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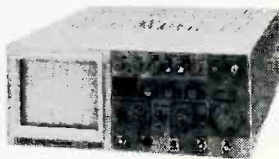
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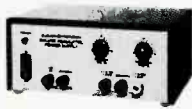
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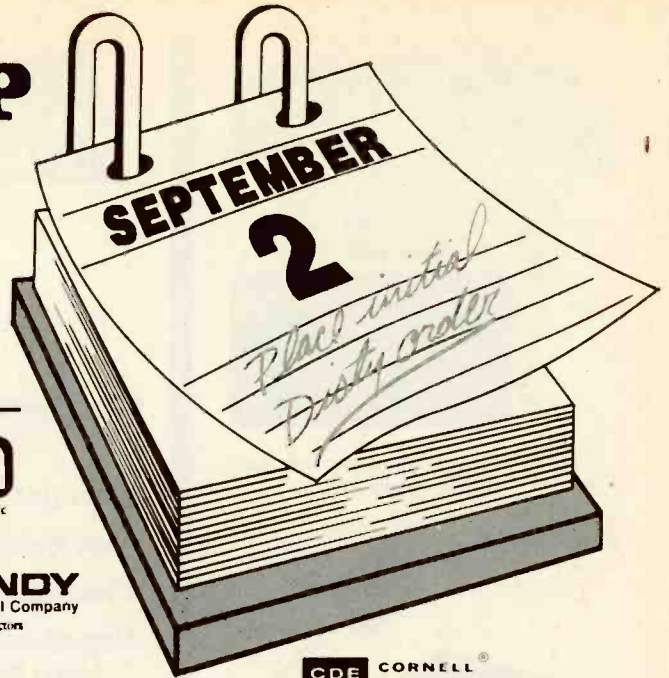
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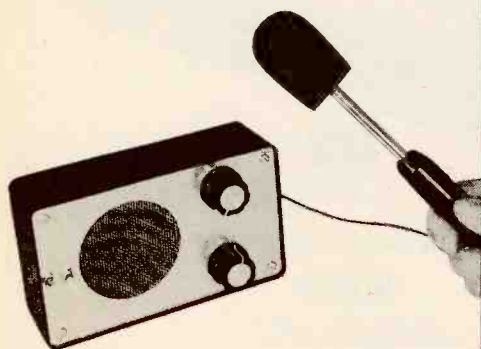


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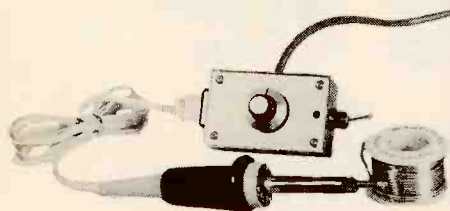
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Get your phone to warble your way
(See page 55)



You won't recognize your own voice
(See page 73)



Spare the heat and save the part!
(See page 92)



The play transmitter
that can do a lot
of work.
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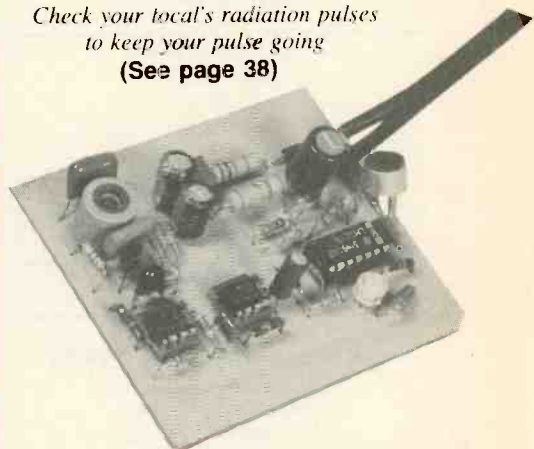
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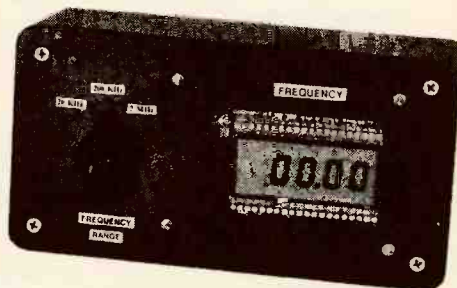
*You don't need perfect pitch for perfect tuning
(See page 15)*



*Check your local's radiation pulses to keep your pulse going
(See page 38)*



*Tune in baby and tune out anxiety
(See page 57)*



*Counting pulses and cycles up to two million is no problem
(See page 45)*

Since some of the equipment and circuitry described in *Popular Electronics 1993 Electronics Hobbyists Handbook* may relate to or be covered by U.S. patents, we disclaim any liability for the infringement of such patents by the making, using, or selling of any such equipment or circuitry, and suggests that anyone interested in such projects consult a patent attorney.
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Editorial

You're holding in your hands the latest issue of the **Popular Electronics' Experimenter Handbook**. The editorial staff knows that you will enjoy it more than we did when we put it together. Our task was a labor of love. We selected the best of the projects that appeared in **Popular Electronics** during 1992 and put them in one tightly packed handbook. We say the projects are the best—based not only on what we believe to be true, but we also evaluated our readers' responses to reinforce our decisions.

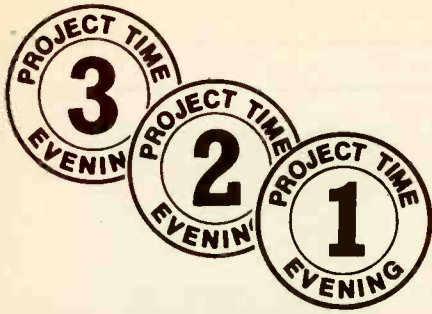
The projects are time rated and you should know something about the time rating system. For example, for some of us with amply-packed spare parts supplies and ready access to commercial parts suppliers, obtaining project parts is no problem at all. Not so for many hobbyists and the novice. In fact, the most grueling part of project building could very well be the wait for mail-ordered parts to arrive. Thus, you would expect us not to consider the acquisition-of-parts time as a factor of the project's construction time, because of the variables involved.

We consider the project's construction time to begin after all the parts are available, and that includes the printed-circuit board. Although there are modern methods for adding resist

patterns to the copper-clad surface of a board, even that time is an indeterminate quantity. So, the gun fires to start the clock when all the parts are on the workbench and you plug in the soldering iron.

Projects that require tuning, alignment or adjustment have the time interval thus required added to the total time. The making of simple boxes, cabinets, etc., and other minimal cosmetic tasks such as nameplates, dial markings, paint jobs, etc., are included in the total time. As before with the parts, materials and equipment necessary for the task to be completed, they must be on the workbench or available nearby so as not to interrupt the flow of work.

We assume that most of the work will be done in the evenings after your normal work day, so that a typical one-evening project takes about three hours. Expect a give or take of one hour depending upon your skill and the quality and availability of tools and equipment on your workbench. For example, we consider that at least one solder connection must be redone for whatever reason. If you have a "suction-tip" desoldering iron, add 30 seconds to the task. If you use a copper braid to sap off the solder, add two minutes. If you let the tip of the iron do the job, add five minutes. (Of course, the latter



technique should not be used!)

A small drill press, power jig saw, desk-top illuminated magnifying lens, electric screw-nut driver, and other convenient hand tools speed up most hobbyist's projects. Also, what many readers fail to do is study the text carefully before they begin to build a project. Know what you have to do, then do it. Don't look for short cuts or redesigning efforts as you assemble the project. It's best to stop all work and seriously think out and plot out what you want to do and how to do it. In most cases, it is wiser to complete the project, get it working, then redesign for a specific purpose.

Now you know the time-evaluation system, look for the "Project Time" label for each article. (See above.) The editors would like to know if this system was of value to you, so drop us a line and tell us what you think and what you experienced. Remember, your views are our eyes. Happy project building.

Julian S. Martin
Handbook Editor

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Q&A

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How strong are Muscle Wires?

The force a wire pulls with varies with size, from 35 to 330 grams. For more strength, use several wires in parallel.

How fast can Muscle Wires activate?

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Flexinol Muscle Wire Specifications

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Model 2703A. *Model 2704A* adds AC current, capacitance, and transistor tests. The *Model 2706* adds a temperature-measurement function. Similar to the 2704A, the

Model 2707 has a built-in frequency counter and logic-probe functions.

Models 2703A, 2704A, 2706, and 2707 DMM's have list prices of \$39, \$59, \$79, and \$89, respectively. For additional information, contact B + K Precision, Division of Maxtec International Corporation, 6470 West Cortland Street, Chicago, IL 60635; Tel: 312-889-1448; Fax: 312-804-9425.

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SOLDERING-IRON CONTROLLER

A compact accessory from *M.M. Newman Corporation* makes fixed-temperature soldering irons adjustable. When it is desirable to lower their full operating temperature, the *Dial-Temp* soldering-iron controller lets the user adjust the tip temperature based upon the job at hand. The *Dial-Temp* is equipped with a three-prong grounded plug and receptacle. It gets plugged into any 117-VAC outlet and the soldering iron is then plugged into the controller. Once connected, a knob on top of the unit is used to adjust the temperature from 150°F to full heat. Compatible with soldering irons from 15 to 1600 watts and other devices that use heating elements, the *Dial-Temp* has a 15-amp



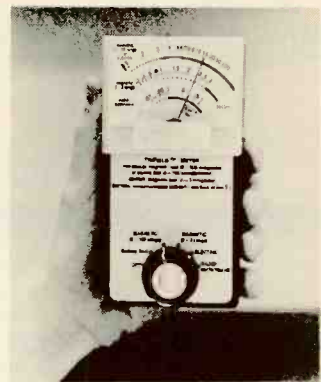
capacity. Besides controlling soldering-iron temperature, it can be used to moderate hot plates and to adjust wood-burning tools.

The *Dial-Temp* soldering-iron controller has a list price of \$31.95. For additional information, contact M.M. Newman Corporation, 24 Tioga Way, P.O. Box 615, Marblehead, MA 01945; Tel: 617-631-7100; Fax: 617-631-8887.

CIRCLE 74 ON FREE INFORMATION CARD

TRI-FIELD METER

The *Tri-Field Meter* from *AlphaLab* independently reads AC electric fields, AC magnetic fields, and radio/microwaves with multi-directional sensors that read field strengths in all directions simultaneously. The meter reads all three types of fields both numerically and with a safe/borderline/high scale that is weighted proportionally to the field's effect on the human body. Thresholds are based on epidemiological and laboratory



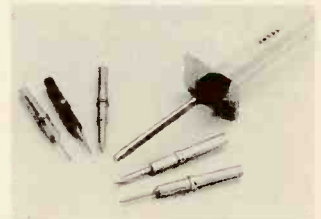
studies; although no absolute hazard levels have been established, reduction of relative exposure levels is recommended. The compact meter comes ready-to-use with battery, instructions, and a one-year limited warranty.

The *Tri-Field Meter* costs \$144 postpaid (\$154 for Canadian orders). For further information, contact AlphaLab, 1272 East Alameda Avenue, Salt Lake City, UT 84102-1703; Tel: 503-621-9701.

CIRCLE 61 ON FREE INFORMATION CARD

MINIATURE SOLDERING IRON

Designed for thermal efficiency, the *Antex Model G/3U* miniature soldering iron from *M.M. Newman Corporation* features a heating element placed directly under the tip. Because of that design, the 18-watt unit performs like a 30-watt soldering iron. It is ready to solder quickly by reaching 725°F in only 45 seconds, the handle always stays cool, and the tip recovers instantly after soldering. The unit is positively grounded from the tip to protect sensitive electronic components. It is available with more than



40 different styles of slide-on tips, ranging from a 0.012-inch tapered needle point to a 3/16-inch diameter chisel. The tips are totally interchangeable and will not stick or bind.

The *Antex Model G/3U* miniature soldering iron, including a standard tip, costs \$24.95. Replacement tips are priced from \$1.55 each. For further information, contact M.M. Newman Corporation, 24 Tioga Way, P.O. Box 615, Marblehead, MA 01945; Tel: 617-631-7100; Fax: 617-631-8887.

CIRCLE 58 ON FREE INFORMATION CARD

New Products

WIRELESS MICROPHONE

Aimed at professional and serious amateur videographers, Azden's WHX-PRO microphone system has both the transmitter and the antenna built into the microphone, making it completely wire-free. Its powerful miniature receiver measures 3 x 2 1/8 inches and can be attached to the camera with the supplied shoe mount or with Velcro. The telescoping antenna features a shorter design, allowing it to be placed in a shirt pocket. The WHX-PRO has two switchable



frequencies—169.445 and 170.245 MHz—and a range of more than 250 feet. Its three-position ON/STANDBY/OFF switch reduces noise when the microphone is passed from person to person during recording. An octagonal ring surrounding the windscreen prevents the microphone from rolling when it is set down.

The WHX-PRO wireless microphone system has a suggested retail price of \$275. For further information, contact Azden Corporation, 147 New Hyde Park Road, Franklin Square, NY 11010; Tel: 516-328-7500; Fax: 516-328-7506.

CIRCLE 55 ON FREE INFORMATION CARD

FREQUENCY DETECTOR/COUNTER

Intended for use in counter-surveillance, police tactical situations, private investigations, and secure installations, Optoelectronics Handi-Counter model 2300 can also be used inexpensively in two-way radio, ham radio, frequency monitoring ap-



plications. The counter features full eight-place readout resolution up to 2.4 GHz; 10-mV sensitivity for signal detection at maximum distance from the transmitter, all the way through 900 MHz for cellular phone use; and a convenient display-hold switch so that the user won't have to remember or write down the detected frequency. An optional 600-mAH Ni-Cd battery pack is available.

The Handi-Counter model 2300 costs \$99; the battery pack costs \$29. For additional information, contact Optoelectronics, Inc., 5821 NE 14th Avenue, Fort Lauderdale, FL 33334; Tel: 800-327-5912 or 305-771-2050; Fax: 305-771-2052.

CIRCLE 77 ON FREE INFORMATION CARD

ONE-KNOB METAL DETECTOR

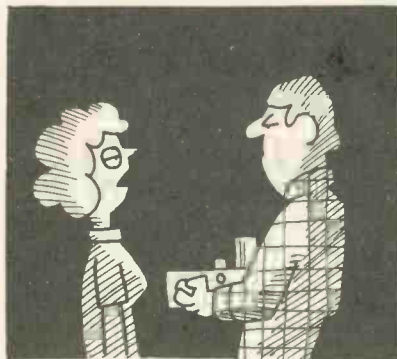
Hunting for treasure couldn't be easier than with Fisher Research Laboratory's model 1212-X metal detector. Providing high performance with no extras, the unit has only one



knob (to set the trash-rejection level); no tuning or meters are required. The 1212-X offers a deep search range, a cushioned "S"-shaped handle, a headphone jack, a built-in speaker, automatic VLF-ground rejection, and automatic tuning. The metal detector operates on just one 9-volt battery, and has an eight-inch coil that is ESI (electro-static insulated) shielded to reduce false signals.

The model 1212-X metal detector has a suggested list price of \$230.00. For a free specifications sheet, write to Fisher Research Laboratory, Dept. PE, 200 West Wilmott Road, Los Banos, CA 93635.

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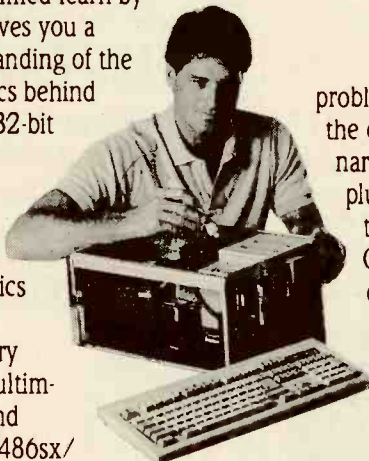
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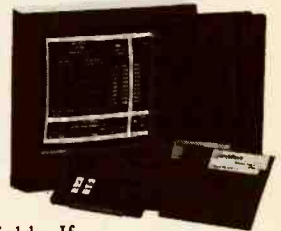


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New Books

THE CIRCUIT DESIGNER'S COMPANION

by Tim Williams

There are two main areas of electronic circuit design: The first involves designing a circuit that still fulfills a desired function and the second involves designing the same circuit so that every production model of it will fulfill its specified function

The circuit designer's companion



Tim Williams

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reliably over its lifetime. This book deals with the latter type of circuit design, and is aimed at those designers who can appreciate the techniques and tools used in that process. The book covers subjects including grounding, printed-circuit design and layout, the characteristics of real-world active and passive components, cables, linear IC's, logic circuits and their interfaces, power supplies, electromagnetic compatibility, safety, and thermal management. The emphasis throughout the book is on how to design for real-life production, staying within budget. Linear and digital designers, as well as undergraduates in electronics engineering, can benefit from the book's easy-to-follow advice and its presentation of design techniques.

