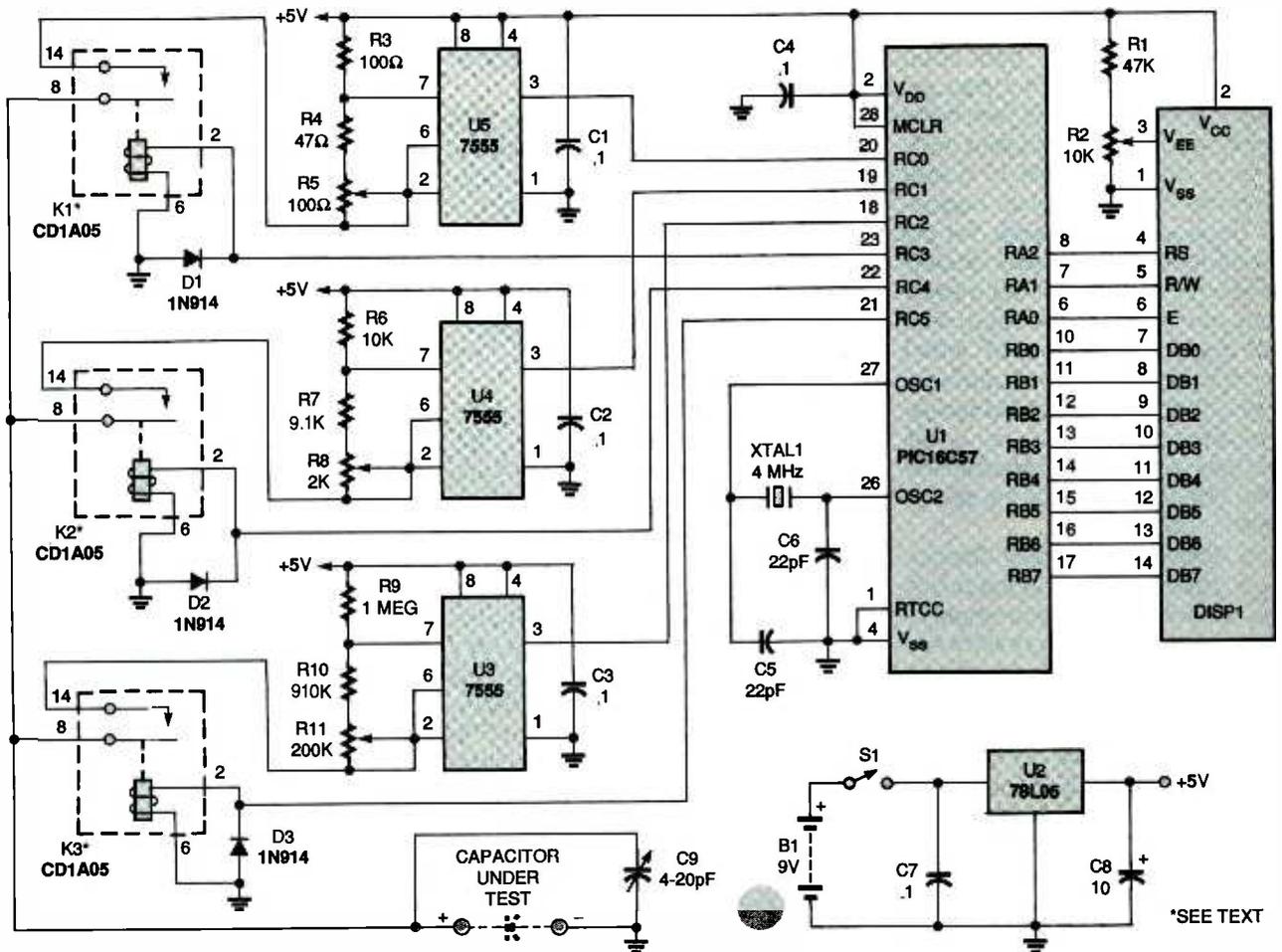


Fig. 1. Here's the schematic for the Digital Capacitance Meter. Most of the functions of the circuit are handled by U1, a PIC16C57 microcontroller. That chip's EPROM is programmed with the Meter's rather complex program.

**Software Description.** Before you can use the PIC microprocessor in the Meter, you have to program it. If you have the equipment to do that, you can obtain the software from the Gernsback BBS (516-293-2283). Otherwise, you can get a preprogrammed PIC from the source mentioned in the Parts List.

Here's how the program works: It counts the number of low-to-high edges on one of three input pins per second, thus determining the frequency. That frequency can be converted to capacitance via the formula:

$$C = 1.44 / (R1 + 2R2) f$$

where C is the capacitance in farads, R1 and R2 are the resistances in ohms in the selected timer circuit, and f is the frequency in hertz.

Figure 2 is a flowchart of the main program. For the purposes of explaining the flowchart, we'll refer to the 1-

megohm timer as circuit C, the 10,000-ohm timer as circuit B, and the 100-ohm timer as circuit A.

The program assumes the capacitance will be quite small, and begins by examining the frequency of the high-impedance circuit, C. If the frequency is too high (above "initmin"), that means that no capacitor is in place, and "Ready" is displayed. If the frequency is too low (below CB, which stands for C to B), circuit B is activated and another frequency is measured. Circuits B and A do similar testing. The initmin, CB, BC, BA, AB, and max values are defined constants and can be changed to alter the circuit's behavior.

The mathematical calculations are done via floating-point routines. The capacitance is obtained using the formula given earlier, and the stray capacitance is subtracted from that value. The base-2, floating-point capacitance is converted to a usable

form by multiplying it by ten as many times as possible without exceeding 8,000,000, which is the maximum a 24-bit signed-magnitude number can represent. The conversion is then finished using a binary (24 bit) to binary-coded-decimal (7 digit) conversion routine. The resulting BCD version is output to the LCD with the correct decimal point and unit as determined by the multiplier obtained in the conversion process.

**Construction.** To avoid possible stray capacitances, and for the sake of compactness, the Meter should be built on a double-sided circuit board. A pre-etched, drilled, and plated-through board is available from the source mentioned in the Parts List. Or, you can use the solder- and component-side patterns shown in Figs. 3 and 4, respectively to etch your own.

The screw holes for mounting shown on the boards were designed

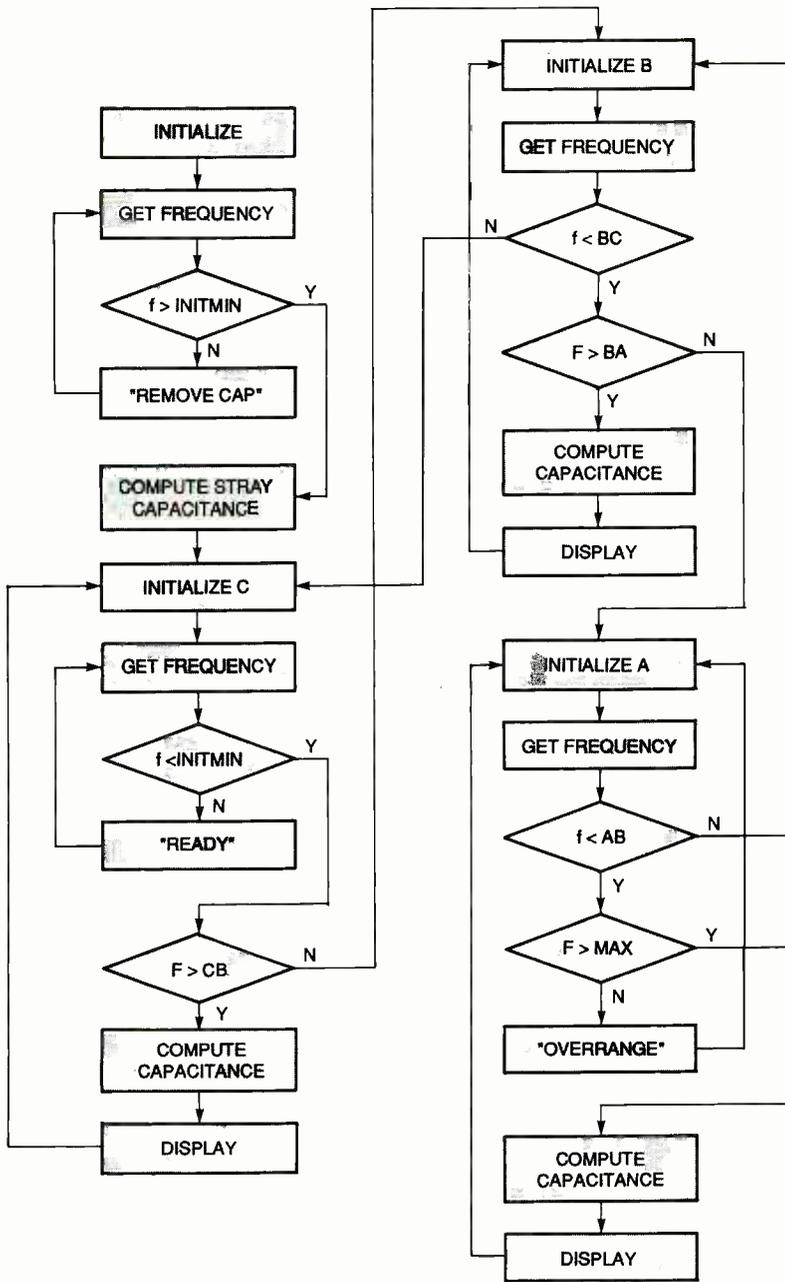


Fig. 2. This is a flowchart of the program used in the Meter's microcontroller. The 1-megohm timer circuit is referred to as C, the 10,000-ohm timer circuit is B, and the 100-ohm timer circuit is A.

to fit in a Digi-Key (P.O. Box 677, Thief River Falls, MN 56701-0677; Tel. 800-344-4539) 3- x 4- x 2-inch enclosure (#SR232 or equivalent). However, you can use any enclosure you want, as long as you allow for access to the switch and suitable room for a viewport for the LCD.