The Circuit Designer's Companion costs \$74.95 and is published by Butterworth-Heinemann, 80 Montvale Avenue, Stoneham, MA 02180; Tel: 800-366-BOOK.

ETCHING YOUR OWN PRINTED CIRCUIT BOARDS

from Etching Info

The circuits and projects being designed and built by hobbyists are becoming increasingly complex, and the completion of those projects require the ability to create your own printed-circuit boards. This book describes in detail the entire process, from analyzing and laying out the circuit to assembling the components. A photographic process is used to create a circuit mask, that is then exposed onto the copper-clad board. Using this method, 100% of the traces appear after etching and a near-industrial-quality board with narrow traces and pads can be produced. The manual is fully illustrated with CAD drawings. A list of readily available material, aimed specifically at hobbyists, keeps the process cost-effective.

HOW TO ETCH YOUR OWN PRINTED CIRCUIT BOARDS

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Etching Your Own Printed Circuit Boards is available for \$9.95 from Cover To Cover Desktop Publishing, Attn: PCB Book, P.O. Box 8064, Westfield, MA 0186-8064.

COMPUTERIZED RADIO MONITORING

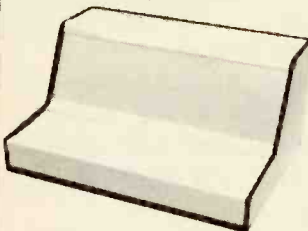
by Todd D. Dokey

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DS-3	8 x 6 x 4 x 12 x 1.9 x 2.4 x 1.8	67.50
DS-4	10 x 6 x 4 x 12 x 1.9 x 2.4 x 1.8	71.50
DS-5	12 x 6 x 4 x 12 x 1.9 x 2.4 x 1.8	76.00
DS-6	10 x 8 x 4 x 12 x 1.9 x 2.4 x 1.8	81.00
DS-7	4 x 8 x 6 x 2 x 3.1 x 3.5 x 1.9	69.00
DS-8	8 x 8 x 6 x 2 x 3.1 x 3.5 x 1.9	73.00
DS-9	8 x 8 x 6 x 2 x 3.1 x 3.5 x 1.9	78.00
DS-10	10 x 8 x 8 x 2 x 3.1 x 3.5 x 1.9	82.75
DS-11	12 x 8 x 8 x 2 x 3.1 x 3.5 x 1.9	87.75
DS-12	16 x 8 x 8 x 2 x 3.1 x 3.5 x 1.9	100.75

EXTRUDED SERIES

MODEL	DESCRIPTION W x D x H (inches)	PRICE \$
ET-1	4.52 x 4.35 x 1.57	10.00
ET-1B	4.52 x 4.35 x 1.57	10.00
ET-2	4.52 x 6.00 x 1.57	24.00
ET-2B	4.52 x 6.00 x 1.57	24.00
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2RU5	19 x 5 x 3.5	33.10
2RU7	19 x 7 x 3.5	35.25
2RU10	19 x 10 x 3.5	37.50
3RU5	19 x 5 x 5.25	41.90
3RU7	19 x 7 x 5.25	44.10
3RU10	19 x 10 x 5.25	48.30

SHEET METAL PUNCHES

MODEL	HOLE SIZE & SHAPE	PRICE \$
PUNCH 1	3/8" ROUND	9.95
PUNCH 2	7/16" ROUND	9.95
PUNCH 3	1/2" ROUND	9.95
PUNCH 4	9/16" ROUND	12.95
PUNCH 5	5/8" ROUND	12.95
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METAL CABINETS

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MC-1A	4 x 3 x 2	16.50
MC-2A	6 x 3 x 2	18.75
MC-3A	8 x 3 x 2	20.95
MC-4A	4 x 4 x 3	18.75
MC-5A	6 x 4 x 3	20.95
MC-6A	8 x 4 x 3	23.15
MC-7A	4 x 7 x 4	20.95
MC-8A	6 x 7 x 4	23.15
MC-9A	8 x 7 x 4	25.75

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MODEL	DESCRIPTION W x D x H (inches)	PRICE \$
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3RU10 HD	19 x 10 x 5.25	121.00
3RU14 HD	19 x 14 x 5.25	134.00
4RU7 HD	19 x 7 x 7.0	121.00
4RU10 HD	19 x 10 x 7.0	129.00
4RU14 HD	19 x 14 x 7.0	134.00
8RU7 HD	19 x 7 x 8.75	126.00
8RU10 HD	19 x 10 x 8.75	133.00
8RU14 HD	19 x 14 x 8.75	143.00

HAND TOOLS

MODEL	DESCRIPTION	RANGE (inches)	PRICE \$
MD-1	MICRO REAMER	1.0-5.5	16.50
MD-2	REGULAR REAMER	3.0-12.0	26.00
MD-3	LARGE REAMER	10.0-25.0	48.00
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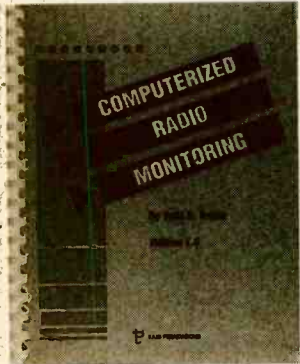
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New Books

monitors have entered a new era in radio-monitoring efficiency by interfacing their radios with their computers. That arrangement allows them to tune, search, scan, log, analyze, decode, and even do remote monitoring, right from the computer keyboard. This book, which assumes that the reader has some knowledge of computers, details the ins and outs of computerized radio monitoring, from scanning frequency



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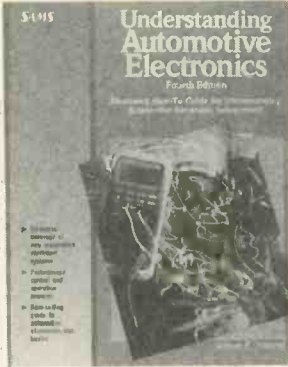
lists into a database to decoding RTTY and fax, to getting results from the data. The book discusses many of today's high-end radio software. It examines computer-friendly shortwave sets, scanners, and terminal units, and explains how to set up a computerized shack, develop computerized monitoring strategies, plan databases, deal with noise problems, and collect and use information. Also included are technical notes and an extensive glossary of computer and radio terms.

Computerized Radio Monitoring is available for \$22.95 plus \$2 shipping (\$3 foreign) from *Tiare Publications, P.O. Box 493, Lake Geneva, WI 53147; Tel: 414-248-4845.*

UNDERSTANDING AUTOMOTIVE ELECTRONICS: Fourth Edition

by *William B. Ribbens*

The field of automotive electronics has been experiencing rapid, radical changes in recent years. This book provides readers with a hands-on resource



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that's packed with essential reference material and illustrations. The fourth edition has been updated to include coverage of the latest automotive subsystems.

Designed as a series of self-paced tutorial lessons, the book introduces readers, step-by-step, to the most vital areas of auto electronics. It explains the fundamentals, and defines the systems approach to control and instrumentation. It describes how sensors and actuators work, the latest digital engine-control techniques, and the future of automotive electronics systems. The book offers the latest advice and information on determining engine performance, fuel economy, speed control, emissions, ride control, braking, and air-bag safety using analog or digital means. A wealth of illustrations help to clarify the information presented, and quizzes at the end of every chapter help to ensure the learning process.

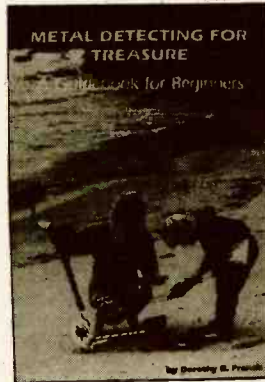
Understanding Automotive Electronics: Fourth Edition costs \$24.95 and is published by *Sams, Division of Macmillan Computer Publishing, 11711 North College, Carmel, IN 46032; Tel: 800-428-5331 or 317-573-2500; Fax: 800-448-3804 or 317-573-2655.*

METAL DETECTING FOR TREASURE: A Guidebook for Beginners

by *Dorothy B. Francis*

Intended to introduce the beginning treasure hunter to the sport

and offer some tips for the intermediate treasure hunter, this easy-to-read book contains just about all the information



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needed to get started in using a metal detector. Tips for the beginner include pointers on what type of detector to buy, what tools to use in any given treasure-hunting situation, how to pin-point with accuracy, how to use the sensitivity and discrimination controls, and how to dig

treasure. On a slightly more advanced level, the book explains how to treasure hunt on the land, at the beach, and in shallow water; how to research potential sites; and how to prospect for gold. The book includes illustrations and photographs, and contains some inspirational tales of real-life treasure-hunters and their sometimes spectacular finds.

Treasure Hunting with a Metal Detector: A Guide for Beginners is available for \$8 plus \$2 shipping and handling (CA residents must add 7.25% sales tax) from *Fisher Research Laboratory, Dept. PE, 200 West Wilmott Road, Los Banos, CA 93635.*

FALCON 3.0 AIR COMBAT

by *Pete Bonanni and Bernard Yee*

If you want to experience being a real fighter pilot in head-on air combat—while keeping both feet firmly on the ground—playing Spectrum-Holobyte's Falcon

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New Books

3.0 is the way to go. This book, co-authored by an actual F-16 fighter pilot and weapons and tactics officer, shows players the ins and outs of jockeying and fighting with the F-16 and the newest version of the Falcon simulator. The book explains basic maneuvers, beyond-visual-range radar deployment, advanced air-to-air combat techniques, weapons deploy-

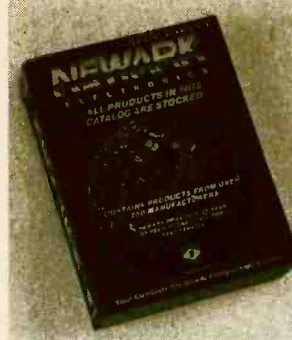
ment, advanced surface attack tactics, and campaign management. The book covers version 3, the latest release of the Falcon flight simulator for the IBM PC and compatibles. A keyboard template and command cards are included.

Falcon 3.0 Air Combat costs \$19.95 and is published by Osborne/McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710; Tel: 510-549-6600; Fax: 510-549-6603.

NEWARK ELECTRONICS CATALOG

from Newark Electronics

This 1200-page catalog contains detailed technical information and dimensions on more than 100,000 products from 250 leading manufacturers. Twenty new manufacturers and more than 15,000 new products are featured in its pages. Catalog #112 also includes an expanded, 24-page, four-color product section



CIRCLE 75 ON FREE INFORMATION CARD

and an easy-to-follow "how-to" section for using the catalog.

Catalog #112 is free upon request from Newark Electronics, 4801 North Ravenswood Avenue, Chicago, IL 60640-4496; Tel: 1-800-367-3573.

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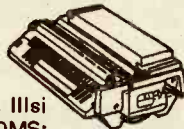
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CIRCLE 11 ON FREE INFORMATION CARD

Air is the most important ingredient to our survival. Think about it; you may survive a few days without water, a little longer without food, but, deprived of air, your survival time can be measured in minutes.

The quality of the air surrounding many cities has become so poor that many local news stations provide an air-quality report along with the weather forecast. Air pollution is so commonplace now that words have been created to describe it. The word "smog" for example, a contraction of the words "smoke" and "fog." As if smog wasn't enough, today there are new pollution concerns, not the least of which are the increasing CO₂ level, the green-house effect, the depletion in the ozone layer, and acid rain.

Research. Long before there was any talk or concern about air pollution and such, some scientists and experimenters noticed that the ionization of even clean air can improve its quality. Clean air (principally composed of 78% nitrogen and 21% oxygen) is typically full of positive and negative ions in approximately a 5-to-4 ratio. What researchers found was that when this ratio changes one way or the other it has an effect on biological systems.

This idea was popularized by Fred Soyka who, in the 1970's, wrote a book titled "The Ion Effect." Mr. Soyka studied natural occurrences of negative and positive ionized air. His findings and inquiries demonstrated that negatively ionized air had substantial health benefits.

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, materials and substances. Furthermore, the information contained in this article is being provided solely to readers for educational purposes. Nothing contained herein suggests that the negative-ion generator described herein has any health benefits whatsoever. 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.

BY JOHN IOVINE



Build a Negative-Ion Generator

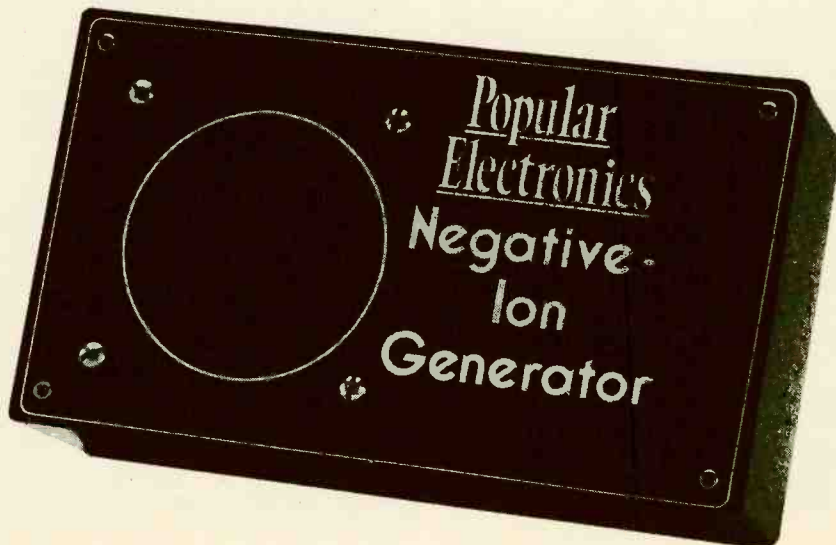
Make the very air you breathe healthier with an easy-to-build high voltage project.

To summarize a few points from his book, negative ions help elevate mood, enhance physical performance and training, and sterilize harmful airborne bacteria. An abundance of positive ions on the other hand can be held responsible for a number of low grade medical problems, such as fatigue, headaches, and anxiety.

There are detractors to this point of view. So before I started to design a negative-ion generator, I did some research to find out if it would be worthwhile. I surveyed approximately 100 world-wide scientific reports on the effects of negative ions from 1973 through the present. I can report that out of my survey approximately 80% of the citing's note the beneficial effects of

negative ions. Greater than 19% of the reports described no effect, and a few (less than 1%) detailed some detrimental effect. Since the preponderance of the evidence supports the beneficial effects of negative ions, I felt that building an ion generator was a worthwhile project. A summary of some of the beneficial effects reported by some researchers are listed in the boxed text entitled "The Positive Effects of Negative Ions." It is by no means an exhaustive list, it's just a sampling of the scientific benefits noted. But if this is the case it would be to our benefit to improve the quality of air that we breathe with a negative ion generator.

Despite the numerous scientific reports supporting the health benefits of



The Positive Effects of Negative Ions

- Learning enhancement in normal and learning-disabled children. The task used to test the children was a dichotic listening test.
- Negative ions can be used to decrease amounts of radon in a building atmosphere.
- In one animal study 1279 calves were broken into two groups, one of 649 head and the other of 630 head, negative air ionization was used to test for a prophylactic effectiveness against respiratory diseases. The results were remarkable: In the treated group (649 head) 45 calves became sick and 3 died. In the control group (630 head) 621 became sick and 33 died.
- A 40-50% reduction of microbial air pollution in dental clinics.
- A test using college students showed improved performance on a visual vigilance task.
- In 1983 it was reported that chickens raised in a negatively ionized atmosphere showed improved anabolic processes. The chickens raised in negatively ionized air had an overall greater weight than a control group fed the same quality and quantity of feed. The meat of the treated group had higher protein and essential amino-acid content. In addition, higher concentrations of vitamins E and A were found in their livers.

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Effect of Artificial Air Ionization on Broilers, P. Stoianov, G. Petkov, and B.D. Baikov, Vet Med Nauki, Bulgaria, 1983

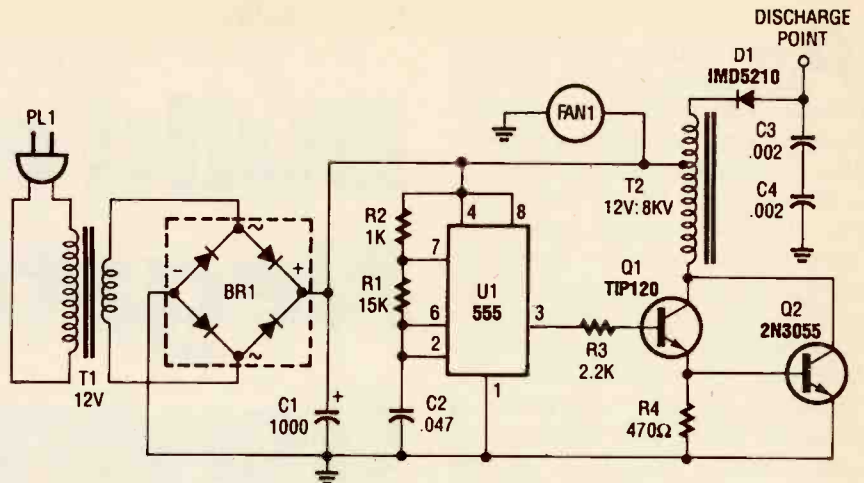


Fig. 1. This is the simple schematic for the Negative-Ion Generator. Note that it is basically a timer that induces a high voltage in the windings of T2.

ionized air, no manufacturer of negative-ion generators can make any health-benefit claims without running afoul of the FDA. For that reason I also will make no such claims. Instead, the

research papers supporting this article are listed in the text entitled "Bibliography" so you can do the research on your own and make your own decision.

The Ion Generator. The design of the Negative-Ion Generator is fairly straightforward (see Fig. 1). The circuit is a high voltage generator. It contains a standard 555 timer that's used to generate square-wave pulses. The pulses are applied to the base of the TIP120 NPN Darlington transistor. The Darlington provides sufficient current to the base of the 2N3055 power transistor to turn it on. Each time that happens, current flows through the high voltage autotransformer, T2. The high voltage lead of the transformer is connected to a 10 kilovolt high voltage diode. Notice the polarity of the diode. It is biased to place a negative charge on C3 and C4, leaving the discharge point negatively charged. The voltage at the discharge point negatively charges the air forced past it by the fan.

The author's prototype was built on sections of perfboard using point-to-point wiring. It is a suitable method that you can use in your own ion generator provided you follow some precautions: Make sure you place C3, C4, D1, and the discharge point (which we'll describe momentarily) on a piece of perfboard all their own. The junctions between those components should be at least a centimeter apart. Both this little high voltage board and the autotransformer should also be kept at least 1 centimeter away from the perfboard containing the other components, the fan, and the power transformer.

(Continued on page 108)

PARTS LIST FOR THE NEGATIVE-ION GENERATOR

SEMICONDUCTORS

- U1—555 timer, integrated circuit
 Q1—TIP120 NPN Darlington transistor
 Q2—2N3055 power transistor
 D1—10,000-volt, 10-mA silicon rectifier diode (see text)
 BR1—4-amp, 50-PIV bridge rectifier

RESISTORS

- (All resistors are ¼-watt 5% units.)
 R1—15,000-ohm R3—2200-ohm
 R2—1000-ohm R4—470-ohm

CAPACITORS

- C1—1000-µF, 15-WVDC electrolytic
 C2—0.047-µF, polyester-film
 C3, C4—.002-µF, 6,000-WVDC, ceramic-disc

ADDITIONAL PARTS AND MATERIALS

- T1—12-volt, 1.2-amp power transformer
 T2—12 volt to 8 kilovolt autotransformer
 FAN1—12-volt DC fan
 Enclosure, line cord, switch, TO-3 socket and heat sink, perfboard, wire, solder, etc.

The following are available from Images Company (P.O. Box 140742 Staten Island, NY 10314-0024; Tel. 718/698-8305): D1 (\$1.50), C3 and C4 (\$1.50 ea.), and T2 (\$17.95). Include an additional \$2.50 for shipping and handling. NY residents must add appropriate sales tax.

NOTE: The above prices are subject to change.

How To Electronically Tune Pianos



Traditionally, piano-tuning has been the exclusive domain of craftsmen who've spent years perfecting their skills. Having to discern pitches by ear, they were as much practitioners of art as of science, with accompanying fees for their services ranging as high as \$60. But the *Precision Audio-Frequency Generator* described in this article will change all of that.

Coupled with an oscilloscope and a digital frequency counter, the generator allows you to tune a piano or another instrument (say a violin) to an accuracy of 0.01 Hz, or better, throughout most of its range.

Just the Basics. A block diagram of the Precision Audio Frequency Generator, which consists of several sub-circuits—an audio-amplifier/filter circuit, an automatic level control, a variable voltage-controlled oscillator, a frequency divider circuit, an integrator, and an audio output amp—is shown in Fig. 1.

An electret microphone element is used to pick up the audio tone produced by the instrument. That signal is then fed to an amplifier/filter/level-controlled circuit and output via channel 1 (CH1) to an oscilloscope for display.

The variable voltage-controlled-oscillator (VCO) is used to produce a signal of from less than 10 kHz to more than 99 kHz. The VCO output is fed to a digital frequency counter for display, and is also routed to a chain of frequency dividers, where the signal is divided by 10, 100, or 1000, depending on the setting of a selector switch.

From there, the selected signal fre-



And Other Instruments

BY STEVEN A. BROWN

This circuit will let you use your oscilloscope and digital frequency counter to tune pianos and more to an accuracy of .01 Hz.

quency divides along two paths; one going to CH2 (which feeds the oscilloscope's sweep synchronization input) and to an integrator that converts the squarewave output of the divider into a triangular waveform. The output of the integrator is then amplified and fed to a set of stereo headphones via an audio output jack.

A Closer Look. A complete schematic diagram of the Precision Audio Frequency Generator is shown in Fig. 2. An electret microphone element (which has a flat frequency response to within 3 dB down to 20 Hz) is used to pick up audio from the piano or other instrument. The microphone element, con-

nected to J2, converts the audio to an electrical signal, which is fed to the non-inverting input of U2-a (half of an LM358 dual op-amp that is configured as a unity-gain voltage follower).

At the same time, about +4 volts DC is also delivered to U2-a's non-inverting input at input pin 3 via Q1 and R3, so that the microphone signal rides on the DC voltage. The output of U2-a is then fed to U2-b, which is configured as an inverting amplifier. That op-amp provides a gain 40 dB when S1 is in the FLAT position. Capacitor C6 is included in the circuit to roll off frequencies above 4400 Hz. Those frequencies are not wanted in this application.

When S1 is placed in the LP position, C7 rolls off frequencies above 13.5 Hz, which is an octave below the lowest note on the keyboard, so that the rolloff is 6-dB-per-octave from that note upward. Placing S1 in LP position permits tuning of the lowest two octaves of

the piano, where overtones would otherwise make the fundamental of the waveform difficult to see.

The output of U2-b at pin 7 is fed to a compander (U3). The compander, which is used as an automatic level control, provides a variable gain of from 0 to 20 dB, depending on the input level. Thus, U3 maintains a more constant output amplitude over a 10:1 range for a rapidly-decaying note. The output of U3 is fed via J3 (CH 1) to an oscilloscope.

The VCO portion of a CMOS phase-locked loop (U5) is used as the oscillator in the circuit. The frequency of the VCO is adjustable via R10 (FINE) and R11 (COARSE). For stability, a separate voltage

regulator, U4, is used to power U5 and its associated circuitry. Devices with a low-temperature coefficient were selected for the frequency-determining components, C15, R12, and R13, in the VCO.

The VCO's output is attenuated by a 10:1 voltage divider, comprised of R15 and R16 before being routed to J4, which is the output to an external frequency counter. The VCO output is also fed through R14, which is used as a current limiter, to a chain of cascaded 4017 CMOS decade counter/dividers (U6-U8). Each counter/divider output is routed via its associated resistor (R17-R19, respectively) to rotary switch S2.

The squarewave output selected by S2 travels along two paths; in one path, the signal is routed to J5 (CH 2); in the other path, the signal is fed to an audio output circuit consisting of U9, Q2, and Q3. The portion of that signal that goes to the audio circuit is applied across C16 to the input of U9-a (half of a second LM358 dual op-amp) through R20. Capacitor C16 is used to extend the rise time of the selected squarewave-output signal to 20 microseconds so that it doesn't cause glitches to appear at CH 1.

The output of U9-a can be adjusted via R21. (In effect serving as a VOLUME control). The squarewave output of U9-a is fed to U9-b, which is configured as

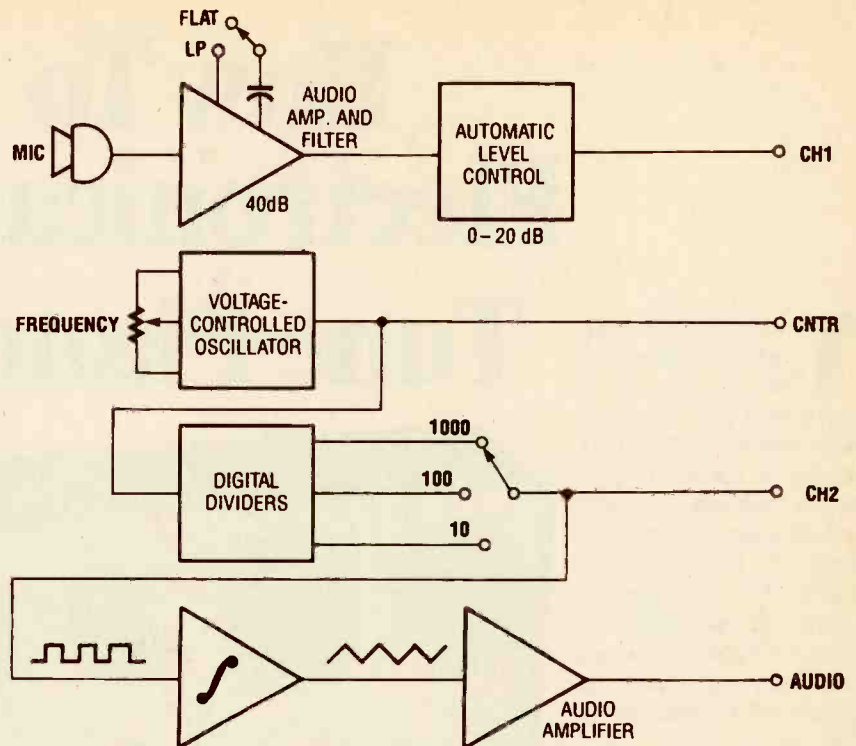


Fig. 1. The Precision Audio Frequency Generator is comprised of several sub-circuits—an audio amplifier/filter circuit, an automatic level control, a voltage-controlled oscillator, a frequency-divider circuit, an integrator, and an audio-output amp.

an integrator. The integrator transforms its squarewave input to a triangular waveform, which approximates the waveform of a vibrating string. The output of U9-b is simultaneously fed to the bases of two transistors, Q2 and Q3, for

amplification. The output of that pair of transistors is fed through C19 to J6. Connecting a set of stereo headphones to J6 allows that signal to be audibly compared to the pitch¹ of the note being played.

PARTS LIST FOR THE PRECISION AUDIO-FREQUENCY GENERATOR

SEMICONDUCTORS

- U1, U4—78L09, 9-volt, 100-mA voltage-regulator, integrated circuit
- U2, U9—LM358 dual op-amp, integrated circuit
- U3—NE570 compander, integrated circuit
- U5—CD4046 CMOS phase-locked loop, integrated circuit
- U6, U7, U8—CD4017 CMOS decade counter/divider, integrated circuit
- Q1, Q2—2N4401 (or similar) general-purpose NPN silicon transistor
- Q3—2N4403 (or similar) general-purpose PNP silicon transistor

RESISTORS

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

- R1—27,000-ohm
- R2, R22—47,000-ohm
- R3, R16, R20—1000-ohm
- R4, R5—12,000-ohm
- R6—1.2-megohm
- R7—200,000-ohm

- R8, R9, R23, R24—33,000-ohm potentiometer
- R10—1000-ohm linear-taper potentiometer
- R11—100,000-ohm linear-taper potentiometer
- R12—12,000-ohm, 1% metal-film
- R13—300,000-ohm, 1% metal-film
- R14—10,000-ohm
- R15, R17-R19—9100-ohm
- R21—10,000-ohm linear- or audio-taper potentiometer
- R25—470,000-ohm

CAPACITORS

- C1, C4, C20—47- μ F, 16-WVDC, electrolytic
- C2, C3, C13, C14—0.22- μ F, monolithic ceramic
- C5—4.7- μ F, 16-WVDC, electrolytic
- C6—27-pF, ceramic-disc
- C7—.01- μ F, 10% polyester
- C8-C12, C17—10- μ F, 16-WVDC, electrolytic
- C15—0.001- μ F, 5% polystyrene
- C16—.01- μ F, ceramic-disc

- C18—0.1- μ F, 10% polyester
- C19—470- μ F, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

- J1—See text
- J2—1/8-inch mono phone jack
- J3, J4, J5—RCA or BNC jacks (see text)
- J6—1/8-inch stereo headphone jack
- S1—SPST miniature toggle switch
- S2—SP3T rotary switch (see text)
- Perfboard materials, enclosure, electret microphone element (Radio Shack 270-090 or equivalent), knobs, 3/8-inch heat-shrink, 12-volt AC-to-DC adapter, Walkman-type stereo headphones, shielded audio cable wire, solder, hardware, etc.

Note: The software described in the text for the IBM or compatible PC is available for \$10 postpaid from Andromeda Electronics, 125 N. Prospect St., Washington, NJ 07882. NJ residents must add sales tax. Specify 5/4-inch or 3/2-inch disk. Check, money order, VISA, or M/C accepted.

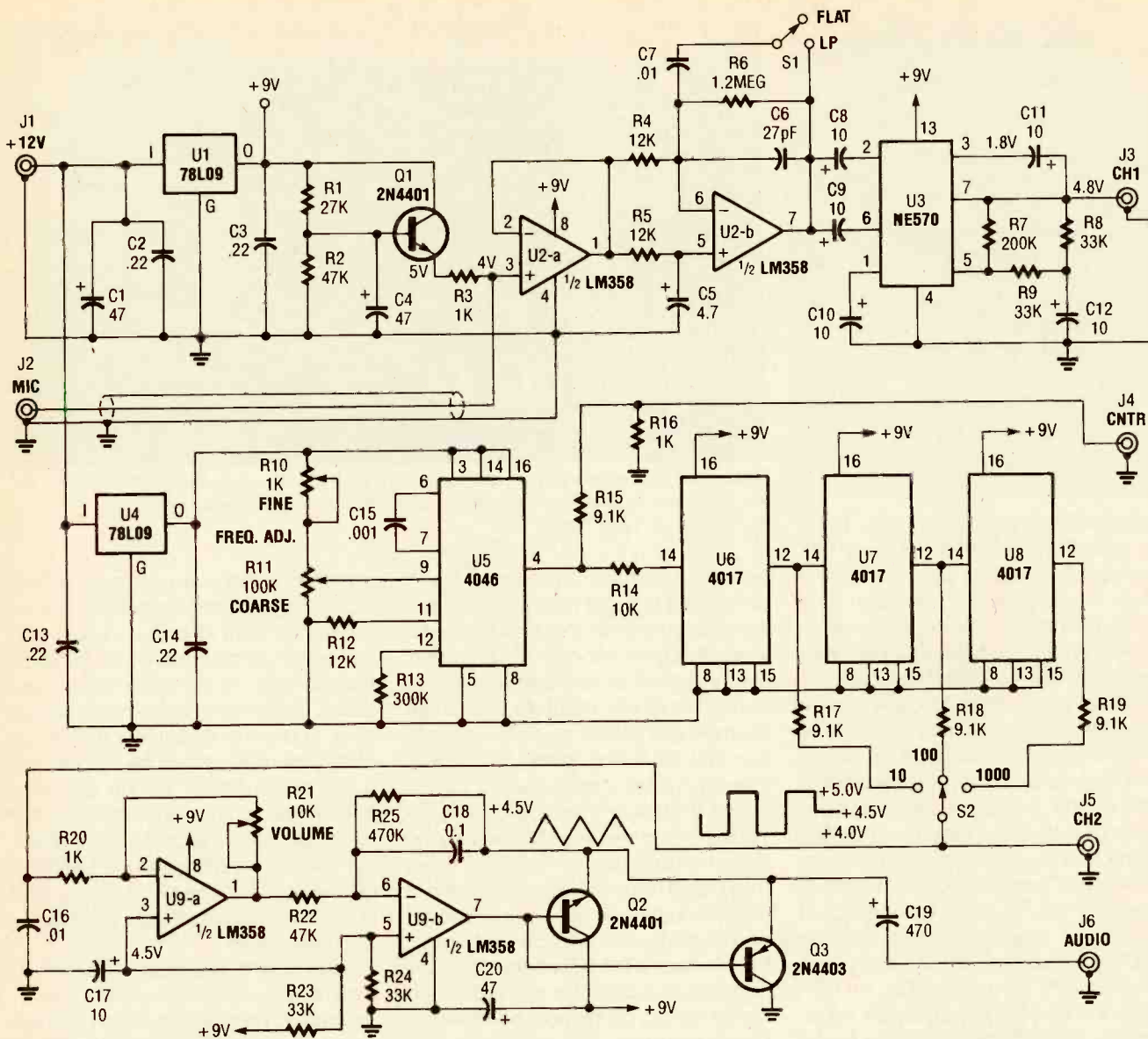


Fig. 2. One section of the Precision Audio Frequency Generator uses an electret microphone element to pick up audio from the piano. That signal is then processed and sent to one channel of a dual-trace oscilloscope. The other section of the circuit is used to produce a variable-frequency signal that is fed to a digital frequency counter and after conditioning, is presented to the second channel of the scope and output to a set of stereo headphones.