To make building the project easier, a parts-placement diagram is shown in Fig. 5. Begin by soldering sockets for U1, U3-U5, and the DIP relays. The relays used in the author's prototype have four pins that correspond to pin-

numbers 2, 6, 8, and 14 in a 14-pin socket. You can simply snip off the other pins on 14-pin sockets and use the sockets for the relays. Don't insert the ICs or relays yet, however.

Next mount the fixed resistors and capacitors. To keep the board relatively small, the resistors R3-R11, and capacitors C1-C3 are "crowded in" near the timers; make sure that none of their leads are touching. Next mount trimmer-potentiometers R2, R5, R8, and R11, which are Bourns

## PARTS LIST FOR THE CAPACITANCE METER

### SEMICONDUCTORS

- U1—PIC16C57 microcontroller, integrated circuit
- U2—78L05 5-volt regulator, integrated circuit
- U3-U5—7555 timer, integrated circuit
- DISP1—16 x 1 alphanumeric LCD module (Optrex DMC-16117N, Epson EA-D16015AR-S, or equivalent)
- D1-D3—1N914 silicon diode

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

- R1—47,000-ohm
- R2—10,000-ohm trimmer potentiometer (Bourns 3352W series, or equivalent)
- R3—100-ohm
- R4—47-ohm
- R5—100-ohm trimmer potentiometer (Bourns 3352W series, or equivalent)
- R6—10,000-ohm
- R7—9100-ohm
- R8—2000-ohm trimmer potentiometer (Bourns 3352W series, or equivalent)
- R9—1-megohm
- R10—910,000-ohm
- R11—200,000-ohm trimmer potentiometer (Bourns 3352W series, or equivalent)

### CAPACITORS

- C1-C4, C7—0.1- $\mu$ F, ceramic-disc
- C5-C6—22-pF, ceramic-disc
- C8—10- $\mu$ F, 16-WVDC electrolytic
- C9—4- to 20-pF trimmer (Sprague-Goodman GKG20011 or equivalent)

### ADDITIONAL PARTS AND MATERIALS

- XTAL1—4-MHz crystal
- K1-K3—CD1A05 DIP-package relay, 500-ohm coil (All Electronics #DRLY-05 or similar)
- B1—9-volt alkaline battery
- Printed-circuit materials, project enclosure, IC sockets, battery connector with leads, wire, solder, hardware, etc.

**Note:** The following are available from Robert Gotchall (P.O. Box 161345, Austin, TX 78716-1345): preprogrammed PIC 16C57—\$13; pre-etched and drilled, double-sided PC board—\$15; 16 x 1 alphanumeric LCD module—\$15; kit of all parts except project case—\$65. Please add \$5 for shipping and handling for any order. Texas residents please add appropriate sales tax.

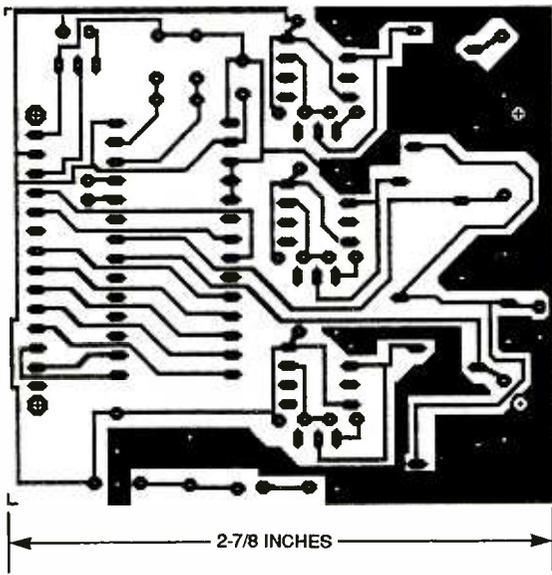


Fig. 3. Here's the solder side of the Meter's PC board.

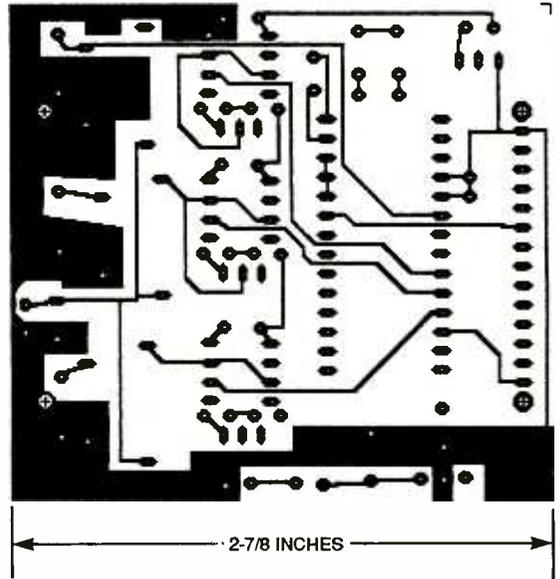


Fig. 4. This is the component side of the board.

3352W-series, vertical-PC-mount units (available individually from Digi-Key, as well as in a parts kit from the source mentioned in the Parts List). Try to get the exact units specified to ensure a perfect fit on the PC board.

Go on to install C9, the 4- to 20-pF trimmer capacitor (Sprague-Goodman GKG20011 or equivalent; available individually from Digi-Key as well as in the kit mentioned earlier). Be careful when soldering the trimmer, as it is placed somewhat close to K2.

Next mount XTAL1, the 4-MHz crystal. Be sure to leave a little length on the leads above the board, so that the case is not accidentally shorted to a trace. Then install diodes D1–D3. Make certain they are oriented properly, as shown in Fig. 5, or the circuit will not work and you might damage the microcontroller.

The row of 14 pads on the far-right side of the board is the off-board connector to LCD-module DISP1. Use ribbon cable to connect the board to the LCD, making sure that pin 1 on the LCD is connected to the top pin on the component side of the board.

There are three other off-board assembly steps that now need to be done. First, connect switch S1 to the board using two short leads. Next, solder the battery connector to the board, making sure the polarity is correct. Finally, Fig. 6 shows how to assemble the test socket using an 8-pin SIP socket. Solder a bit of wire to connect four pins on each side of the socket. That will make each group of four pins

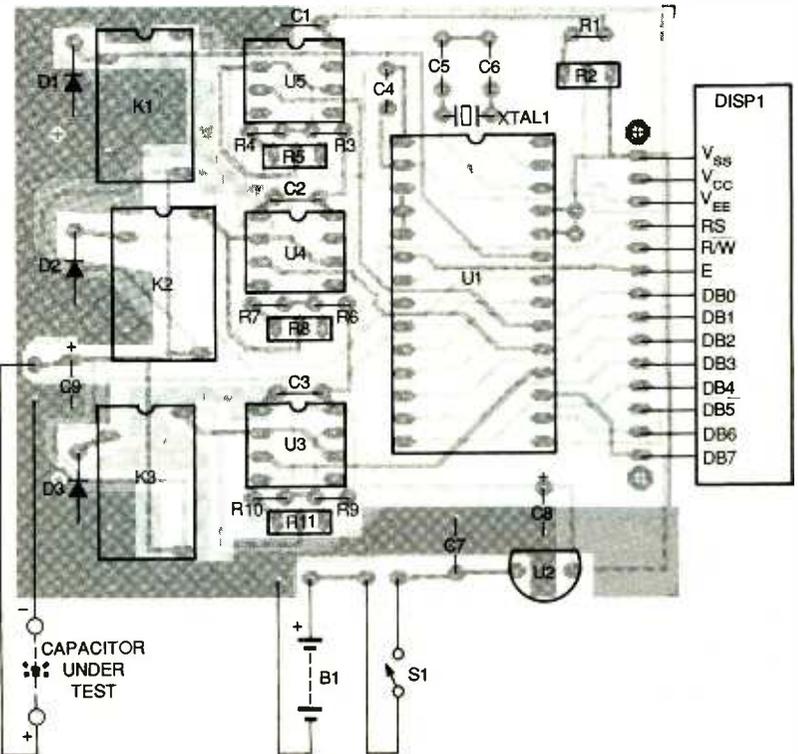


Fig. 5. When assembling the circuit, be sure to use this parts-placement diagram as a guide.

electrically equal, so that capacitors with different-size leads can all be accommodated. Solder a piece of 2-conductor ribbon cable (avoid using 2 ordinary wires) to each side of the socket, and solder the other end to the board as shown in the parts-placement diagram.