Construction. The author's prototype of the Precision Audio Frequency Generator was hard-wired on a section of perfboard. Once you've collected all of the necessary components, begin assembling the circuit using Fig. 2 as a guide. It is suggested that you socket the IC's. The benefit of using sockets is that they help to avoid thermal and static-discharge damage to the IC's (especially the CMOS units, U5-U8) during assembly.

Also, when assembling the board, attention should be paid to the parts layout. For example, to prevent feedback from the output to the input, U2

and U3 should be positioned on the opposite side of the board from U9. The components that set the lower and upper limits of the VCO frequency must be temperature-stable; capacitor C15 should be a polystyrene unit, and both R12 and R13 should be 1% metal-film resistors.

Assemble the board-mounted portion of the project first, leaving the off-board components (all of the jacks and controls) for last. Once that's done, label and solder over-sized lengths of wire (which will be trimmed later) to the appropriate points on the board for connection to the off-board compo-

nents. Note that in Fig. 2 shielded audio cable is indicated for the connection from J1 (the mic jack) to the circuit-board. Once you've completed the circuit board assembly, check your work for the usual construction errors: mis-connected components, improper polarity, cold solder joints, etc.

Once you are reasonably sure that the circuit board has been properly wired, put the board to the side for a while and begin preparing the enclosure that will house the board. The author used a plastic enclosure with a metal lid to house the prototype. Prepare the enclosure by drilling several

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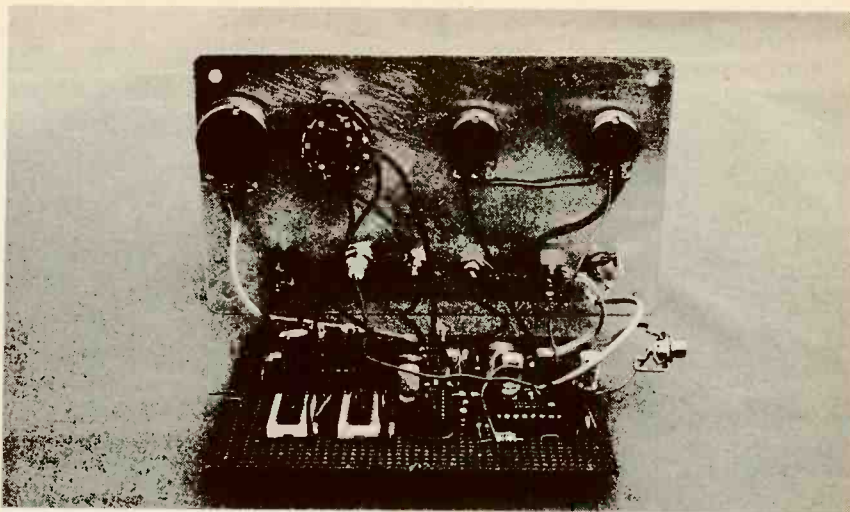
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holes in its lid—starting with four holes for potentiometers R10, R11, and R21, and switch S2 across what will be the upper edge of the lid. Although S2 is shown as a single-pole, 3-position rotary switch in Fig. 2, any single- or double-pole, multi-position switch will do.

Drill six more holes below the ones previously drilled to accommodate all of the I/O jacks and controls, except J1. That jack should be mounted to the side of the enclosure. Note: Various types of jacks were used for J1–J6. For example, J1 was selected to mate with an AC-to-DC adapter; for J2, the author used a 1/8-inch mono phone jack; for J3 and J5, he used RCA jacks (although BNC types are fine); for J4, a BNC jack (which might be replaced by an RCA unit); and for J6, a 1/8-inch stereo headphone jack. It will be necessary to drill appropriate size holes for each jack type.

Once mounted, all of the jacks, except for J1, will be grounded via the enclosure lid. That means that it will not be necessary to provide a ground wire for each jack. However, the shield of the microphone cable connected to J2 should not be expected to serve as the sole ground-return for the outputs, especially where the high-current audio output is concerned. To handle the expected current, a separate wire should be soldered between Q3's collector and the ground terminal of J6. The ground terminal of J6 (which should contact the lid of the enclosure), in turn, provides the necessary ground-return path. The remaining two terminals of J6 should then be bridged and wired to C19.

Once the holes for the panel-



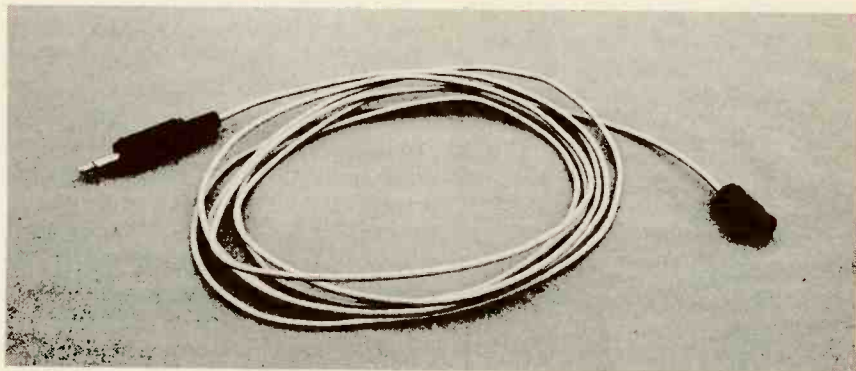
The author's prototype circuit was hard-wired on a section of perfboard. Shown here is the perfboard assembly wired to the panel-mounted components prior to being installed in its enclosure.

mounted components have been drilled, drill a single hole in the side of the enclosure for J1. That jack requires a separate connection to circuit ground. Mount the off-board components to the enclosure and measure off the minimum length of wire for each connection that will be necessary to connect the off-board components to the board, and solder them in place. Keeping the wiring between the board and panel-mounted controls and jacks short and direct helps to prevent crosstalk between channels. Once all of the off-board components have been wired to the board and the connections checked for accuracy, the board should be rechecked for errors before going on.

The final step before installing the circuit into its enclosure is to insert the IC's into their sockets. Be very careful when handling the CMOS IC's; they're static sensitive. Once the IC's have been installed and properly seated, turn your

attention to the preparation of the microphone element. Solder the microphone element to one end of a ten-foot length of shielded audio cable or flexible coax. To the other end of the cable, solder a 1/8-inch mono phone plug. To provide strain relief, the microphone element should be slipped into a 3/4-inch length of 3/8-inch diameter heat-shrink tubing. Afterward, fill the space between the cable and the tubing with quick-setting two-part epoxy. It isn't necessary to heat the tubing, and doing so could damage the microphone element.

Before being placed into operation, the Precision Audio-Frequency Generator should be checked out on your test bench. The DC adapter used to power the circuit should be capable of delivering at least 11 volts DC into a 20 mA load, even at the lowest point in its output ripple. All but the smallest (100 mA) 9-volt adapters will suffice, and all 12-volt units can be used without excep-



The electret microphone element that's used to pick up audio from the piano is mounted to one end of a length of microphone cable and a phone jack is connected to the other end.

tion. Be sure the polarity is correct before applying power.

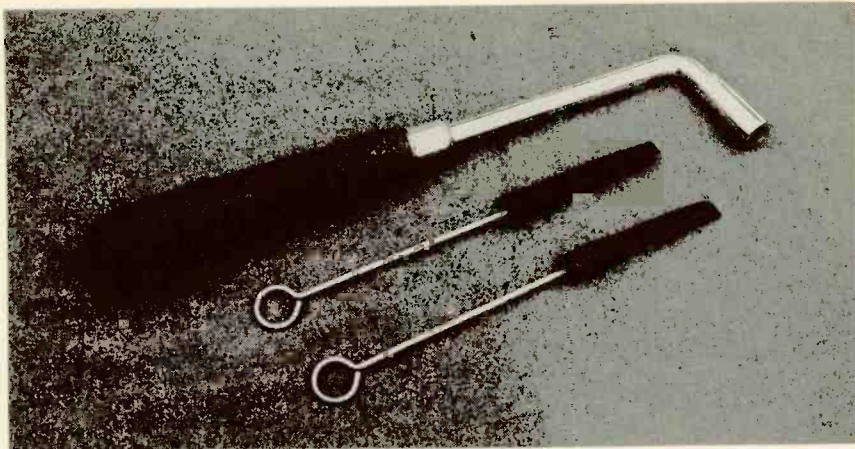
Plug a set of stereo headphones into the AUDIO jack: **DO NOT** use a monophonic set; the plug on mono sets will destroy Q2 and Q3. Set S2 to the 100 position, and advance the VOLUME control, R21, clockwise. You should hear a tone whose pitch should change slightly as you adjust R10, and noticeably as you adjust R11. The pitch will become ten times lower when you switch S2 to the 1000 position, and ten times higher when you switch to the 10 position.

Connect a scope and a digital frequency counter to the output jacks, using 1:1 cables. If your scope has only one channel, connect J5 to the scope's external trigger input. Set the gate time of the counter to 1 second. Verify that the reading on the counter can be varied from less than 10,000 Hz to more than 99,999 Hz by adjusting R11. If not, you can replace R12, which sets the upper frequency limit, with a smaller value, or R13, which sets the lower limit, with a larger value.

Plug in the microphone and speak into it, observing the output waveform on channel 1. The amplitude should be about 2 volts peak-to-peak for a wide range of input amplitudes, although some variation will occur. If the unit does not check out, go back and carefully check all of the circuit connections, verifying that the voltages at various points agree with those indicated on the schematic. Correct any errors that you may find and verify that the problem(s) have been solved, then move on to the phase of construction.

Operation. To tune a piano, the audio generator can be placed on the piano, but the scope and frequency counter need to be placed on a stand, within easy reach. I have found that a platform of plywood, mounted to the top of a camera tripod with a 1/4-inch bolt, makes an excellent stand. The instruments can be secured to the platform with a bolt, and adjusted to any convenient angle.

The microphone should be placed in close proximity to the soundboard of the piano, in such a way so as to exclude ambient noise. A four-inch square of 2-inch polyurethane foam serves that purpose well, if a hole is drilled or punched through its center and the microphone inserted nearly all



Aside from the audio generator, a few additional tools—a wrench (known in the trade as a tuning hammer), and a pair of rubber wedges, or mutes, with wire handles—will be needed to tune the piano. The mutes are inserted between the strings as necessary, so that only one string at a time will sound when a key is struck.

the way through. The essential tools required to adjust the tension of the strings are a wrench (known in the trade as a tuning hammer), and a pair of rubber wedges, or mutes, with wire handles. The mutes are inserted between the strings as necessary, so that only one string at a time will sound when a key is struck. Those and other useful tools can be obtained from your local piano supply house, which will be listed in the yellow pages. If there are none in your area, you can order tools from one of the supply houses listed elsewhere in this article under the heading of "Piano Supply Houses."

Before you attempt to tune your piano, you are urged to do some further reading. It is beyond the scope of this article to provide a course in piano tuning and repair have been written by skilled craftsmen, some of which can be found in practically any library. (See the listing entitled "Suggested Reading").

Basically, the procedure to follow is first to set the audio generator to the frequency of the note that you wish to

tune. As an example, let's start with the note on the keyboard that provides the reference pitch for all the other keys: A above middle C, which is the 49th key on the keyboard, counting from key 1 at the extreme left of the keyboard, and is denoted A49. All the other keys are tuned relative to the pitch to which A49 is tuned. The international standard for A49 is 440.00 Hz.

When setting the pitch of the audio generator, switch S2 must be set for the correct range. For keys between G23 and C64, S2 should be set to 100. For keys C64 and above, S2 is set to the 10 position. For keys G23 and below, set S2 to the 1000 position. Once the correct range is selected, adjust the COARSE and FINE frequency controls until the correct reading is displayed.

Once that is done, check channel 2 of the scope for the presence of a 440 Hz squarewave, and trigger the sweep to that waveform. Now switch to channel 1, but leave the sweep locked to channel 2. Mute two of the strings for this note, so that only one string will vibrate when the note is struck. Strike the key, and observe the waveform on channel 1. If the note is flat, or lower than 440 Hz, the waveform will move to the right. If it is sharp, or higher than 440 Hz, it will move to the left. The speed of motion will correspond to the degree of sharpness or flatness.

As the tension of the string is adjusted to bring the note in tune, the waveform will drift more slowly across the screen. For the best resolution, the sweep period should be adjusted to display two or three complete cycles. When the waveform is arrested, the string is in

SUGGESTED READING

Electronic Piano Tuning
Floyd A. Stevens, Ph.D.
Nelson-Hall, 1974

Piano Servicing, Tuning and Rebuilding
Arthur A. Reblitz
The Vestal Press, 1976

Piano Tuning and Allied Arts
William B. White
Tuners Supply Co., 1978

tune. The mute can now be repositioned, and the other two strings tuned the same way.

The VCO will drift slightly during operation. That is to be expected, and is more noticeable during the first 30 minutes. It isn't necessary to readjust the oscillator every time the least-significant-digit of the display drifts up or down by a few counts, as that digit represents more precision than is required. The least-significant-digit can be allowed to drift ± 4 before readjustment is necessary.

If the pitch of the string is far removed from the setting of the VCO, the waveform will move across the screen too rapidly for its direction of motion to be seen. In that case, adjust the frequency of the VCO up or down as required to arrest the motion of the waveform. That will tell you whether the pitch is sharp or flat. If A49 is flat by more than 20 cents (an explanation of this term follows), the pitch should not be adjusted to 440 Hz.

The 88 keys of the piano keyboard comprise a little more than seven octaves, an octave being a doubling of frequency. See Table 1. In the Equal-Tempered Scale, each octave is divided into 12 steps, called semitones, that progress upward in a geometric scale. Unlike channels in a radio band, which are spaced in a linear scale an equal number of hertz apart, each semitone is higher than the preceding one by a fixed ratio. Since it takes twelve steps to double the frequency, the ratio between adjacent semitones is the twelfth root of 2, or 1.0594631...—an irrational number. Multiply 440 by that number, and you get 466.16, the pitch of the next key higher than A49. Multiply 440 by the inverse of this number (1/1.0594631), and you get 415.30, the pitch of the next key lower than A49. Notice that as you go up the scale, the difference in hertz between adjacent keys becomes geometrically wider.

If the ratio between two pitches is other than an integer multiple of semitones, the cents unit is used. The cent is one-hundredth ($\frac{1}{100}$) of a semitone. It is also a ratio, being the twelve-hundredth root of 2, or 1.000577807.... The pitch of any key on the keyboard, relative to A49, can be calculated from the ratio:

$$2 \text{ } \epsilon / 1200$$

where ϵ equals the absolute value in cents of the difference in pitch be-

TABLE 1—THE EQUAL-TEMPERED SCALE

Note/ Octave	Key#	Hertz	Stretch in Cents	Note/ Octave	Key#	Hertz	Stretch in Cents
A/0	1	27.184	-20	F/4	45	349.03	-1
Bb/0	2	28.817	-19	Gb/4	46	369.78	-1
B/0	3	30.548	-18	G/4	47	391.77	-1
C/1	4	32.384	-17	Ab/4	48	415.07	-1
Db/1	5	34.329	-16	A/4	49	440.00	0
D/1	6	36.391	-15	Bb/4	50	466.16	0
Eb/1	7	38.578	-14	B/4	51	493.88	0
E/1	8	40.895	-13	C/5	52	523.25	0
F/1	9	43.352	-12	Db/5	53	554.37	0
Gb/1	10	45.956	-11	D/5	54	587.33	0
G/1	11	48.717	-10	Eb/5	55	622.61	+1
Ab/1	12	51.644	-9	E/5	56	659.64	+1
A/1	13	54.746	-8	F/5	57	698.86	+1
Bb/1	14	58.035	-7	Gb/5	58	740.42	+1
B/1	15	61.522	-6	G/5	59	784.44	+1
C/2	16	65.180	-6	Ab/5	60	831.57	+2
Db/2	17	69.096	-5	A/5	61	881.02	+2
D/2	18	73.204	-5	Bb/5	62	933.41	+2
Eb/2	19	77.602	-4	B/5	63	988.91	+2
E/2	20	82.217	-4	C/6	64	1047.7	+2
F/2	21	87.106	-4	Db/6	65	1110.7	+3
Gb/2	22	92.285	-4	D/6	66	1176.7	+3
G/2	23	97.773	-4	Eb/6	67	1246.7	+3
Ab/2	24	103.65	-3	E/6	68	1321.6	+4
A/2	25	109.81	-3	F/6	69	1400.1	+4
Bb/2	26	116.34	-3	Gb/6	70	1484.3	+5
B/2	27	123.26	-3	G/6	71	1572.5	+5
C/3	28	130.59	-3	Ab/6	72	1667.0	+6
Db/3	29	138.35	-3	A/6	73	1766.1	+6
D/3	30	146.58	-3	Bb/6	74	1872.2	+7
Eb/3	31	155.29	-3	B/6	75	1984.7	+8
E/3	32	164.53	-3	C/7	76	2103.9	+9
F/3	33	174.31	-3	Db/7	77	2230.3	+10
Gb/3	34	184.73	-2.5	D/7	78	2230.2	+10
G/3	35	195.71	-2.5	Eb/7	79	2506.3	+12
Ab/3	36	207.41	-2	E/7	80	2656.9	+13
A/3	37	219.75	-2	F/7	81	2818.1	+15
Bb/3	38	232.81	-2	Gb/7	82	2989.2	+17
B/3	39	246.66	-2	G/7	83	3170.6	+19
C/4	40	261.32	-2	Ab/7	84	3363.0	+21
Db/4	41	276.86	-2	A/7	85	3567.1	+23
D/4	42	293.33	-2	Bb/7	86	3783.6	+25
Eb/4	43	310.86	-1.5	B/7	87	4013.2	+27
E/4	44	329.44	-1	C/8	88	4259.2	+30

*Standard pitch, A49= 440 Hz
Values shown are stretched for the average piano

tween A49 and the key in question. That's always the ratio of the higher pitch to the lower, so to calculate the pitch of a key higher than A49, simply multiply the pitch of A49 by the calculated ratio. To calculate the pitch of a note lower than A49, multiply A49 by the inverse of that ratio. For example, to calculate the pitch of middle C (C40), which is 9 semitones, or 900 cents, down from A49, multiply the value of A49 (we'll use 440 Hz) by the inverse of 2 to the 900/1200 power, or:

$$C40 = [440] 1/(2^{900/1200}) = 261.63 \text{ Hz}$$

The calculated value would, of course, have been different for any val-

ue of A49 other than 440 Hz. Many pianos do not have A49 tuned to 440 Hz. The reason for that is that when they are first tuned at the factory, they are usually tuned a semitone lower, so that they will stay in tune longer during shipment and in the store. It takes a minimum of five tunings to bring the piano up to standard pitch, each tuning bringing all the keys up by 20 cents. If a step greater than 20 cents is attempted, the piano will not stay in tune for long. Therefore, if you find a piano that is still a semitone lower than standard pitch, it is best to tune it to that pitch, unless the owner wants it raised. If

(Continued on page 110)



VOLTAGE ADAPTER for your car



In just one evening, you can build a device to power your Discman, boombox, portable fridge, laptop computer, or any other device that requires 3, 6, or 9 volts, right from your car's cigarette lighter. It can even provide almost any DC voltage!

If you've got an older car without a tape player or, more commonly, without a compact-disc player, you might feel that you're missing out on something. And even if you've got those gizmos in your car now, your tastes in music might not be the same as those of your passengers. The most cost-effective and diplomatic answer to both dilemmas is to use a portable, perhaps personal, sound system in your car for you or your passenger. (Of course a driver should not use headphones; there are speakers on the market that can plug into a personal audio system and I strongly recommend using them in such circumstances.)

By now you're probably saying "Cost effective? Batteries for portables aren't cost effective." That's very true, and that's where the *Car-Power Adapter* described in this article comes in. It's a small, unobtrusive device that converts the 12 volts available via your car's cigarette lighter into 3, 6, or 9 volts. I'll also show you how to modify the device to provide any DC voltage up to almost 12 volts.

The Car-Power Adapter can be used for many more things. My favorite use is as a power supply for my garage-door opener transmitter. (I'll never get stuck opening my garage door in the rain because the little battery went dead.)

Of course there are devices like the Car-Power Adapter on the market, but they're pretty noticeable in the dashboard and can get in the way of other stuff there. They're also more expensive and, of course, not configurable.

What's in It?. The Car-Power Adapter contains an LM317 adjustable-voltage regulator. Its output voltage is determined by the resistor network accompanying it. Take a look at the example circuit in Fig. 1. Resistors R_A and R_B set the regulator's output voltage according to the following equation:

$$V_{OUT} = V_{ref}(1 + R_B/R_A) + I_{adj}R_A$$

In most applications, V_{ref} (which is the voltage across R_A) is 1.25 volts and I_{adj} is about 50 μ A. Those values make the equation:

$$V_{OUT} = -1.25(1 + R_B/R_A)$$

which is the equation that you should use if you want different output voltages than the ones presented here.

The Car-Power Adapter circuit is shown in Fig. 2. In the circuit, the role of R_A is played by R2. Resistors R1, R3, and R4 perform the function of R_B and act as follows: If the single-pole double-throw center-off switch (S1) is in the center position, only R2 and R1 are in the circuit. They program the reg-

ulator to output 9 volts. Switching S1 to put R3 in the circuit causes the resistance between the adjust terminal and ground to drop. The effective resistance of the R1/R3 parallel combination sets the regulator to output 3 volts. Similarly, with R4 in parallel with R1, the output voltage is 6 volts.

Circuit Construction. Although the Car-Power Adapter is not a critical circuit, you should pay special attention to the following instructions because of the compactness required. One other thing that deserves mention is that the instructions are for negative-ground car wiring. If you've got a positive-ground vehicle, switch all the connections between the lighter plug's ground clip (mentioned later) and its center contact.

Start by sawing the heat sink off of the LM317 regulator. The heat sink will not be necessary because of the low currents required by most low-voltage devices. The heat sink will only make the device impossible to fit in the lighter plug, so carefully get rid of it.

For the rest of the assembly take a look at Fig. 3 (which, with the exception of the plugs and the switch, represents the physical layout of the circuit). Wrap one lead of R2 around the LM317's center terminal as shown. Lay the resistor directly on the regulator leaving room for R1 as shown.

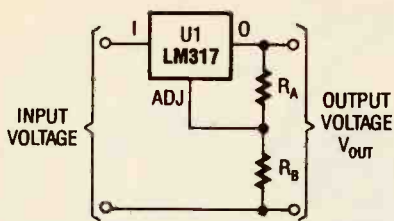


Fig. 1. This is the standard way of wiring an LM317 adjustable-voltage regulator. The output voltage is determined by the values of R_A and R_B .

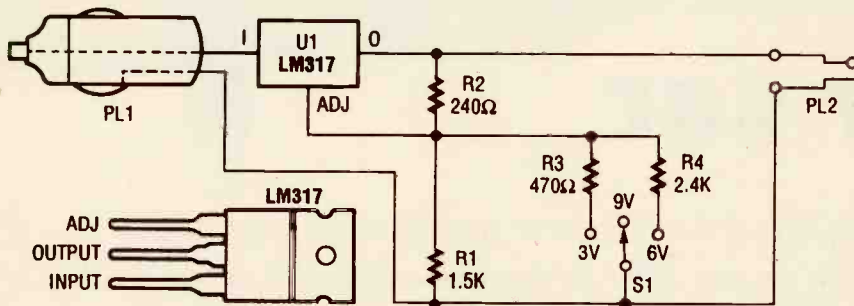


Fig. 2. In the schematic diagram for the Car-Power Adapter, note how the value of R_B (which is R_1 with S_1 in the center position) is changed by putting R_3 or R_4 in parallel with R_1 .

Wrap the remaining lead around the adjust terminal leaving no slack in the lead. Solder both ends of R_2 to their respective terminals.

Take six pieces of stranded wire about $\frac{5}{8}$ -inch long, strip off $\frac{1}{16}$ -inch of insulation from one end of each, and tin that end. I suggest you use different colors for easy identification. Solder one of them to the LM317's center terminal, close to the regulator's body, and trim the terminal as short as possible. Use a small piece of heat-shrink tubing to insulate the connection. (Don't worry if you do not have a heat-shrink gun; a blow dryer will do.) Take another piece of prepared wire and solder it to the input terminal, again trimming the terminal short and using heat-shrink tubing.

Take another piece of tinned wire and solder it close to the body of R_3 . Use a piece of heat-shrink tubing to insulate the connection, but don't slip it over the end of the resistor—that will make it too bulky. Repeat the procedure for R_1 and R_4 , but use two pieces of wire on one end of R_1 .

Lay R_3 next to R_2 , wrap its free lead around the lead of R_2 as shown, and solder the connection. Follow the same procedure to connect R_4 to R_3 . Now connect the free end of R_1 to R_2 , but don't lay it next to R_2 just yet.

Wrap a piece of electrical tape over resistors R_2 , R_3 , R_4 , and the long lead of R_2 . The tape will insulate R_2 's long lead from R_1 . Now place R_1 next to R_2 . Wrap another piece of tape over the end of the regulator where the heat sink was to cover that sawed-off terminal. Now it's time to bundle up the assembly with some wide heat-shrink tubing. Make sure that it's long enough to wrap around the edges of

the regulator. Shrink the tubing and trim the excess. You should have a compact package with wires coming out one side.

Strip $\frac{1}{16}$ -inch of insulation off the ends of the wires from R_3 , R_4 , and one of the wires from R_1 . Strip $\frac{1}{8}$ -inch off the remaining ends of the other three wires and tin them all.

Final Assembly. Before putting everything together, you must first prepare the switch and case (which is the cigarette-lighter plug). You have to expand the hole in the back end of the cigarette-lighter plug for the switch to fit through it. You can do that easily by twisting a triangular hand file around in the hole until it's large enough to accommodate the switch's threads.

You also have to grind down the plastic sides of the switch to fit it in the cigarette-lighter plug. You can use a hand file or power grinder. If you use a power grinder, go slow—the plastic turns to powder very quickly. Your goal is to take enough off of the sides of the switch to allow it to enter the plug and seat firmly against the rear. Be sure to leave enough plastic around the outside terminals to prevent them from breaking off.

Now you must determine where to drill the hole for the power cord, which

PARTS LIST FOR THE CAR-POWER ADAPTER

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

- R1—1500-ohm
- R2—240-ohm
- R3—470-ohm
- R4—2400-ohm

ADDITIONAL PARTS AND MATERIALS

- U1—LM317 1-amp adjustable-voltage regulator, integrated circuit
- PL1—Cigarette-lighter plug
- PL2—See text
- Heat-shrink tubing, stranded wire, coax, electrical tape, solder, etc.

should be a coax type to prevent inductive pickup of noise. Put the switch in position inside the cigarette-lighter plug and measure the distance from the front of the case (the end that is inserted into the dashboard) to the terminals on the switch. Use the measurement to help you drill a hole for the power cord so the cord can enter without interference from the switch. About $\frac{1}{2}$ -inch from the end with the switch worked well for me. Remove the switch and drill the hole for the power cord large enough to loosely accommodate the coax power line that you use.

Connect the wire with the $\frac{1}{16}$ -inch lead from R_1 to the spring clip that connects the cigarette-lighter plug to ground. Connect the remaining wire from R_1 to the center contact of S_1 . Connect the wires from R_3 and R_4 to the remaining terminals on the switch, as indicated in Fig. 3.

Solder the wire from the regulator's input terminal to the center terminal on the cigarette-lighter plug. Run the power-cord coax through the hole you made for it and solder its shielding to the ground clip. Slip a small piece of heat-shrink tubing over the wire from the regulator's center terminal and solder the coax's center conductor to the wire. Position the tubing over the joint and shrink it.

Position the ground clip so that it surrounds the regulator. As a final touch, you might want to slip some heat-shrink tubing over the wires soldered to the clip to provide some strain relief. The tubing should be positioned to hold a bit of the wire's insulation tightly against the clip.

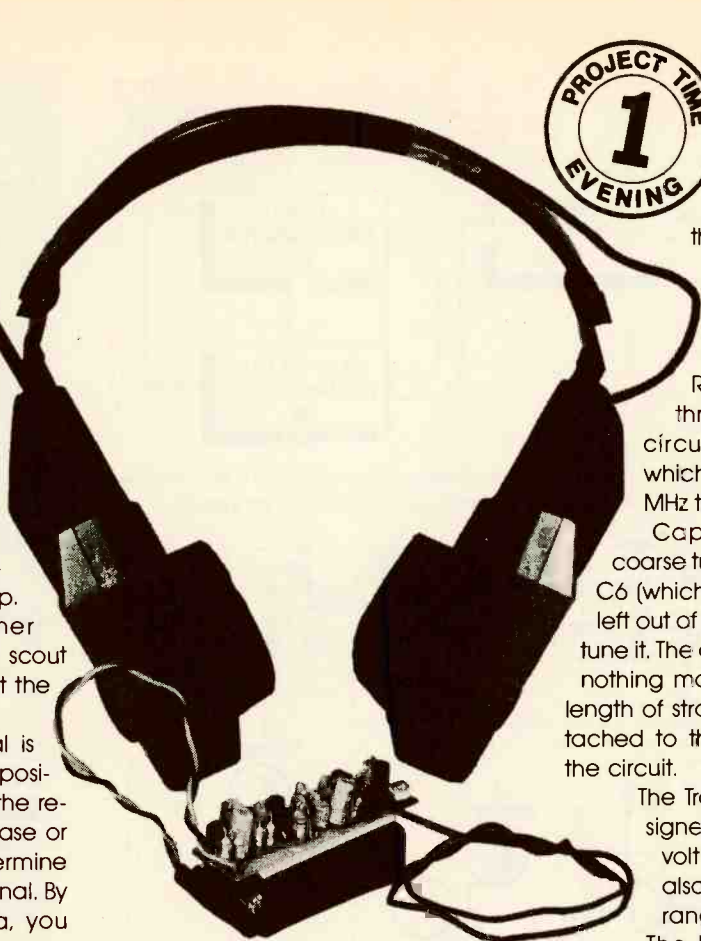
(Continued on page 110)

When we need to locate an object, the first sense that we use is sight. Well, with the *Tracking Transmitter* described in this article, you can also use your hearing. The Tracking Transmitter outputs a series of short, tone-modulated pulses that can be picked up on almost any FM receiver, as a recognizable beep. Using an FM receiver (either mobile or portable), one can scout areas where you might expect the object to be located.

When the transmitted signal is detected, simply varying the position of the receiver will cause the received signal strength to increase or decrease, enabling you to determine the general direction of the signal. By continuing to scan the area, you should soon be able to pinpoint the location of the object.

Circuit Description. The Tracking Transmitter (see the block diagram in Fig. 1) is a fairly simple circuit consisting of four distinct sub-assemblies; a free-running multivibrator, a transmit switch, an audio-tone generator, and an FM transmitter. The multivibrator is used to control the transmit switch, which turns both the audio generator and the transmitter on and off at a given rate. That helps to reduce power consumption to a bare minimum. The output of the audio generator is fed to the FM transmitter, which puts out a periodic beep in the 88- to 108-MHz range that can be detected using an ordinary FM receiver.

A schematic diagram of the Tracking Transmitter is shown in Fig. 2. The multivibrator is comprised of components Q1, Q2, C1, C2, and R1 through R4. The values of R2 and R3 have been chosen to produce a pulse width of 300 milliseconds with a pulse separation of 1500 milliseconds. The output of the multivibrator, which is taken from the collector of Q2, is coupled through R5 to the base of Q3. The output of Q3, taken at its emitter, is used to drive Q4. Together those two



This little circuit can help you to find your car in a packed parking lot; locate a child who has disappeared in a crowd; or reunite you with a dog that has escaped the confines and safety of your yard.