If you like, you can add external test leads to the board, so that you can measure capacitors that are still part

of a circuit or that have leads that are too wide apart. Just keep them tightly wound up or otherwise immobile after turning the unit on, because any stray capacitance they add to the circuit will only be canceled out by the software when power is first applied. After that, any movement of the leads could result in error.

**Checkout.** After you're done build-

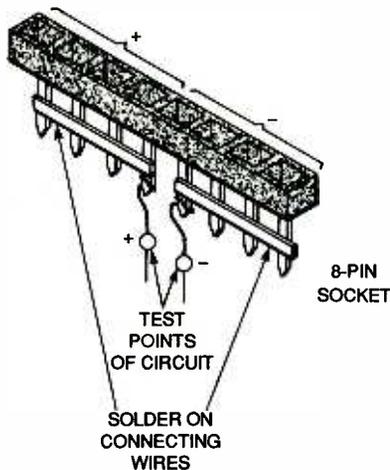


Fig. 6. By soldering a bit of wire to connect four pins on each side of the socket, you get two groups of pins, made up of four each, that are electrically equal.

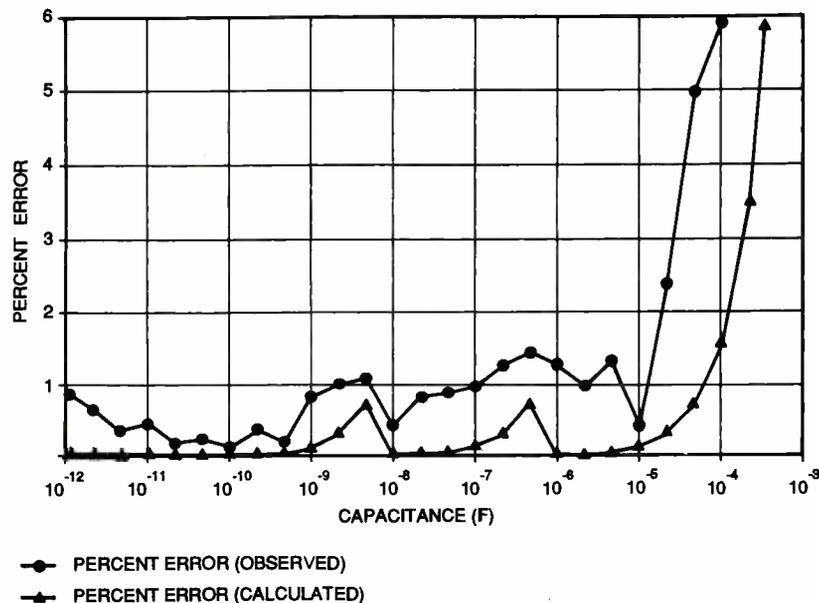


Fig. 7. This chart shows the error due to the quantization of the pulse counts from the timers in the Meter, and the author's measured results. Notice the error tends to shoot off to infinity for large-value capacitors, at least in theory.

ing the circuit, but before you insert the ICs and relays, check that you don't have a short between power (+5V) and ground. Connect a 9-volt battery to the battery connector, measure the voltage on the power rail, and verify that 5 volts is being supplied. If not, check for a short, and check that you have the orientation of the regulator correct.

Next, insert the relays and verify that there is an open circuit between pins 8 and 14 when pin 2 is grounded, and a closed circuit when pin 2 has +5V present. Then insert the timer ICs and,

if possible, verify that they are oscillating at output-pin 3. The 100-ohm circuit, "A," should be oscillating at the highest frequency.

Finally, turn off the power and insert U1, the microcontroller. Turn on the power again. The LCD might display black squares; if so, adjust R2 until the desired contrast is obtained. When correctly operating, the LCD will display "Please wait" upon power-up. After 1.3 seconds, the LCD will display "Ready" or "Remove capacitor." If it displays the latter, adjust C9 until the unit displays "Ready." Turn the Meter off, then on, so that it can re-calibrate with the new setting of C9. Ideally, you should have C9 set so that it is just low enough to give "Ready" upon power up, but no lower.

**Sources of Error.** The microprocessor's software operates by assuming that R3 and the sum of R4 and R5 are exactly 100 ohms. The same is true for the other timer circuits, but with the substitution of 10,000-ohm and 1-megohm values. The discrete resistors are 5% tolerance, which translates to a source of 5% error.

Another source is in the timers—they are not all created equal. The internal circuit of a timer generates references at  $\frac{1}{3} V_{CC}$  and  $\frac{2}{3} V_{CC}$  using 3 resistors as voltage-dividers. Amazingly, those resistors are only 10%

tolerance! Fortunately, those errors add to create one linear-error term, which can be effectively canceled out with calibration.

The primary source of error that remains is that associated with the quantization of the pulse counts from the timers. Figure 7 shows the error due to that phenomenon as well as the author's measured results. Notice the error tends to shoot off to infinity for large-value capacitors, at least in theory. The reason for that is the quantization error increases when the counts-per-second (frequency) approaches zero. For example, if a large-value capacitor, say 3407  $\mu\text{F}$ , is generating a 1.408743-Hz pulse train, the Meter is likely to measure it as either 1 Hz (giving a 4800- $\mu\text{F}$  reading) or 2 Hz (giving a 2400- $\mu\text{F}$  reading). Those are 41% and 29% error rates, respectively.

To partially counter large error rates, there is a special section in the software to manage large-value capacitors. If you do measure a large-value (1000  $\mu\text{F}$  or larger) capacitor, expect the time required to get a measurement to increase to as much as 13 seconds per reading. That extra time helps to minimize error in slow-frequency signals. Also, if you measure very-small-value capacitors (less than 47 pF), keep in mind the capacitance of long leads. A 1-pF capacitor with leads two-inches long and a half-inch apart will read 1.5 to 2 pF. To get an accurate reading, trim the leads and separate them 180° at the capacitor's package.

**Calibration.** There are two methods of calibrating your Meter. The first method is the more accurate, but it requires access to an accurate capacitance meter. Select a 100-pF, 0.01- $\mu\text{F}$ , and 1- $\mu\text{F}$  capacitor. Other values will do, but they must be close to those. Measure those capacitors as accurately as possible, keeping in mind that most commercial capacitors are 20% tolerance. Therefore, if you get a surprising reading, you can still probably trust the meter.

Place the 100-pF capacitor in your Meter. Adjust R11 until the value displayed on the LCD closely matches the known value. Repeat that with the 0.01- $\mu\text{F}$  capacitor, adjusting R8, and the 1- $\mu\text{F}$  capacitor, adjusting R5. That

(Continued on page 112)

## XMAS TREE

(Continued from page 54)

batteries. Solder short hookup wires to connect the power and ground traces on the circuit board to the holder. The hookup wires should be long enough to allow you to move the circuit board out of the way to change batteries, but short enough to remain out of view. Four to six inches is a good length.

Install the batteries and wedge the circuit board between them. Visually examine the assembled board to ensure there are no solder bridges or cold joints. Double check for proper parts placement and orientation of the diodes, IC sockets, and LEDs. If everything checks out, install the ICs with pin 1 towards the bottom of the Tree. Then apply power by rotating the terminals (at the unwired end) of the battery holder until they come in contact with each other. If all is well, all 17 LEDs

should begin blinking in a seemingly random fashion, with the top LED flickering.

**Troubleshooting.** If the top LED isn't working properly, check the orientation of the two 1N4148 diodes as well as the LED itself. Check the orientation of the other LEDs if they aren't lighting either. If groups of four LEDs aren't working, trace them back to U3 and make sure that section of the 74HC04 is getting a clock signal. If it is, the problem is either one of the LEDs and/or resistors, or the IC itself. Double check for shorts or solder bridges before blaming the IC.

If some LEDs still aren't blinking, go back to the appropriate section of the timer circuitry and check the support components. To eliminate the possibility of the 7556 timers being at fault, switch them with each other. If the same LEDs are still not blinking, the problem is in the support circuitry. If swapping the 7556 chips causes one

group of LEDs to start working and a different group to fail, then and only then is it safe to assume one timer is defective.

**Decorating Your Tree.** Imagination is the only limitation in decorating the Tree. You can paint the Xmas Tree board (before mounting components) or use glitter (care must be taken in certain areas to avoid shorts across components or leads to the ICs if glitter is used). Another option is to glue cotton balls to the Tree. You can also use a scrap of felt to make a skirt that will hide the batteries, and string small beads to make garlands. For those inclined towards arts and crafts, the possibilities are almost endless.

A pair of fresh D batteries will provide power for about two months of continuous operation. And because there are no parts to wear out or burn out, the Electronic Xmas Tree will give years of enjoyment during the Holiday Season. ■

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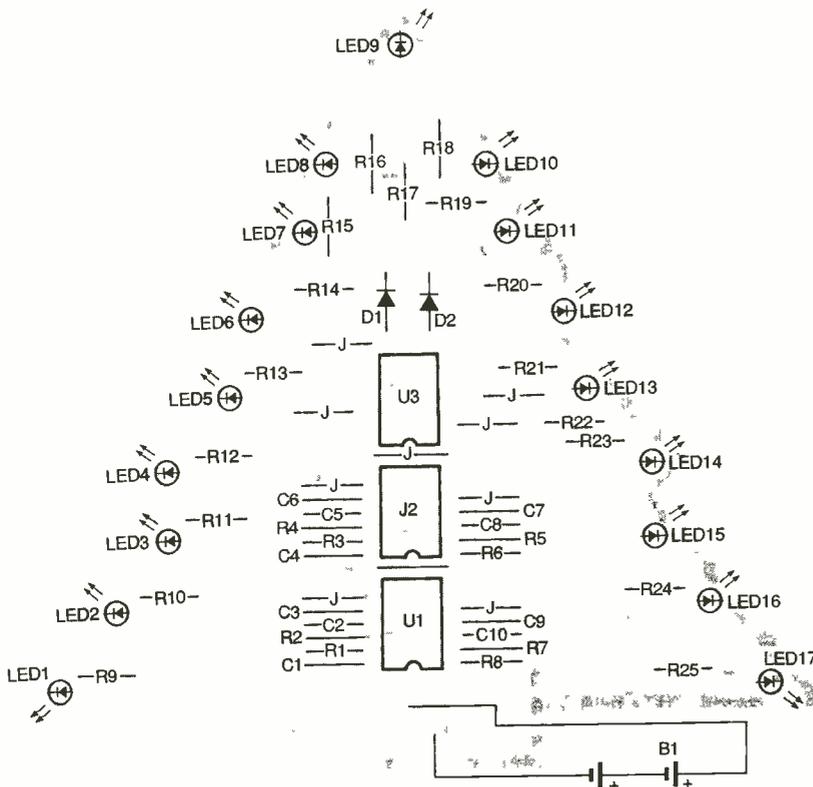
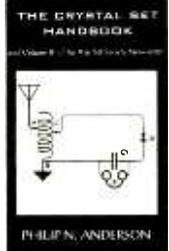


Fig. 3. Use this parts-placement diagram as a guide when mounting components on the Xmas Tree board.

## SCOPE CALIBRATOR

(Continued from page 73)

checked with any good-quality digital multimeter. Temporarily connect a jumper from the junction of R1 and D1 to ground. That will hold the calibrator output at exactly 1-volt DC. Check to make sure that is so.

To check the output frequency, you could use a digital frequency counter, but there is another very accurate method you can try. Acquire an audio-test CD and use the 1-kHz sine-wave track as a frequency standard. With the calibrator output connected to one channel of the stereo, and the CD playing on the other channel, adjust the calibrator frequency for a near-zero audible-beat frequency. That process of sound-matching is familiar to anyone who's used a piano or guitar tuner.

**Using The Calibrator.** A scope's vertical amplifier gain can be checked by using the 1-volt-DC height of the Calibrator squarewave and comparing it with the vertical display graticule. The time base can be checked by comparing the 1-millisecond cycle time for the squarewave against the horizontal display graticule.

It's also easy to check passive, high-impedance scope probes ( $\times 10$ ,  $\times 100$ ) against the Calibrator's squarewave output. Because the Calibrator rise time is very fast, any distortion in the waveform is due to a mismatch of probe compensation. The compensation should be adjusted until the squarewave is restored on the scope's display. ■



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and examine the board for errors. While viewing the logo, you can adjust R6 to set the contrast of the display to your liking.

Plug the phone cord of the DTMF Decoder/Logger into any phone jack on the line and use a touch-tone phone (on the same line) to begin entering numbers. As you do that, you will see those characters displayed on the LCD module. As the display fills up with new characters, it will start scrolling the old characters off the left hand side of the display. If you pause more than 10 seconds between entries, the next number entered will cause the display to clear, and the new character will be placed at the far left side of the display as if you had cycled the power switch or cleared the memory. That is for appearance only—all previously entered numbers are still held in memory.

At any time, you can press the **SHIFT BACK** button to scroll backwards and see all numbers that were previously entered (even though they had disappeared from the display). Pressing or holding down the **SHIFT FWD** button will return you back to the most recent entries, and the **CLEAR** button will erase all numbers stored in memory.

The memory will hold up to 240 characters, including the blank spaces between groups of numbers. When the memory fills up, the oldest entries will be overwritten by the new ones. Because the EEPROM uses its own dedicated address pointer, the scrolling action will automatically halt upon reaching the beginning or end of memory even if the memory is full. Also, all new touch-tone entries will always be added to the end of memory regardless of the portion of memory being viewed at that particular time.

Because the memory is stored in a non-volatile EEPROM, the DTMF Decoder/Logger can be turned off and still retain all data. When the unit is turned back on, the display automatically jumps to the end of memory and shows a blank screen. Use the **SHIFT BACK** button to scroll back and see all entries previously stored in memory.

And remember, you're not limited to just logging numbers dialed on a phone line you connect to. By feeding the input of a radio to the DTMF Decoder/Logger, who knows what numbers you'll capture and log! ■

## MAGIC EYE

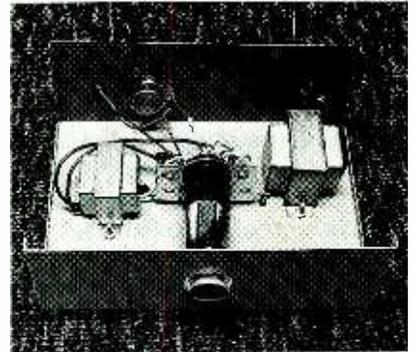
(Continued from page 25)

transformers and tube socket as connection points for the few other components.

Begin wiring the circuit by mounting a socket for the magic-eye tube on a couple of hardware-store, 1½-inch brass-corner "irons." The "shadow area" of the tube is oriented between pins 1 and 8. Keep in mind when mounting the tube that it's customary to have that area pointing down. You will need to cut a 1½/32-inch-diameter hole in the front panel to accommodate the tube.

Next go on to wire the rest of the circuit. If you are planning on using the circuit for show only, you will only need to wire the components shown in Fig. 1. Add the components shown in Fig. 2 if you would like to use the Magic Eye as a tuning indicator.

Whichever version you build, keep the following in mind: The center-tap



Note that no circuit board was used in the author's prototype. The transformers and tube socket can be used as connection points for the other parts.

connection to the 12.6-volt windings of T1 and T2 isn't used and can be trimmed short and either taped or curled out of the way. Tie a knot in the power cord so an inadvertent pull won't tear the wiring.

If you're using the Magic Eye as a tuning indicator, make sure that the input wires are kept short. Also, use grommets to protect them at their points of entry to the project box.

## PARTS LIST FOR THE MAGIC EYE

### RESISTORS

(All fixed resistors are ½-watt, 5% units.)

R1—470,000-ohm

R2—1-megohm\*

R3—1-megohm potentiometer\*

### ADDITIONAL PARTS AND MATERIALS

C1—0.1-µF polyester capacitor\*

V1—1629 vacuum tube

T1, T2—117-volt to 12.6-volt, 450-mA or greater, power transformer

PL1—AC plug, two-terminal

Project enclosure, octal tube socket, 1½-inch brass corner irons, power cord, grommets, nuts, bolts, wire, solder, hardware, etc.

All parts marked with an asterisk (\*) are only necessary for the tuning-indicator version of the Magic Eye shown in Fig. 2.

**Note:** The following are available from Antique Electronic Supply (6221 S. Maple Ave., Tempe, AZ 85283; Tel. 602-820-5411; Fax: 602-820-4643): A complete kit of all above parts (K-PE-EYEKIT)—\$29.95; a 1629 magic-eye vacuum tube—\$5.30. Contact Antique Electronic Supply for shipping and handling information.

**Using the Magic Eye.** If you built the version of the Magic Eye shown in Fig. 1, then using it is simple. Just place it on top of your stereo or radio and plug the Magic Eye into the wall. Then, when you shut off the lights, you'll be ready to relive the old days.

If you built the version of the circuit shown in Fig. 2, you will need to attach your Magic Eye to your radio's ground and AVC line. In most radios, the AVC line is connected to the end of the loop antenna or to the antenna coil opposite the end connected to the grid of the input tube.

**Note:** Never attach any accessory to a radio without isolating the radio first. A so-called AC-DC radio can be made safe by using an inexpensive isolation transformer between the radio and power outlet.

Once the Magic Eye is connected to the radio, turn on both units. Then, adjust potentiometer R3 so that the Eye closes as stations are tuned in. That's all there is to it. ■

# BUY BONDS

## BIO-STIMULATOR

(Continued from page 24)

**Calibration and Use.** Insert a battery and turn on the power using R10/S1; then continue to adjust R10 to its middle setting. Place the acorn nuts across the inside of your arm and toggle S2 to each position. You should feel an increase or decrease of the shock pulse. Slowly turn R10 clockwise or counterclockwise to feel an increase or decrease (respectively) of the shock-pulse intensity.