BY VINCENT VOLLONO

transistors (Q3 and Q4) form the transmit switch.

When the output of the multivibrator swings positive, Q3 turns on, which then turns Q4 on. With Q4 on, the emitter of Q6 is pulled to ground, causing it to conduct. With Q6 conducting, any signal applied to its base is transferred to the antenna, which is connected to the junction formed by C8 and C9. Components Q5, R6, R7, R8, and C3 make up the audio-tone generator, whose output is coupled to the base of Q6 through C4 and R8.

During the negative alternation of

the multivibrator output, Q3 and Q4 turn off, which also turns off the transmitter. Components Q6, R10, R11, R12, L1, L2, and C5 through C9 comprise the circuit's transmitter section, which operates from below 88 MHz to above 108 MHz.

Capacitor C7 is used to coarse tune the transmitter, while C6 (which is optional and can be left out of the circuit) is used to fine tune it. The antenna for this project is nothing more than a 6- to 12-inch length of stranded insulated wire attached to the appropriate point in the circuit.

The Tracking Transmitter is designed to operate from a 9-volt battery; however, it will also operate from voltages ranging from 5 to 18 volts. The higher voltages would produce the most powerful output signals.

Circuit Construction. The layout for the Tracking Transmitter is fairly compact. The circuit board measures only 2½-inches long by 1¼-inches wide (see Fig. 3). When building the Tracking Transmitter, it is important that all leads be kept as short as possible to avoid any unwanted capacitances. You must also avoid any looping of the component leads to limit unwanted inductances.

All of the components, with the exception of the battery supply, are mounted on the printed-circuit board. Install all of the board-mounted components using Fig. 4 as a guide. Be sure to double-check all transistor pinouts before mounting those units.

Note that all of the axial-lead components (R1 through R12 and L1) are vertically mounted. The electrolytic capacitors should be miniature radial-lead units. If axial-lead electrolytics are used, they must also be mounted vertically and be miniature types.

Note that inductor L2 is a hand-wound, air-core coil, consisting of seven turns of #22 solid magnet wire.

PARTS LIST FOR THE TRACKING TRANSMITTER

SEMICONDUCTORS

Q1-Q4, Q6—PN2222 general-purpose NPN silicon transistor
 Q5—2N2646 N-channel unijunction transistor

RESISTORS

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

R1, R4—6800-ohm
 R2—180,000-ohm
 R3—39,000-ohm
 R5, R11—10,000-ohm
 R6—100,000-ohm
 R7-R9—1000-ohm
 R10—33-ohm
 R12—4700-ohm

CAPACITORS

C1, C2, C4—10- μ F, 16-WVDC, miniature radial-lead Electrolytic
 C3, C5—.01- μ F, ceramic-disc
 C6—1.5- to 3-pF miniature variable
 C7—10- to 50-pF miniature variable
 C8, C9—27-pF, ceramic-disc

ADDITIONAL PARTS AND MATERIALS

L1—2.2- μ H coil
 L2—See text
 ANT1—See text
 Printed-circuit board materials, #22 magnet wire, 1/32-inch drill bit (see text), 9-volt transistor-radio battery, battery connector, enclosure (optional), on/off switch (optional) wire, solder, hardware, etc.

Note: The following items are available from Xandi Electronics, P.O. 25647, Tempe, AR 85285-5647; Tel. 602-829-8152 (catalogs and general information) or 800-336-7389 (orders only). A complete parts kit (#XTR100KB) for \$28.90 + \$3.00 S/H, containing an etched and drilled printed-circuit board, all resistors, capacitors, inductors, transistors, and battery snap. COD orders, add \$6.00. Arizona residents add 6.7% sales tax.

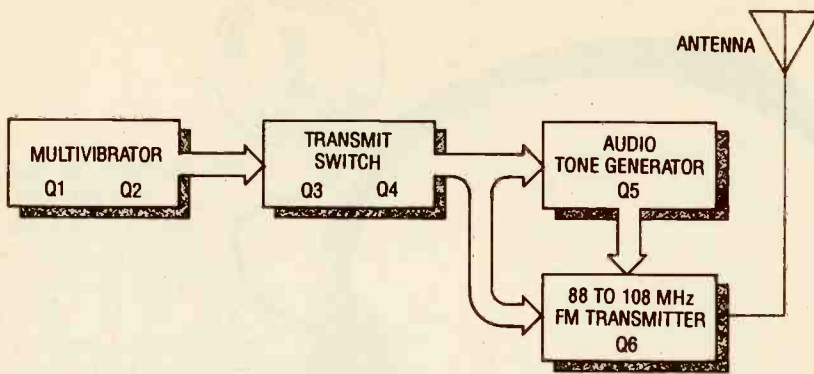


Fig. 1. The Tracking Transmitter consists of four distinct subassemblies; a free-running multivibrator, a transmit switch, an audio-tone generator, and an FM transmitter.

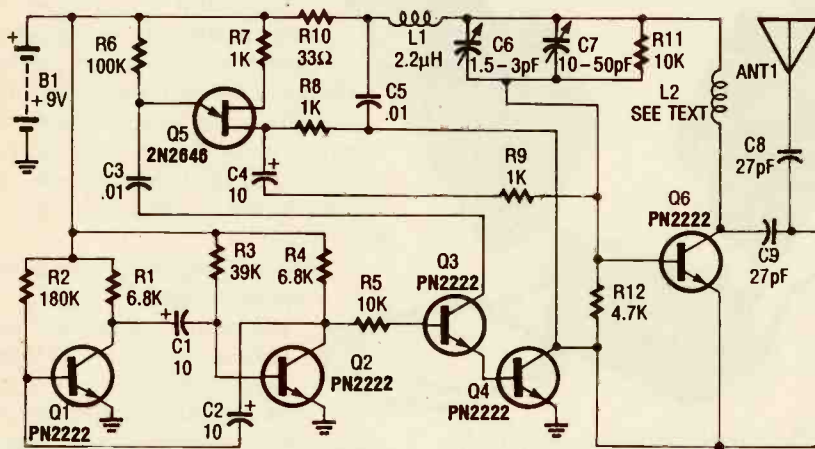


Fig. 2. The multivibrator (which produces a pulsewidth of 300 milliseconds with a pulse separation of 1500 milliseconds) is built around Q1 and Q2. The multivibrator output is coupled through R5 to the base of Q3, whose emitter feeds Q4, which controls the circuit's transmitter section.

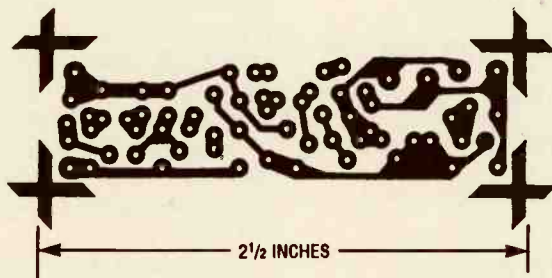


Fig. 3. The Tracking Transmitter was assembled on a small printed-circuit board, measuring only 2 1/2-inches long by 1 5/16-inches wide. Because of its size, the axial-lead components (all resistors and L1) must be mounted vertically.

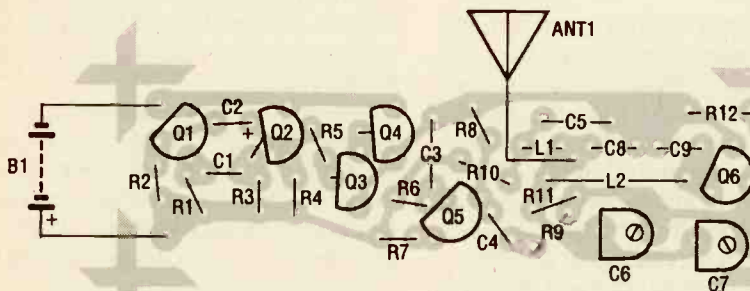


Fig. 4. All of the components, with the exception of the battery supply are mounted on the board. Install all of the board-mounted components using this diagram as a guide.

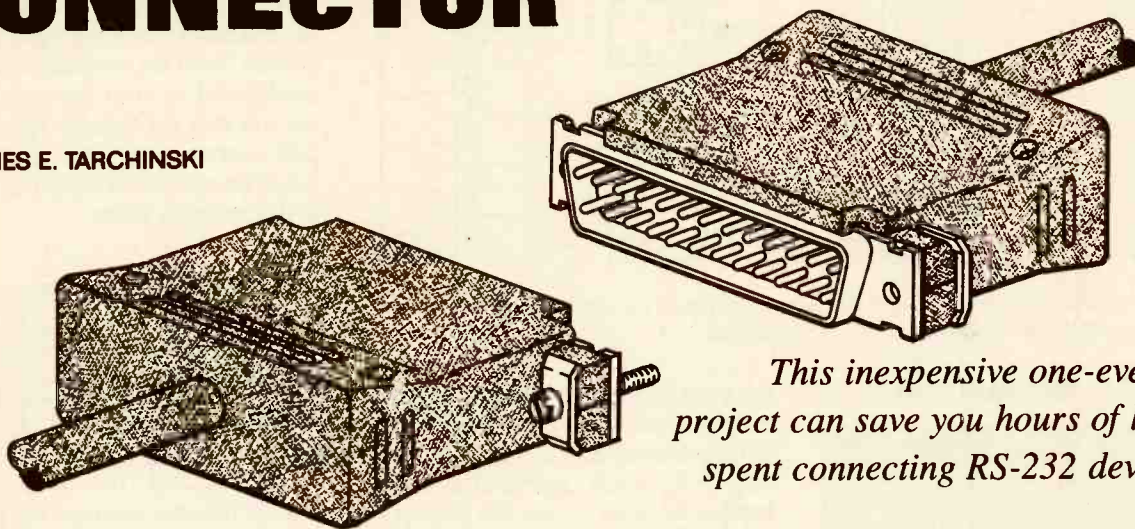
That coil is made by carefully wrapping 7 turns of the specified wire on a 1/32-inch drill bit. Once wound, scrape the insulation off of each end of the coil and insert the ends into the appropriate holes in the printed-circuit board, and solder it into place; make sure that you have a good electrical connection. Once the coil is formed and installed on the circuit board, you must be careful not to move the coil, or the windings may accidentally

(Continued on page 109)

UNIVERSAL RS-232 CONNECTOR



BY JAMES E. TARCHINSKI



This inexpensive one-evening project can save you hours of labor spent connecting RS-232 devices.

The RS-232 serial communications standard is the electronic equivalent of Rubik's Cube.

When you set out on a venture to connect two RS-232 devices, there is no obvious path to get from your starting point to where you want to be. But just like that insidious little cube, if you fiddle around with the devices long enough, you can generally arrive at your objective. Armed with the Universal RS-232 Connector described in this article, a little knowledge, and a little patience, you should be able to greatly shorten your journeys down the often bumpy RS-232 road.

The Universal Connector is a simple, one-evening project. It is essentially a dedicated break-out board that makes the important RS-232 signals easily accessible and reconfigurable. With it, you can debug a communications link by testing a multitude of different pin configurations very quickly. It saves you the time and trouble of wiring numerous "permanent" cables before you find the magical combination that will allow the two devices to talk to one another. Before discussing the Universal Connector and its construction in detail, however, let's first look at some of the causes of RS-232-phobia.

The Root of the RS-232 Problem.

There are many reasons why connecting two devices by the RS-232

protocol can be such a headache. First of all, no computer or peripheral manufacturer follows the true and complete standard! Of the 25 pins in the protocol's standard D-type connector, only three are not assigned functions. And of the 22 pins that do have assignments, in five years of searching the author has yet to encounter a piece of equipment that uses any more than eight of them. This is, of course, the reason why the industry is now moving to a 9-pin, D-connector version of the RS-232 standard—the complexity detailed in the original specification is not needed with today's electronics.

Another main source of RS-232 aggravation is the generally poor documentation that comes with modern computers and peripherals. Most manuals now days are written for non-technical users, people who neither know nor care to know the difference between a transmit signal and a receive signal. Those who do care about such things are forced to find other reservoirs of information besides the owner's manuals. Or, more often, they simply resort to the time-proven method of trial-and-error wiring.

A third cause of RS-232 connection problems, one that is really more a blessing than it is a curse, is the sheer number of devices that have the ability to communicate via RS-232. Be-

cause there is such a vast assortment of computers, printers, plotters, scanners, and such on the market today, there would be no way to fully document all the possible interconnections. People are therefore often left to fend for themselves. This situation is further complicated by the fact that different software packages sometimes require different signals to be present on the RS-232 cable before they will operate properly.

The Universal Connector. Figure 1 is a schematic diagram of the unit. It consists of two 25-pin, D connectors, each wired to a series of small solderless circuit board sections. To test a prototype cable design with the Universal Connector, all you need to do is connect one device to each side of the Universal Connector and then use small jumper wires to test different pin linkages. You'll no longer need to solder and unsolder countless pins to debug an RS-232 junction.

Note that not all of the 25 pins are used for the unit, this being a result of the market's trend to the "abbreviated" RS-232 standard mentioned previously. Table 1 lists the names of the eight RS-232 lines that are used in this project. Although some of the older devices may use some of the other 17 pins, the vast majority of today's devices can be connected with some combination of the eight lines

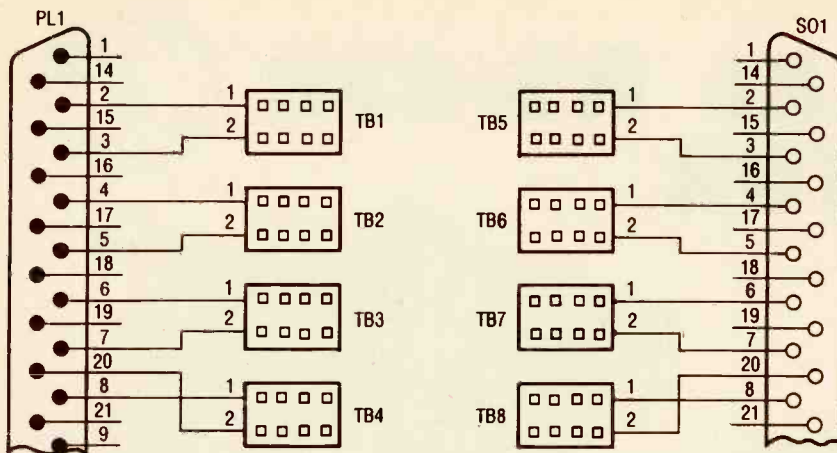


Fig. 1. The schematic for the Universal Connector reveals the simplicity of the project, but not its usefulness in debugging RS-232 interfaces.

TABLE 1—IMPORTANT SIGNALS

Signal Name	Abbreviation	Pin
Transmit Data	TX	2
Receive Data	RX	3
Request To Send	RTS	4
Clear To Send	CTS	5
Data Set Ready	DSR	6
Signal Ground	GND	7
Data-Carrier Detect	DCD	8
Data Terminal Ready	DTR	20

used by the universal connector. If you think you'll need to interface with any of those older devices, you may want to wire in some additional solderless circuit-board sections in your version of the project.

Construction. Being fairly simple,

this is an excellent project to learn to use the "iron-on PC pattern method" of board construction detailed in the July, 1990 issue of **Popular Electronics**. Another reason this project is an ideal candidate for the iron-on method has to do with the circuit's symmetry. Because of its inherent symmetry, the foil pattern given in Fig. 2 is the same as its mirror image—so there is no need to photocopy the pattern twice to obtain an inverted image.

Before you stuff the board, though, you should decide whether or not you'll want to install the finished unit in an enclosure. To facilitate easy access to all the tie-blocks, no enclosure was used for the author's prototype. Instead, rubber feet were placed on the

bottom of the PC board to prevent any accidental shorting of the board traces.

If you would like a more finished version of the Universal Connector, an enclosure would certainly be in order. One method worth considering is to use the "bottom" of a polystyrene enclosure. Such an enclosure could be configured so that the two D-connectors stick out through holes in opposing ends of the case, and the top could be quickly removed for access to the tie-block array.



Fig. 3. The only important thing to keep in mind when stuffing the board is to place the male connector J1 (and thus the female connector J2) into the right set of holes on the board.

PARTS LIST FOR THE RS-232 UNIVERSAL CONNECTOR

- TB1-TB8—2 × 4-hole solderless circuit-board sections
- J1—25-pin, male D-connector
- J2—25-pin, female D-connector
- Printed-circuit board materials, project enclosure, labeling kit, solder, etc.