See Fig. 4 for a list of ailments that traditional acupuncture has been claimed to remedy. If you suffer from one of those problems, then choose the appropriate acupuncture point and place cap-nut J2 directly over it. The other cap nut, J1, can be placed on any part of the skin. For best results, try applying the Bio-Stimulator up to three times a day for durations of between 5 and 15 minutes. You should be able to stop when the pain is reduced to your satisfaction.

**Electrode Pads.** Many electronic-acupuncture practitioners attach electrode pads to a patient's skin at various pressure points (determined by an electrode-placement chart), thereby allowing stimulation of an entire group of nerves covering a large area. With a simple modification, electrode pads can be attached to the Bio-Stimulator, adding to the unit's versatility. However, keep the following in mind:

**Note:** Federal and State laws regulate the sale of electrode pads. Check with your doctor to find out if you need a prescription to purchase them.

Three items are necessary to add electrodes to your unit: alligator clips (Radio Shack part number 270-347 or equivalent), test leads with pin tips (Radio Shack part number 278-705 or equivalent), and Unipatch 624 electrode pads (available at major medical suppliers). Assembly is simple. Remove the probe from each test lead, then solder an alligator clip on to each exposed wire. When finished you should have pin tips at one end and alligator clips at the other.

Clip the alligator clips to J1 and J2. Then insert the pin tips into the electrode receptacles. The electrode

## PARTS LIST FOR THE BIO-STIMULATOR

### SEMICONDUCTORS

IC1—556 dual timer, integrated circuit  
Q1—2N4401 NPN transistor  
D1—1N4005 silicon rectifier diode

### RESISTORS

(All resistors are 1/4-watt, 5% units.)  
R1—100-ohm  
R2, R3—750,000-ohm  
R4—390-ohm  
R5—22,000-ohm  
R6—10,000-ohm  
R7, R9—47,000-ohm  
R8—150-ohm  
R10—50,000-ohm potentiometer with SPST switch (S1)

### CAPACITORS

C1—1- $\mu$ F, 16-WVDC, electrolytic  
C2—0.1- $\mu$ F, ceramic-disc  
C3—0.01- $\mu$ F, ceramic-disc  
C4—4700-pF, ceramic-disc  
C5—1- $\mu$ F, ceramic-disc  
C6—0.047- $\mu$ F, ceramic-disc

### ADDITIONAL PARTS AND MATERIALS

T1—Audio transformer, 8-ohm primary, 1,200-ohm secondary (Mouser KM003)  
J1, J2—Acorn cap nut  
S1—SPST switch (part of R10)  
S2—SPST switch  
B1—9-volt alkaline battery  
Printed-circuit materials, project enclosure, battery clip with leads, alligator clips (optional, see text), test leads with pin tips (optional, see text), Unipatch 624 electrode pads (optional, see text), wire, solder, hardware, etc.

**Note:** The following items are available from RAH Projects (P.O. Box 15904, Newport Beach, CA 92659): etched and drilled PC board—\$6.95; kit of parts including the PC board (but no project enclosure)—\$30.00; pre-drilled project enclosure—add \$7.50. Add \$2.50 shipping and handling; California residents please also add appropriate sales tax. Check or money order only; personal-check orders will be shipped after the funds have been cleared. Allow 4 to 6 weeks for delivery.

pads can be removed from the plastic sheet and applied to various body locations. Keep in mind that the adhesive material that is on the electrode pads allows for greater conductivity. Therefore, to keep the

adhesive from wearing off too quickly, and to make it possible to use the pads more than once or twice, make sure to place them back on the plastic sheet after each use.

Refer to Fig. 5 to find the locations of nerves where you can place the electrode pads. The spinal system, which is the original base for all nerves, consists of 31 nerves divided into 4 major groups. The Cervical (C1 to C7) and Sacral (S1 to S4) groups spread to the arms and legs, while the Thoracic (T1 to T12) and Lumbar (L1 to L5) groups spread to all parts of the body as shown in the Figure.

The path to both ends of the nerve groups can be found by looking for the C, S, T, or L locations in Fig. 5. You can place the electrode pads at both ends of or along the nerves crossing the pain area. You will then have to experiment to find the optimum locations for reducing pain.

Experimenting with all the possible uses of the Bio-Stimulator could take you quite a bit of time; however, the results you get from the device could be worth it. You just might be pleased to discover the benefits of East-meets-West technology. ■

## DTMF TONE PAD

(Continued from page 46)

coated them with a layer of clear lacquer to protect them from damage in everyday use. You can do the same or use another type of labeling technique.

To use the Tone Pad with a transceiver you have to first decide how you would like to connect the two. While the unit could be hard-wired to the transceiver, using matching plug-and-socket connectors would be a better idea. Some transceivers have +12-volt, ground, transmit audio, and PTT keyline connections already available at an accessory socket on the rear panel. If that is the case, simply use matching plugs on the unit's connection wires.

And that's all there is to it! Once it's connected to your transceiver, the DTMF Tone Pad can be used for countless tasks, making it a constant reminder of the money-saving benefits you can enjoy by being an electronics hobbyist. ■

## SWITCHING AMPLIFIER

(Continued from page 18)

board. Attach to the other end of those wires a connector that matches the one you used on the other board's power-connection wires.

To finish the on-board assembly, insert IC1 into its socket. Then examine both circuit boards to make sure all your electrical connections are correct and error free, be especially careful to check for solder bridges.

Now you are ready to mount the boards in a project enclosure. You should buy or make a plastic case with minimum internal measurements of 8.2 x 7.7 x 2.5 inches. Make sure it has adequate ventilation holes for letting out the heat produced by the high-wattage resistors, MOSFETS, and diode heatsinks. The author's prototype was built in an attractive home-made enclosure.

Drill holes in the bottom of the case to match the mounting holes on the PC boards. Then do the following for each of the holes: Slide a washer onto a round-head screw and insert the screw from the outside into the drilled mounting hole on the bottom of the enclosure. Next, use a hex nut to secure the screw and washer in place. Then place another nut on top of the one just put in place to form a spacer. The last step is to install the boards and secure them at each screw with another nut.

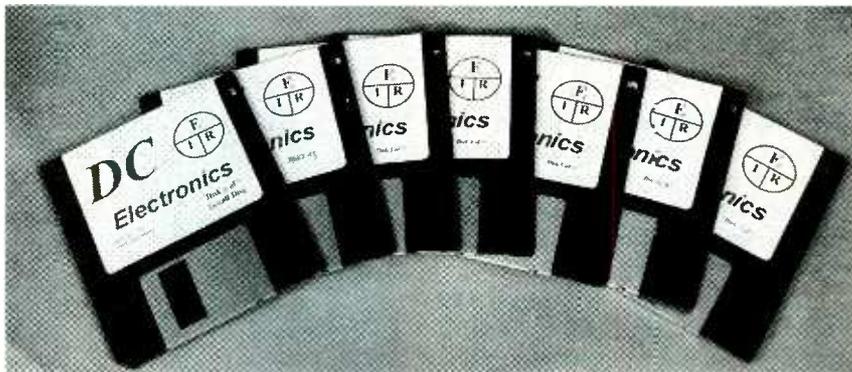
Once the boards are in place, begin mounting the components that go onto the enclosure itself. Place the four jacks on what will be the back of the case and solder each to its proper pair of wires. Then mount the potentiometer to the front panel of the unit and connect it to its respective wires.

Mount the neon assembly and rocker switch to the front of the case. The fuse assembly should be mounted on the rear of the case. Make all the electrical connections between those components and the proper wires on the power-supply board. Finally, attach a power cord with a two-terminal AC plug to the unit.

Make sure the two boards in the Amplifier are connected before plugging the unit into an outlet. If all is well, you'll soon be enjoying great-sounding audio. ■

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| 5. Resistor Color Codes         | 16. Inductors and L/R Time Constants |
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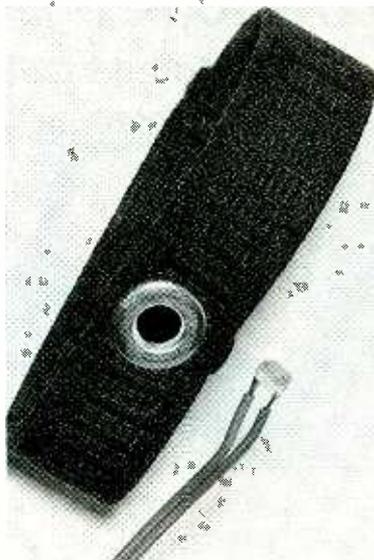
(Continued from page 83)

flashlight on the photocell. The flash should fire. If so, the Tester is ready to use.

**Testing the Batteries.** Put the batteries to be tested into your flash. Again, strap the photocell around your flash so that the photocell sits directly over the ready light. Then connect PL1 to your computer.

Enter the program in Listing 1 into your computer. If you have a modem, and don't feel like typing the program in yourself, you can download it instead from the Gernsback BBS (516-293-2283).

Load and run the program. Be sure that a formatted diskette is in drive A.



Here's what the elastic band looks like before the photocell is inserted into it.

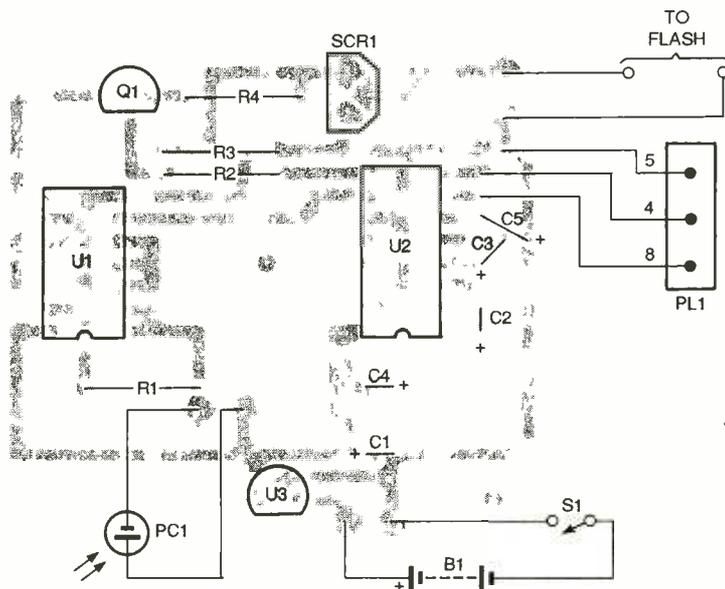


Fig. 4. If you're building the project on a PC board, use this parts-placement diagram as a guide.

All data collected by the program is stored on a disk in that drive in comma-delimited ASCII format. That makes the data easy to use with any spreadsheet program. At the prompts, name the disk file, enter the battery description, and then press RETURN.

Turn on the flash. Once the ready light comes on, press the spacebar as prompted on the screen. The test will

continue until the flash takes more than 45 seconds to recycle. That's because when the batteries get that weak, their useful life is over. The computer shuts off the test and closes the disk file.

When the program ends, you can shut off the flash. Then import the data file into Lotus 123, Microsoft Works, Excel, or some other spreadsheet for analysis. That's all there is to it. ■

## EXPANDED RANGES

(Continued from page 86)

Then, connect a precision 1-megohm resistor to the test leads, and adjust R4 for a reading of 3 volts.

If a meter with different input resistance is used, R4 must be recalibrated. Most DMMs have an input resistance of about 10 megohms. However, catalog descriptions of some of the lower-priced DMMs quote an input resistance of 1 megohm. If the resistance of your DMM is 1 megohm, it could be used with the Megohm Tester by removing R3 and R4, but there is no way to adjust R (in Fig. 3) to a value of exactly 1 megohm.

Another problem is that on some DMMs that are specified as having a 10-megohm input resistance, the input resistance changes for different ranges. On one meter the author checked (a Micronta 22-185A), the change in input resistance occurred between the 3-volt and 300-millivolt ranges, resulting in a 6-percent error when measuring 30 megohms with the Tester. However, some other meters did not show that change.

The circuit shown in Fig. 6 can be used to check for a change in input resistance between the lowest DC-voltage ranges of a DMM. The circuit can be powered by 1- to 5-volts DC. Potentiometer R1 can be 100 to 10,000 ohms. Resistors R2 and R3 can be 1 to 5 megohms.

To use the circuit in Fig. 6, first check the meter calibration with a low-resistance voltage source. Set the meter to its lowest DC voltage range, connect it to points A and G, and adjust R1 for a reading slightly below the maximum reading (slightly below 200 millivolts for a meter with 200-millivolt and 2-volt scales). Then switch the meter to the next higher scale. If there is a significant difference in the reading (more than 2 or 3 millivolts), there is a problem with the meter divider resistors or internal calibration.

To check for a change in input resistance when the meter range is switched, connect the meter to points B and G. Readjust R1 for a reading slightly below the maximum on the lowest scale. Again, switch between the two lowest scales. If the difference is significantly higher than in the first

test, the meter is changing input resistance between scales, and readings from the Megohm Tester will be in error. That test is hard to do on an auto-ranging meter without scale hold, but adjusting R1 very slowly across the limit of the lowest scale will show if there is a difference between scales.

To use the Low-Ohms Tester, connect the test clips to the resistance being measured, and move them slightly to get the lowest reading. Unlike some circuits, the Low-Ohms Tester is not limited to very low resistances, as the current is nearly constant for voltage readings up to more than 5 volts. A 5-volt potential corresponds to 50 ohms on the 100-mA range ( $R = V \times 10$ ), and to 500 ohms on the 10-mA range ( $R = V \times 100$ ).

To use the Megohm Tester, connect the test leads to the resistance being measured, and use a calculator and the formulas given earlier to convert the voltage reading to resistance. ■

#### 4-MODE COUNTER

(Continued from page 71)

smoked Mylar, pasteboard, and black vinyl tape.

The three switches and the LED mount to the project enclosure. When the components are secured in their positions, attach leads to them and connect those wires to the correct points in the board. Check to see that all parts have been connected properly before applying power.

**Checkout and Use.** Apply power to the unit, and set S2 to FREQUENCY. The display should read 000000. If some of the segments are not lit up, go back and check your wiring again.

Connect the Counter to a signal source with a known frequency, using jack J1. The displayed number should match the frequency value. If it doesn't, then you have to make sure the connections on the board are all correct and solid (make sure there are no cold joints). ■

# NAVY

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#### VOCAL EFFECTS GENERATOR

(Continued from page 94)

tors (C1–C5) to their respective pads. Then install the electrolytic capacitors (C6–C9); be sure to properly orient those components on the board.

Next, solder the 4-position DIP switch, S2, to the circuit board; check the orientation of that component. To connect the jacks and potentiometer to the circuit, use pieces of 24-gauge stranded hookup wire. After you've done that, attach the battery holder to the PC board.

Now you can insert U1 and U2 into their respective sockets. Use care when handling the ICs; they are static sensitive.

Drill three holes for J1, J2, and R5 in the top edge of the enclosure you

holder inside the plastic enclosure below the PC board. Finally, slide the control knob onto the shaft of R5 and tighten the set-screw.

**Note:** If you are using the parts included in the kit (see the Parts List for details), then your speaker and microphone will come already connected to their respective plugs. If you wish to use your own parts for MIC1 and SPKR1, however, you will have to connect them to two plugs—PL1 and PL2. For that reason, the plugs are indicated in the Parts List as being optional.

**Using the Generator.** Install four AA batteries and set the DIP switch (S2) to the desired mode, referring of course to Table 1. Plug the electret microphone into J1 and the remote speaker into J2. Turn the unit on and set the volume at about half-way. Keep the

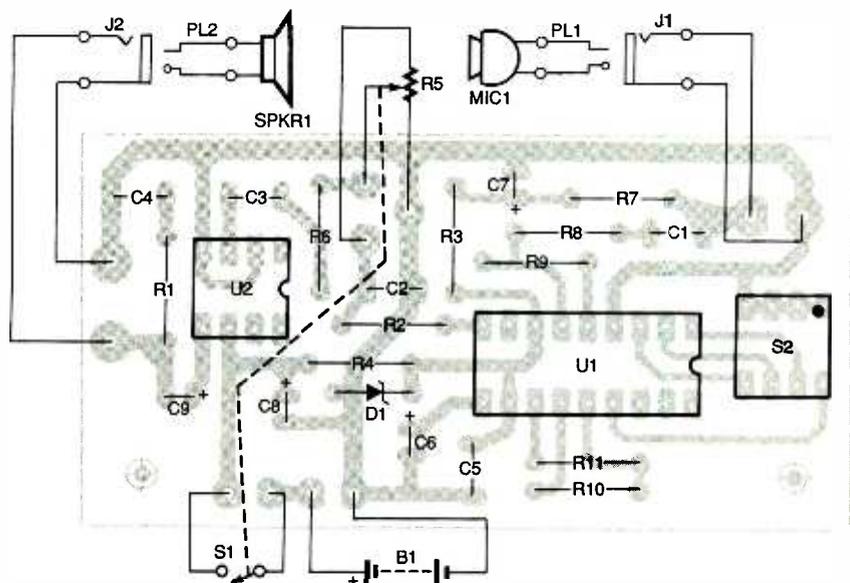


Fig. 3. If you build the Effects Generator on a PC board, use this parts-placement diagram as a guide. Note the off-board connections to J1, J2, and R5/S1.

plan on using. Also cut an opening on the back cover to allow access to the DIP switch. If you plan to wear the unit on your belt, you can also attach a belt clip to the cover at this point.

Mount the PC board inside the plastic case with screws. Then install J1, J2, and R5 into their holes on the enclosure. You might need to remove the small metal tab sticking up from the potentiometer body so that it will not interfere with the component's mounting. Secure the three parts with the appropriate mounting hardware.