Another important point to be made about the circuit is that one connector of each gender is used, and their placement is important. That may sound like a trivial point, but it could cost you hours of frustration if not attended to. Suppose, for example, you were to install two male connectors from your scrap box on a board made with the foil pattern given. Because the same genders were used, the pin numbers from the two connectors would not be aligned, and you would not be connecting the pins you thought you were.

With these simple considerations, you should be able to build your own Universal Connector easily enough. Once completed, it should simplify your next RS-232 job so you can move on to better things. ■

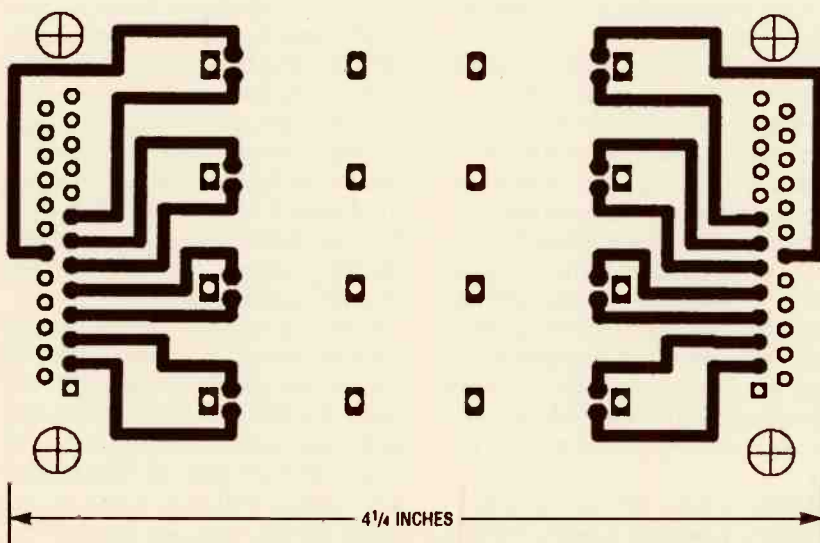


Fig. 2. This artwork can be copied onto translucent plastic for photographic board fabrication, or it can be easily duplicated directly on the PCB for the direct etch method.

Here is a circuit that leaves no doubt as to whether someone has been trying to reach you



BY STEVEN M. O'KELLEY

Recently, telephone companies began offering a new type of service; Electronic Voice Mail. Intended as a replacement for the answering machine, the service leaves a greeting and records messages from callers when a subscriber is unable to answer the phone. Typically, Voice Mail is activated after a preset number of rings to allow subscribers time to answer a call when they are at home.

Instead of using magnetic recording tape, the service records and stores the caller's message in digital form at the telephone-switching office. The user can then retrieve messages using any Touch-Tone telephone.

Even though Voice Mail has some nice advantages over its mechanical counterpart, there is still some room for improvement. For example, when a message has been left, the system lets you know by pulsing the first few seconds of dial tone when you pick up the handset. That means that someone who is in and out several times a day has to pick up the phone each time to check for messages.

While a device that automatically does this would be complex, the next best thing is easy. The simple circuit—dubbed the *Tel-Tale*—described in this article will detect when someone has called and flash an LED to alert you to check for messages.

How It Works. A schematic diagram of the *Tel-Tale* is shown in Fig. 1. The circuit is built around a couple of low-cost IC's: an H11C4 optoisolator/coupler with an SCR output (U1) and an LM3909 LED flasher (U2). The circuit is



Voice-Mail Alert

connected to the phone line's tip (green) and ring (red) wires in the same manner as any extension phone.

When the phone is on hook, there is about 48 volts DC across the line. A neon lamp (NE1) is connected in series with the tip conductor. Because NE1 requires about 60 volts to conduct, the circuit represents a high impedance to the line and no current flows. When a call is made to the covered line, a ring voltage—about 90 volts AC at 20 Hz—is applied to the telephone line by the telephone-switching office. During half of the cycle, current flows from the ring line through R1, D1, NE1, and C1 to the tip line. During the other half cycle, the current reverses and the LED portion of U1 conducts, triggering its internal SCR, allowing a small amount of current to flow through the SCR and R2. That current flow causes capacitor C2 to begin charging.

Integrated circuit U2 and capacitor C3 form a simple LED-flasher circuit that will operate on just over a volt. When the charge on C2 reaches the 1-volt level, U2 flashes LED1 and the charging cycle of C2 starts over. The LED continues to flash until S1 (reset) is pressed. Closing S1 deprives the SCR of holding current, thereby turning it

off. The *Tel-Tale* remains in that state until re-triggered by the next incoming phone call.

Construction. The prototype of the *Tel-Tale* was assembled on a small printed-circuit board, measuring about 1½ inches square. A template of the author's PC pattern is shown in Fig. 2. Note that in that diagram, only one set of IC pads (near the center of the board) are shown; the reason for that will become apparent in a moment.

Once you've etched your board and gathered all the parts listed in the Parts List, construction can begin. A parts-placement diagram for the *Tel-Tale's* printed-circuit board is shown in Fig. 3. In the author's prototype, a single 16-pin IC socket is used for both U1 and U2 (6- and 8-pin devices, respectively). You can do the same thing, or, if you happen to have 6- and 8-pin sockets on hand, you can use individual sockets. In any event, using sockets prevents damage to the IC's during soldering, and makes replacing either IC (should the need arise) simpler.

Once the IC socket (or sockets) is in place, install the rest of the components as shown in Fig. 3. Note that because of tight spacing R1, R2, and D1 were vertically mounted to the cir-

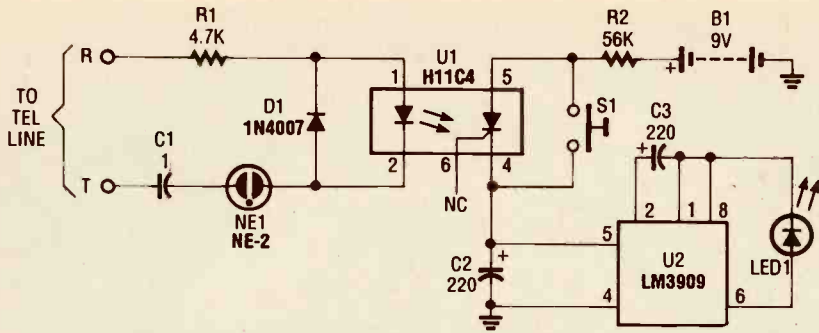


Fig. 1. The Tel-Tale is built around a couple of low-cost IC's: an H11C4 optoisolator/coupler with an SCR output (U1) and an LM3909 LED flasher (U2), and is connected to the phone line in the same manner as any extension phone.

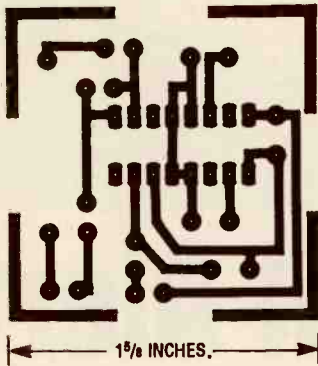
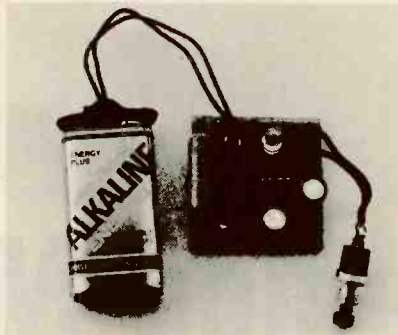


Fig. 2. The prototype of the Tel-Tale was assembled on a small printed-circuit board, measuring about 1 1/8 inches square, a full-size template of which is shown here.



Here's the author's completed prototype.

The author's prototype was housed in a plastic Radio Shack enclosure (catalog number 270-293), which provides ample room for the circuit board and also has a built in battery compartment. The circuit board can be mounted using a small piece of double-sided tape. Switch S1 (either a pushbutton- or a toggle-type momentary single-pole unit) mounts to the case. Because the battery drain is low (about 0.3 mA), the author elected not to use an on/off switch in the design of this circuit.

If you have one of the older desk- or wall-type telephones, you may find that there is ample room to mount the

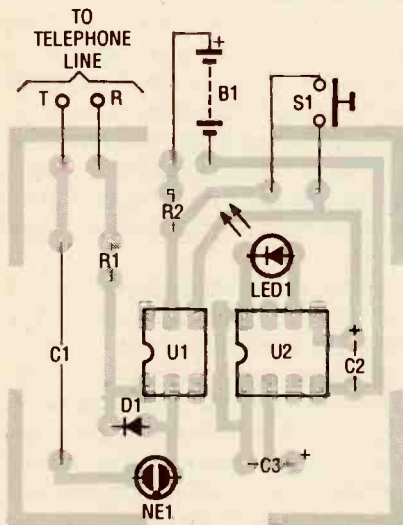


Fig. 3. Once you've etched your board and gathered all the parts listed in the Parts List, construction can begin, guided by this parts-placement diagram. In the author's prototype, a single 16-pin IC socket is used for both U1 and U2 (6- and 8-pin devices, respectively).

cuit board. When installing LED1, leave the leads long enough so that its lens will stick through a hole in the circuit's enclosure.



The circuit can be mounted in a plastic project box or even within some telephones.

PARTS LIST FOR THE TEL-TALE

SEMICONDUCTORS

- U1—H11C4 or NTE3046 optoisolator/coupler with SCR output, integrated circuit
- U2—LM3909 or NTE876 LED flasher, integrated circuit
- D1—1N4007 1-amp, 1000-PIV, rectifier diode
- LED1—Super-bright LED (Radio Shack 276-087)

RESISTORS

- (All resistors are 1/4-watt, 5% units.)
- R1—4700-ohm
- R2—56,000-ohm

CAPACITORS

- C1—1-µF, 200-WVDC, metallized-film
- C2, C3—220-µF, 10-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

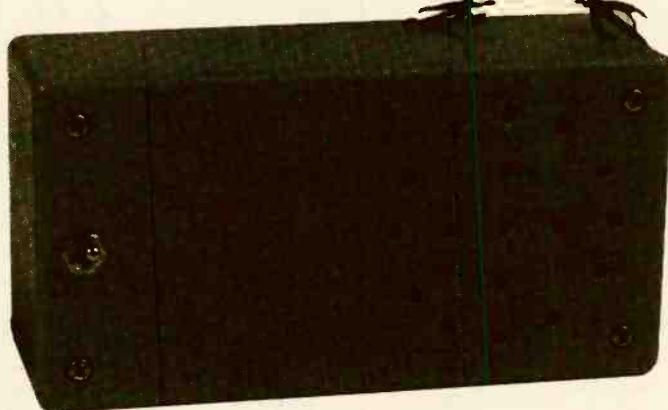
- S1—SPST momentary-contact toggle or pushbutton switch
- B1—9-volt transistor-radio battery
- NE1—NE-2 neon lamp
- Printed-circuit board materials, enclosure, battery holder and connector, telephone wire, solder, hardware, etc.

circuit board and battery inside. Mount LED1 to the case of the phone and use a few inches of wire to connect it to the circuit. Most such phones also have a hook switch with unused contacts that can be used for S1. By using the hook-switch scheme, the circuit will reset itself whenever you use that phone.

Installation. With your circuit completed, connect it to the phone line using standard quad telephone wire or a modular cord. The tip and ring inputs of the unit connect to the green and red wires, respectively, inside the telephone outlet. The Tel-Tale should be mounted so that the LED can be easily seen. The LED radiates most of its light in a narrow pattern so you should be looking into the top of the LED. The next time you are called, the circuit will flash. Even if you don't have Voice Mail, you may find this device handy. It will always let you know that someone has tried to reach you. ■

The Incredible Hot Canaries

BY JOHN CLARKE



This novel circuit will emulate the sounds of two birds singing together in a way that will intrigue you. They start slowly and then sing rapidly increasing trills as they compete with each other for virtuoso supremacy.

Do you love the song of birds around your home, but hate the idea of caging birds? Perhaps you can't stand the thought of cleaning out the cage—birds can be messy little critters. Whatever the reason for not inviting our feathered friends into your home, you can still enjoy their melodic songs by building this electronic bird-song circuit. The dual-bird melody produced by this project will both entertain and amaze your friends, and when you don't feel like listening to them, you can simply turn them off.

The idea of producing artificial bird songs is not new; artificially produced bird song has been used in clocks dating back several centuries. And many bird-song circuits have been devised in the last decade or so. But it's been a while since we've seen or heard of any new arrivals, so we thought, "Why not build a new circuit?"

We could have been really clever and built the unit into a fancy gift cage

complete with an ornamental bird. Instead, we built the circuit into a standard project box, bedecked with a couple of ornamental birds—and dubbed it *Hot Canaries*.

Using just two garden-variety IC's and a handful of resistors, capacitors, and other support components, our circuit can emulate the sound of two canaries happily chirping and trilling away. The period of trilling and chirping, and the pitch of each bird is different, creating a random effect as the birds come in and out of chorus.

One of the problems of producing such a bird-song circuit is that so many parameters have to be controlled—the pitch, rate of chirps and trills, and the duration of the trills. Such a circuit tends to be very complicated because certain sections of the circuit will have to perform more than one function. Our approach was to try and come up with a good compromise—produce an uncomplicated circuit that would also be reasonably easy to build and troubleshoot if necessary, while being powered from a battery.

About the Circuit. Figure 1 is a complete schematic diagram of the circuit, which is built around two LM324 quad op-amps. Essentially, the circuit consists of 7 oscillators connected in such a manner so as to emulate the sound of two canaries singing. One oscillator (built around U1-a) serves as a switching control, which turns the canary sounds off for a short while after a minute or so of chirping.

The remaining six oscillators make up two almost identical circuits—consisting of U1-d/U1-c/U2-c and U1-b/U2-a/U2-b—whose outputs are mixed together and amplified by a single transistor that is used to drive a small speaker. The circuits differ only in the values of two pairs of capacitors—C2/C3 and C8/C9.

Each op-amp is configured for Schmitt-trigger operation by the resistor connected between its output and its non-inverting input. Each Schmitt trigger was then made to operate as an oscillator by connecting a resistor/capacitor network between its output and inverting input. Voltage-divider net-

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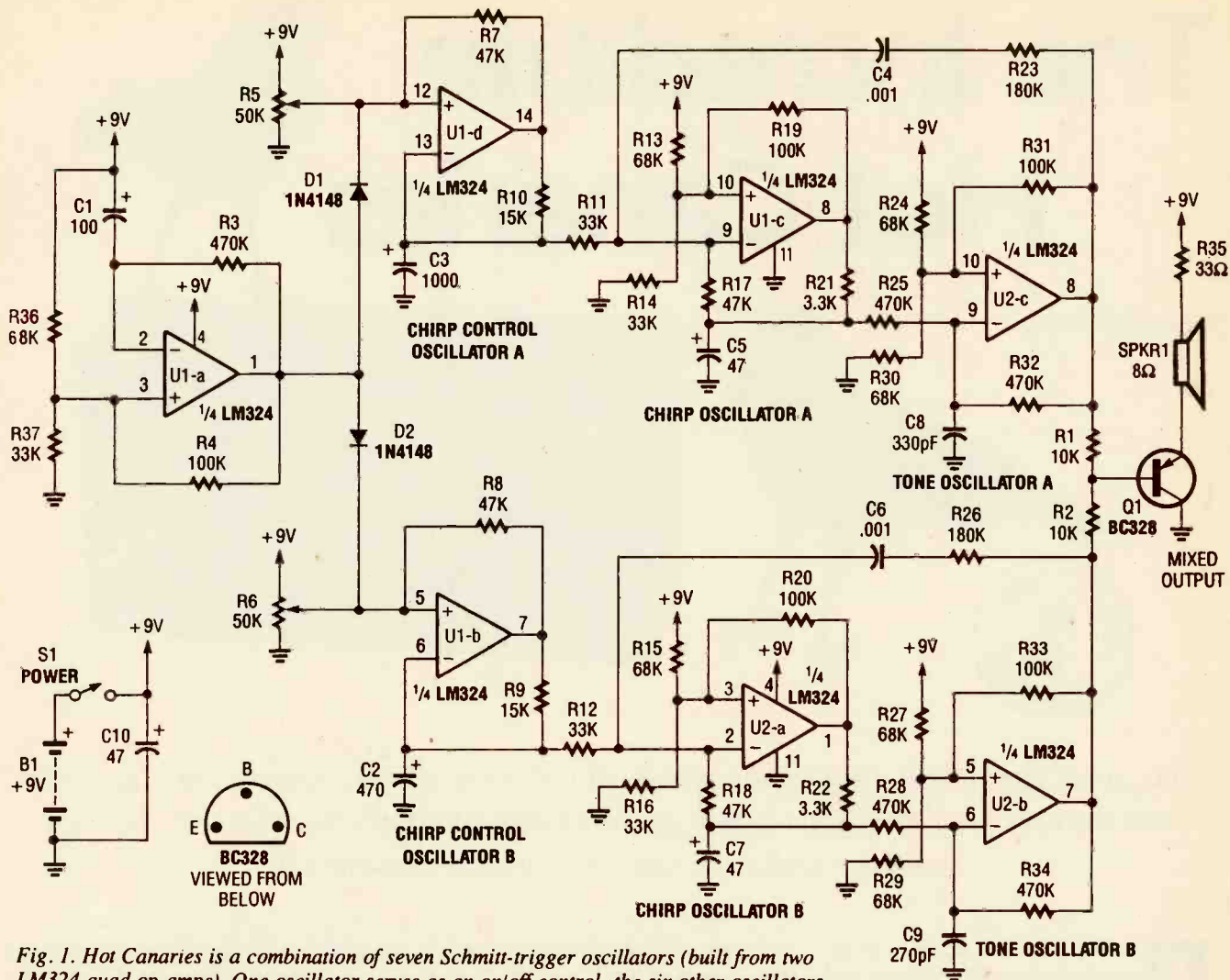


Fig. 1. Hot Canaries is a combination of seven Schmitt-trigger oscillators (built from two LM324 quad op-amps). One oscillator serves as an on/off control, the six other oscillators generate the sounds of two canaries.