The next step is to use hot-melt or epoxy glue to attach the battery

microphone away from the speaker, or you will experience a loud feedback squeal.

Each time that the Vocal Sound-Effects Generator is turned on, it will initialize to the mode selected by S2. As you speak into the microphone, you can change the settings of S2 and experiment to see how your voice sounds when the unit is in each of the modes.

With a little experimentation, you should be able to find the perfect sound to enhance whatever your Halloween plans are this year. So, go out and have some ghastly fun! ■

## SOUND-LEVEL METER

(Continued from page 58)

number P9970-ND) electret condenser element specified at  $-44$  dB sensitivity into a 3000-ohm resistive load (the frequency response is flat within 3 dB to 16 kHz). It should be mounted with the leads just protruding through the board for maximum height. A small drop of silicone rubber can be mounted under the front edge of the microphone to support it more securely.

When the board is completed, mount it in its enclosure. The four internal mounting posts of the SerPac M6 case fit through the four larger outer corner holes. If you use a different case, you will have to come up with an alternative method.

**Testing and Calibration.** Measure the  $V_{CC}$  voltage; it should be approximately 5 volts. Under very quiet conditions, the RSSI voltage should be under 0.2 volts at pin 5 of U1. Sounds should drive the RSSI voltage upward and light the bar graph progressively. Note that the low end of the display is located closest to the switch, so that the display reads properly (left to right) when the microphone is facing away from the user and towards the source.

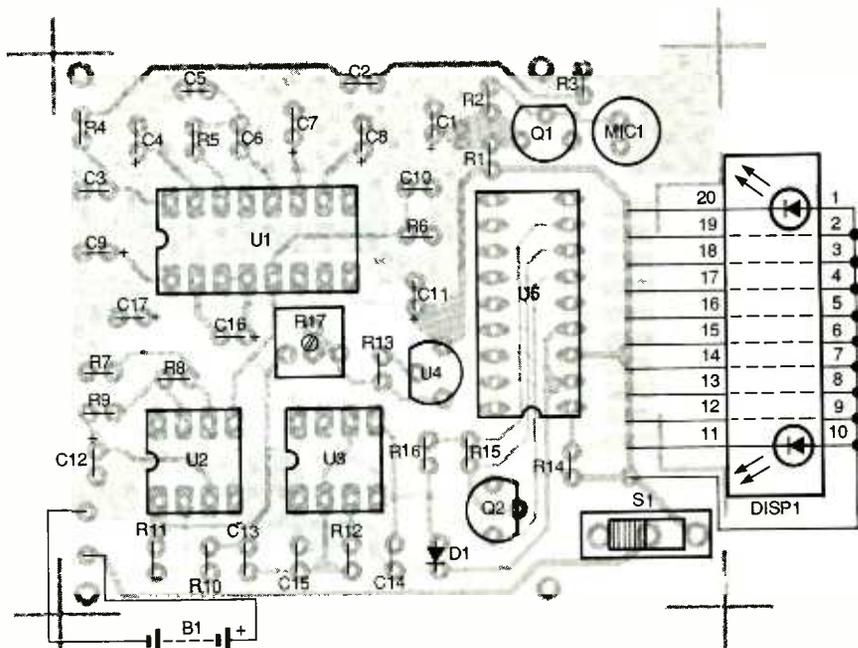


Fig. 4. When installing components to the PC board, use this parts-placement diagram as a guide. The LED display, DISP1, is mounted sideways, off board. The row of pins not connected to pads are connected together by a wire that is then soldered to the pad shown.

Calibration is performed by adjusting R17, the offset potentiometer, so that a given signal level coincides with the proper bar display. Because the slope of the RSSI signal and the display are already equal, only one point of the display need be cali-

brated. The lowest point (the first LED) is almost in the noise of the amplifier, so that merely adjusting R17 to just fully light the first bar in a very quiet room will generally be adequate. The voltage measured across R17 should be about 0.44 volts. ■

## SMART STRIP

(Continued from page 48)

install the relay (check to see if the relay you use has a polarity-sensitive coil). To complete the on-board assembly, mount an IC socket for IC1 and insert the chip.

The next step is to install the Smart Strip circuit into a power strip. Just about any six-socket strip that can be disassembled will work with a few modifications. Whatever strip you use, however, make sure it is **unplugged** before you begin. To make room for the circuit board, one of the three duplex-style outlets should be removed (a duplex-style outlet has two AC sockets on it). It is best to remove the double outlet closest to the line cord to simplify wiring to the circuit board. The opening left by the removed outlet should be covered.

On the remaining duplex-style out-

let that is closest to the location of the removed outlet, cut the metal links that electrically connect the two AC sockets of the outlet (see Fig. 4). You can then make the off-board connections shown electrically in Fig. 3, and mechanically in Fig. 4; use 18-gauge, stranded, insulated wire.

Mount the circuit board inside the outlet strip near the line cord. You can use two screws and 1/4-inch nylon spacers to do that. Make absolutely sure that everything is wired correctly before closing up the strip. If any part of the circuit is not connected properly, or if it makes contact with the metal housing or the outlets, serious damage could result. When you're sure the wiring is okay, reassemble the outlet strip with the circuit board installed.

**Checkout and Use.** To test the circuit, you will need two appliances such as lamps or other small, inexpen-

sive AC-line-powered devices. (It's always a good idea to check AC-power-source projects with cheap devices just in case you made a wiring error; you wouldn't want to damage a computer or TV.)

Plug one device into one of the switched sockets and turn the device's power switch on. Connect the other device into the load-sense socket, but leave its power switch off. Next, plug the Smart Strip into an electrical outlet. If your strip has a power switch, it should be turned on as well. Now, turn on the device plugged into the sense socket and make sure the device plugged into the switched outlet also comes on. If that doesn't happen, unplug the strip and check your wiring.

The Smart Strip can be used with virtually any combination of electrical appliances as long as the sense device draws 5 amps or less, and the switched devices draw less than 10 amps combined. ■

## TV TRANSMITTER

*(Continued from page 36)*

able from Ramsey Electronics allows the board to be mounted in the bottom half, and by lifting the top off, still be aligned. That also protects the underside of the board against shorts during alignment. You should inspect the solder side of the board carefully before mounting it in the case.

**Alignment.** To align the TV Transmitter, you'll need a TV set and a source of video such as a VCR or camcorder. You'll also need a non-metallic tool to adjust coil L4 and transformer T1. A fresh 9-volt battery can be used for alignment, but if you find it difficult to align, try doing it with a 12-volt supply. Note that during alignment and testing, we found that the unit operated much better from 12 volts. If you find the same to be true, it is a simple matter to add an external power jack to the unit and wire it to the appropriate points on the PC board.

Tune a TV set to an unused channel between 2 and 6. The TV must have an indoor antenna connected directly to it; an outdoor antenna or cable won't work. Make sure both potentiometers are in mid-position and apply power to the Transmitter. Adjust L4 with a non-metallic tool until the TV screen goes blank. Then fine-adjust L4 for the "most-blank" picture.

Connect the video and audio outputs from a VCR to jacks J1 and J2 (respectively) of the Transmitter. Then set a tape to play. You should see a picture on the TV screen; if you do, readjust L4 for the best picture; if you don't, check the board for any bad connections. Next, adjust R3 for the best picture brightness and R7 for the best overall picture. You might have to make another minor adjustment to L4 after R3 and R7 are set. Finally, adjust T1 with a non-metallic tool for the best-sounding audio. That's all there is to it.

The whip antenna should be fine for most in-home use. If you need more range, an external antenna can be connected to J3 (remember to install R12). But always keep in mind that it is your responsibility to make sure that your operation does not interfere with your neighbor's TV viewing. Besides, someone might be watching what you are watching! ■

## DISCONE ANTENNA

*(Continued from page 61)*

connector. Next, check that zero resistance (short circuit) exists between the disc and the center terminal of the connector.

Clean all flux residues and the discone construction is done. Alcohol is good for removing rosin flux. Clean with alcohol only outdoors and away from fire as alcohol can be toxic and is highly flammable.

If you have suitable equipment, check the antenna's VSWR at the frequencies of interest. The prototype's measured VSWR was found to be better than 1.5 to 1 at 910 and 1289 MHz. Use type N connectors preferably.

### Mount it

The discone can be mounted to a mast with clamps. Fasten clamps around lower end of brass tube, being careful not to dent or crush it. You can use small metal or plastic cable clamps as the antenna is very light, or it can be plugged directly into the scanner antenna jack. Use a right-angle adapter.

When the antenna was used with a pocket scanner, excellent reception results were obtained on 860 and 935 MHz commercial signals, much better than the 8-inch "rubber ducky" original equipment. Also, a marked reduction in intermodulation and cross modulation effects was noted. Although below the cutoff frequency, satisfactory 450-MHz reception was also obtained. For optimum 450 MHz performance, increase the cone and disk dimensions 75%.

In field tests, the discone assembled by the authors outperformed a 24-inch commercial discone sold for scanner reception at 900 MHz. This is probably because the home-built discone has a lower wave angle and because it is constructed of solid copper elements, with resulting lower losses. Improvement on reception and transmission was about 3 dB. The discone was used with success as an antenna for experimental amateur TV transmissions at 900 and 1300 MHz. ■

## POOR-MAN'S TRANSMITTER

*(Continued from page 92)*

apply solder to the twisted strands until the exposed wire is completely covered. It will appear silvery when that occurs (tin colored). Do not apply too much solder, because that will make the wire thicker, and more difficult to insert into the breadboard.

The antenna can be made out of 4 feet of stiff, 22-gauge wire. If you would like to have the antenna take up less space, wrap the wire around a 1-inch-diameter form, and remove the resulting coil. Attach the antenna to the proper point in the circuit.

**Tuning and Use.** Okay, so you got this thing assembled, now what? Well, like most transmitting devices, the Poor-Man's Transmitter has to be tuned.

Start out by turning on an AM/FM radio and tuning to a frequency on the AM band where there are no other signals. Place your Transmitter near the radio and attach the battery. Then, while holding down S1 with one hand, start turning potentiometer R3 with the other. You will hear an audio tone come in and out of tune as you adjust R3.

Now try this: Set the radio to FM and tune R3. You'll find that you can pick up the signal in the FM band as well, in fact it seems to be all over the place in the FM band, while it just came through on one setting in the AM band. Try turning on a CB, it will come through that as well. It will also come through the VHF stations of your TV, causing horizontal bands in the picture and odd tones in the sound.

Why can you pick up the signals from this 1-MHz AM transmitter on every communications device in your house? Because it is transmitting a squarewave that is, electronically speaking, very dirty. A squarewave is made up of an infinite number of sinewaves, in different proportions. A sinewave is very clean, and is the type of wave that most radio transmitters send.

So, although you might have R3 set to transmit at 1 MHz, you are also generating harmonics (component sinewaves) at 2 MHz, 3 MHz, and so on up to 100 MHz. That covers the FM radio band, the CB band (27 MHz), and the TV VHF band (54-88 MHz). ■

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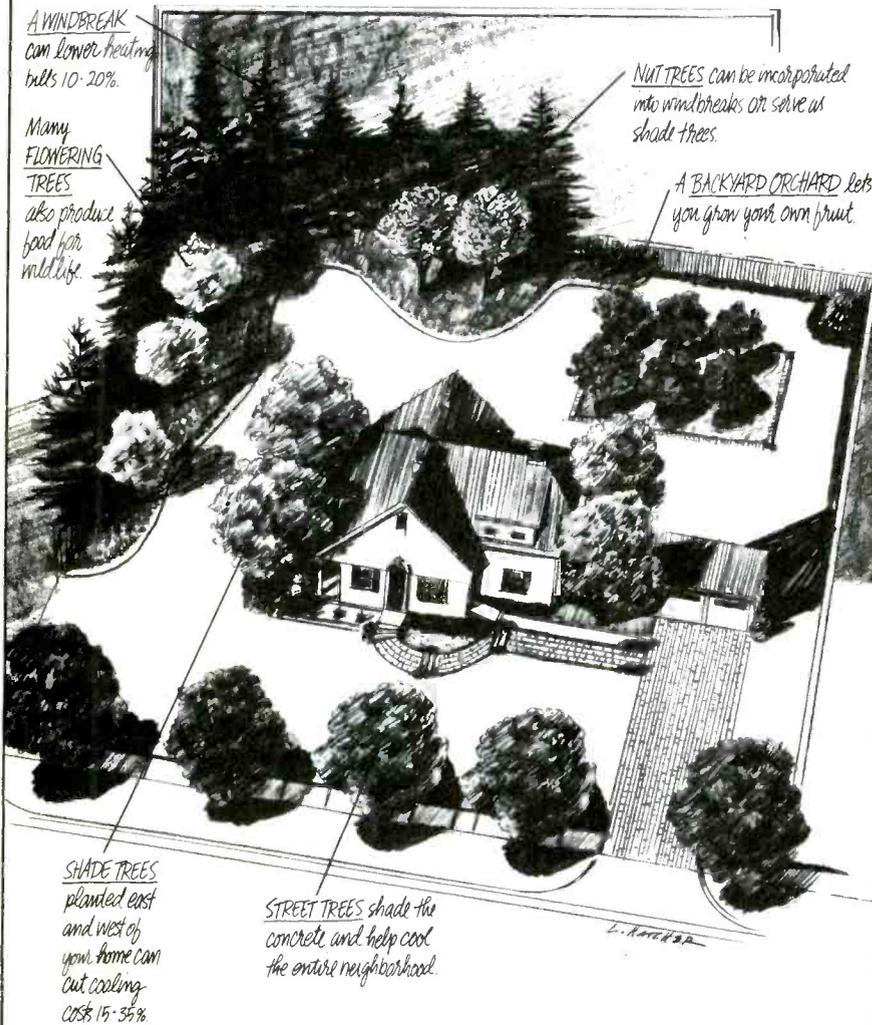
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## CAPACITANCE METER

(Continued from page 99)

will give you the best calibration, subject of course to the accuracy of the meter you used.

The other method you can use will give acceptable results in the absence of another capacitance meter. Carefully measure R9, which is nominally 1 megohm, and R10, which is nominally 910,000 ohms. Then, adjust R11 until it satisfies this equation:

$$R11 = [(3,000,000 - R9)/2] - R10 \\ \approx 90,000 \text{ ohms}$$

Continue by adjusting R8 and R5 until they satisfy these equations:

$$R8 = [(30,000 - R6)/2] - R7 \\ \approx 900 \text{ ohms}$$

$$R5 = [(300 - R3)/2] - R4 \approx 53 \text{ ohms}$$

That procedure will relieve you of the resistor's 5% error, but not the 10% error of the timer's resistors.

**Using the Meter.** As I've said, the Capacitance Meter is user friendly. When calibrated and turned on, the Meter displays "Please Wait." During that time it measures and records any stray capacitance present. That value will vary from meter to meter, and from day to day on the same unit. After about 1.3 seconds, the Meter will display "Ready." If you have a capacitor in the test socket when turned on, the meter will read "Remove capacitor" instead of "Ready." Simply remove the capacitor and wait another 1.3 seconds for "Ready."

To use the Meter then, place a capacitor in the unit's test socket. Note which side of the test socket is the circuit ground. You should always place the negative terminal of electrolytic capacitors in the ground side. The Meter automatically detects the capacitor's presence, selects the appropriate range, and displays the result; the unit will also update the reading every 1.3 seconds. When you remove the capacitor, the display should return to "Ready."

If you measure large capacitors, the time between readings will increase. If you really test the Meter's limits, it will display "overrange" for capacitances larger than about 5000  $\mu\text{F}$  or if you accidentally place a resistor in the socket.

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Hobbyists Handbook

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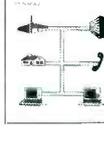
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## 30 Solderless Breadboard Projects - Book 2



□ **BP113—30 Solderless Breadboard Projects - Book 2...\$5.95.** Companion to BP107. Presented in exactly the same style using "Verobloc" breadboards. All the breadboard projects in this book are based on CMOS logic integrated circuits.

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## Beginners Guide To Digital Techniques



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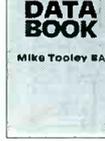
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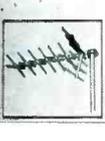
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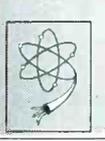
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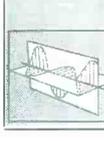
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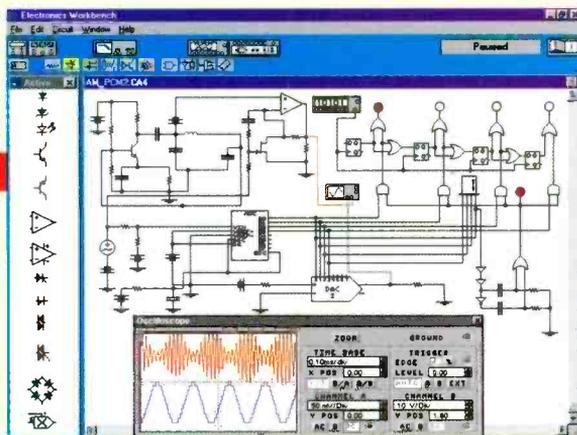
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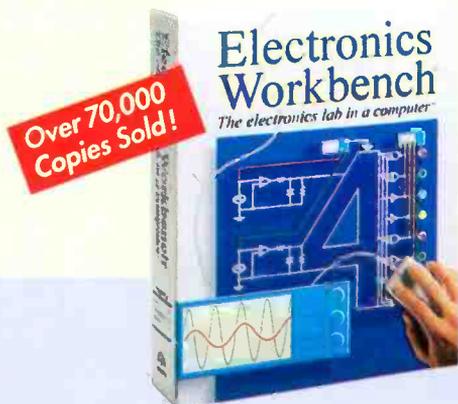
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