PARTS LIST FOR HOT CANARIES

SEMICONDUCTORS

U1, U2—LM324 quad low-power op-amp, integrated circuit
 Q1—BC328, ECC-159, or equivalent, PNP silicon transistor
 D1, D2—1N914, 1N4148, or equivalent small-signal silicon diode

RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)
 R1, R2—10,000-ohm
 R3, R25, R28, R32, R34—470,000-ohm
 R4, R19, R20, R31, R33—100,000-ohm
 R5, R6—50,000-ohm miniature PC mount trimmer potentiometer
 R7, R8, R17, R18—47,000-ohm
 R9, R10—15,000-ohm
 R11, R12, R14, R16, R37—33,000-ohm
 R13, R15, R24, R27, R29, R30, R36—68,000-ohm

R21, R22—3300-ohm
 R23, R26—180,000-ohm
 R35—33-ohm

CAPACITORS

C1—100- μ F, 16-WVDC, electrolytic
 C2—470- μ F, 16-WVDC, electrolytic
 C3—1000- μ F, 16-WVDC, electrolytic
 C4, C6—0.001- μ F, metallized polyester
 C5, C7, C10—47- μ F, 16-WVDC, electrolytic
 C8—330-pF, ceramic or polystyrene
 C9—270-pF, ceramic or polystyrene

ADDITIONAL PARTS AND MATERIALS

SPKR1—8-ohm speaker
 S1—SPDT toggle switch
 B1—9-volt transistor-radio battery
 Printed-circuit board materials, enclosure, 9-volt battery holder and connector, wire, solder, etc.

works, consisting of R13/R14 and R24/R30 for the upper half of the circuit, and R15/R16 and R27/R29 for the lower half, set the upper and lower thresholds of the chirp and tone oscillators.

Each oscillator then works as follows: When power is first applied, the capacitor at the inverting input has no voltage across it and the op-amp's output is high. The capacitor starts to charge via its associated resistor until it reaches the threshold level set at the non-inverting input.

When the charge on the capacitor equals the reference, the op-amp output goes low and the capacitor begins to discharge until it reaches the lower threshold voltage. When the lower threshold is reached, the op-amp's output again swings high and the cycle begins again, producing an approximate square-wave at the oscillator's output. That signal is then fed across a resistor/capacitor network, producing a

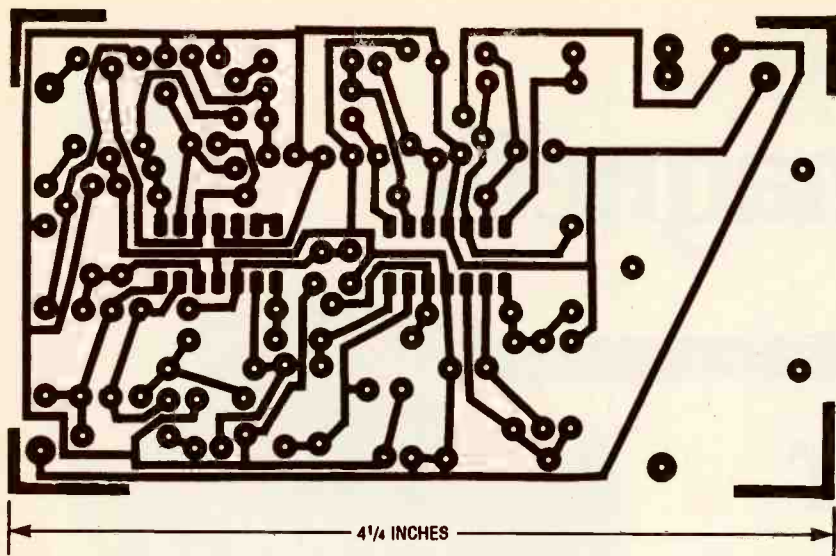


Fig. 2. Here's an actual-size foil pattern for Hot Canaries' printed-circuit board.

sawtooth waveform that is applied to the inverting input.

Now that we've discussed the basic operation of the individual oscillators, let's see how those oscillators interact with each other to produce bird a song.

Oscillator Interaction. To understand the interaction of the oscillators that produce the canary sounds, let's first look at U2-b—the last op-amp in the lower bird-song circuit—which is labelled as a "tone oscillator." Its basic frequency is set at around 2–3 kHz. Note that if R26 and R34 (which tie the oscillator output to other parts of the circuit) were removed, U2-b would just oscillate continuously at around 3 kHz or so. However, it wouldn't sound much like a canary.

To produce a chirping affect, U2-b is

modulated at a rate that starts at about 1 Hz and rises until U2-b runs continuously. The "chirp" frequency is generated by U2-a. To get the chirp frequency to rise, U2-a is controlled by a lower-frequency oscillator, U1-b (the chirp-control oscillator). As the voltage across C2 increases, the chirp frequency rises. When the chirp oscillator rises to its highest value, an RC network, consisting of R26 and C6 connected between pins 7 of U2-b and 2 of U2-a, causes the two oscillators to modulate each other so that the output of U2-b "warbles" just like a canary.

The circuit formed by op-amps U1-c, U1-d, and U2-c—which produces the second canary sound—is virtually identical to the one formed by U1-b, U2-a, and U2-b. The outputs of upper and lower halves of the circuit (at U2-c and

U2-b, respectively) are mixed via two 10k resistors (R1 and R2) and used to drive transistor Q1, which, in turn, drives a miniature 8-ohm speaker (SPKR1).

The 7th (and final) oscillator, built around U1-a, is the control oscillator and is used to turn the two sound-producing circuits on and off. Op-amp U1-a initially has a low output for about 60 seconds since the 100- μ F capacitor has to discharge from +9 volts down to +2.3 volts. From then on, its output goes high for about 20 seconds, low for 20 seconds, and so on. When the output of U1-a is low, the chirp-control oscillators (U1-b and U1-d) are enabled via diodes D1 and D2.

Construction. The Hot Canaries circuit was built on a printed-circuit board measuring 4 1/4 x 2 1/2 inches. A foil pattern for the printed-circuit board is shown in Fig. 2. Once you've etched and drilled your board, and gathered the parts listed in the Parts List, construction can begin. Start by installing IC sockets at the locations indicated in the parts-placement diagram (Fig. 3). It is suggested that you install the passive components (resistors and capacitors) first, beginning with the resistors and then the capacitors. Be sure to observe the proper orientation for the electrolytic capacitors.

Follow the passive components with the semiconductors, beginning with the two diodes; keep in mind that those units must be properly orientated. After that, install transistor Q1, but do not place the IC's in their sockets at this point. Next install a 9-volt, transistor-radio-battery holder on the board where indicated. Connect a 9-volt battery connector to the board. Connect S1 to the board through short lengths of hook-up wire. Do the same for the speaker. Now lay the board to the side and prepare the enclosure that will house the circuit.

The author chose to house the circuit in a plastic enclosure measuring about 6 x 3 1/2 x 1 1/8 inches. Prepare the enclosure by first marking the location of the speaker on the inside of the enclosure's lid using a permanent marker. Within that area, drill several holes in the lid to allow the sound to exit the enclosure. Also drill a hole in the lid away from the speaker location for switch S1. Mount S1 and glue the speaker to the inside surface of the lid. Install the IC's in

(Continued on page 109)

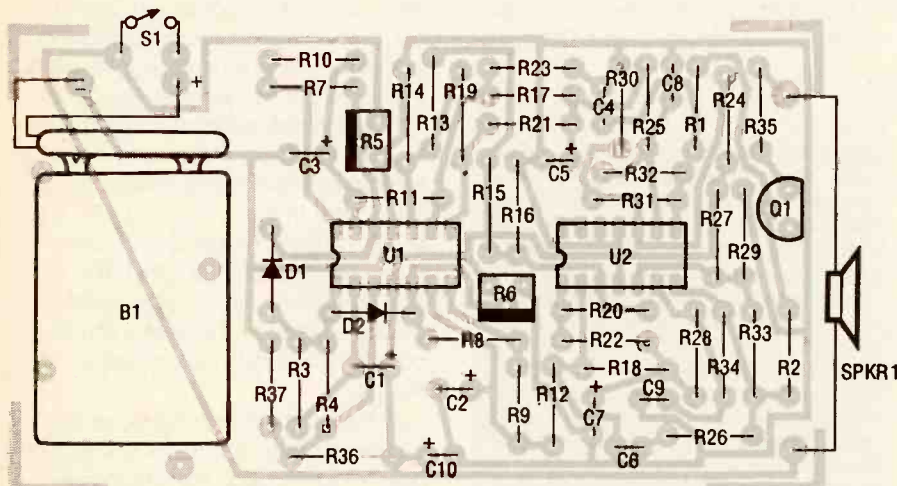


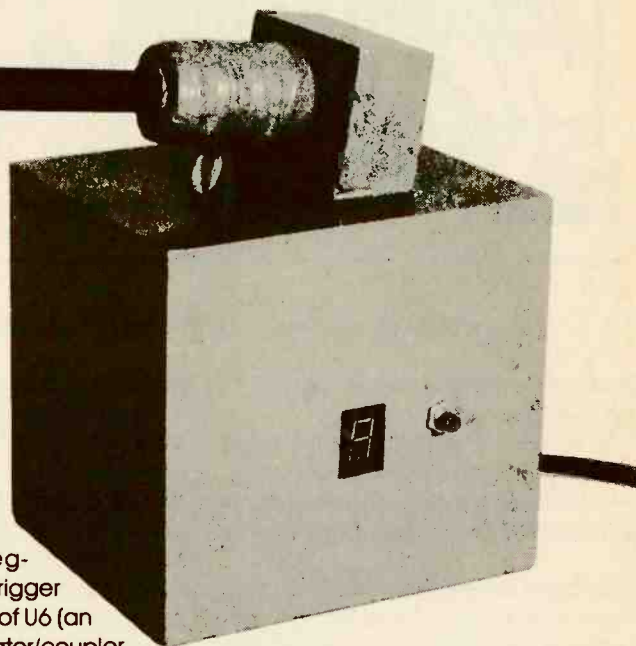
Fig. 3. Assemble the printed-circuit board using this parts-placement diagram as a guide. Take care to observe the proper orientation when installing the electrolytic capacitors and the other polarized components.

The Electromagnetic Ring Launcher

PROJECT TIME
3
EVENINGS

BY VINCENT VOLLONO

Explore the principles of electromagnetic propulsion with this simple ring launcher



Many methods, such as gunpowder, spring action, water power, etc., have been used to propel various objects. But has anyone given any thought to propelling objects by electromagnetic repulsion? The principle of electromagnetic propulsion is a simple one based on the fact that like-charged bodies tend to repel each other; e.g., if a negatively (or positively) charged body is brought near another negatively (or positively) charged body, they tend to push against each other.

That principle (electromagnetic repulsion) is at the heart of the *Electromagnetic Ring Launcher* described in this article.

Circuit Description. Figure 1 is a schematic diagram of the Electromagnetic Ring Launcher. The launcher circuit is comprised of four sub-circuits: a clock circuit, a count-down/display circuit, a trigger circuit, and a reset circuit.

The clock circuit is built around U5 (a 555 oscillator/timer configured for astable operation) and a few support components. The counter circuit is built around U3 (a 74190 synchronous up/down counter with BCD outputs that is configured for count-down operation), U4 (an ECG8368 seven-segment latch/decoder/driver), and

DISP1 (a common-cathode seven-segment display). The trigger circuit is comprised of U6 (an MOC3010 optoisolator/coupler with a Triac-driver output), an SK3665 Triac and a few support components. The reset circuit is composed of U1 (a 7400 quad 2-input NAND gate), U2 (a second 555 oscillator/timer configured for monostable operation), and a few support components.

When power is first applied to the circuit, the output of a flip-flop (comprised of U1-a and U1-b) at U1-b pin 6 is low. That low is applied to pin 11 of U3, disabling it so that the clock pulses from U5 are ignored, and DISP1 dis-

plays a count of 9. When S1 is pressed, the output of the flip-flop goes high. That high enables U3, causing it to begin its descending count, outputting the count (in BCD form) to the seven-segment latch/decoder/driver, U4. The latch/decoder/driver decodes the BCD data and activates the appropriate segments of DISP1 to display the descending count.

When the count on U3 reaches zero, pin 12 of U3 goes high. From U3, the high output divides along two paths. In one path, that signal is fed through R5 (a 470-ohm resistor) to pin 1 of U6 (the optoisolator/coupler). That causes U6's internal LED to turn on, activating its internal Triac driver. The Triac driver, in turn, triggers TR1 (an SK3665 200-PIV, 4-amp Triac), sending a burst of current through L1. The current going through L1 induces an opposing current in the aluminum ring, causing the ring to be propelled into the air.

At the same time, in the other path, the pin 12 output of U3 is fed to the base of Q1 through R4 (another 470-ohm resistor), causing it to conduct. With Q1 conducting, pin 2 of U2 is pulled low, triggering the monostable

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timer. The output of the monostable at pin 3 goes high for about 1½ seconds. That high is fed to pin 1 of U1-a, causing the flip-flop output at pin 6 to go low, once again disabling the counter, and resetting the display to 9. Potentiometer R8 is used control the clock frequency which, in turn, controls the counter rate.

The circuit is powered from a regulated 5-volt power supply consisting of T1, BR1, U7, and C4. Transformer T1 (a 12-volt 2-amp unit) reduces the 117-volt AC line voltage to 12-volts AC. The output of the transformer is then applied to BR1 (the fullwave-bridge rectifier), which provides a pulsating DC output. The output of the bridge rectifier is then filtered by capacitor C1, and fed to U7, which provides a regulated 5-volt DC output.

Construction. The author's prototype of the Electromagnetic Ring Launcher was assembled on a single section of perfboard using point-to-point wiring. When assembling the project, it is recommended that sockets be provided for all of the IC's, and that Triac TR1 be mounted to a heat sink. It is further recommended that a socket be provided for the display; socketing the display allows you to wire the socket to the display without risking thermal damage to the unit itself. Note that the display is not mounted to the circuit board along with the other components, but is instead mounted to the side of the enclosure (where it can be seen) along with S1 (the trigger or start switch).

Begin assembly by mounting the sockets for the IC's to the board; but

do not install the IC's in their sockets until the project is completely assembled and checked for correctness. The sockets, in addition to preventing thermal destruction to the IC's, also allow easy parts substitution should that become necessary. Once the sockets are installed, wire the circuit together using Fig. 1 as a guide. Be careful when installing the polarized components (diodes, Triac, fullwave-bridge rectifier, etc.). Installing one or more of those components incorrectly can, and probably will, result in an inoperative circuit and destroyed components. In the worst-case scenario, incorrect wiring of the circuit could also place you at greater shock hazard; remember, coil L1 is fed directly from the AC line. In short, a little care now can save a lot of aggravation.

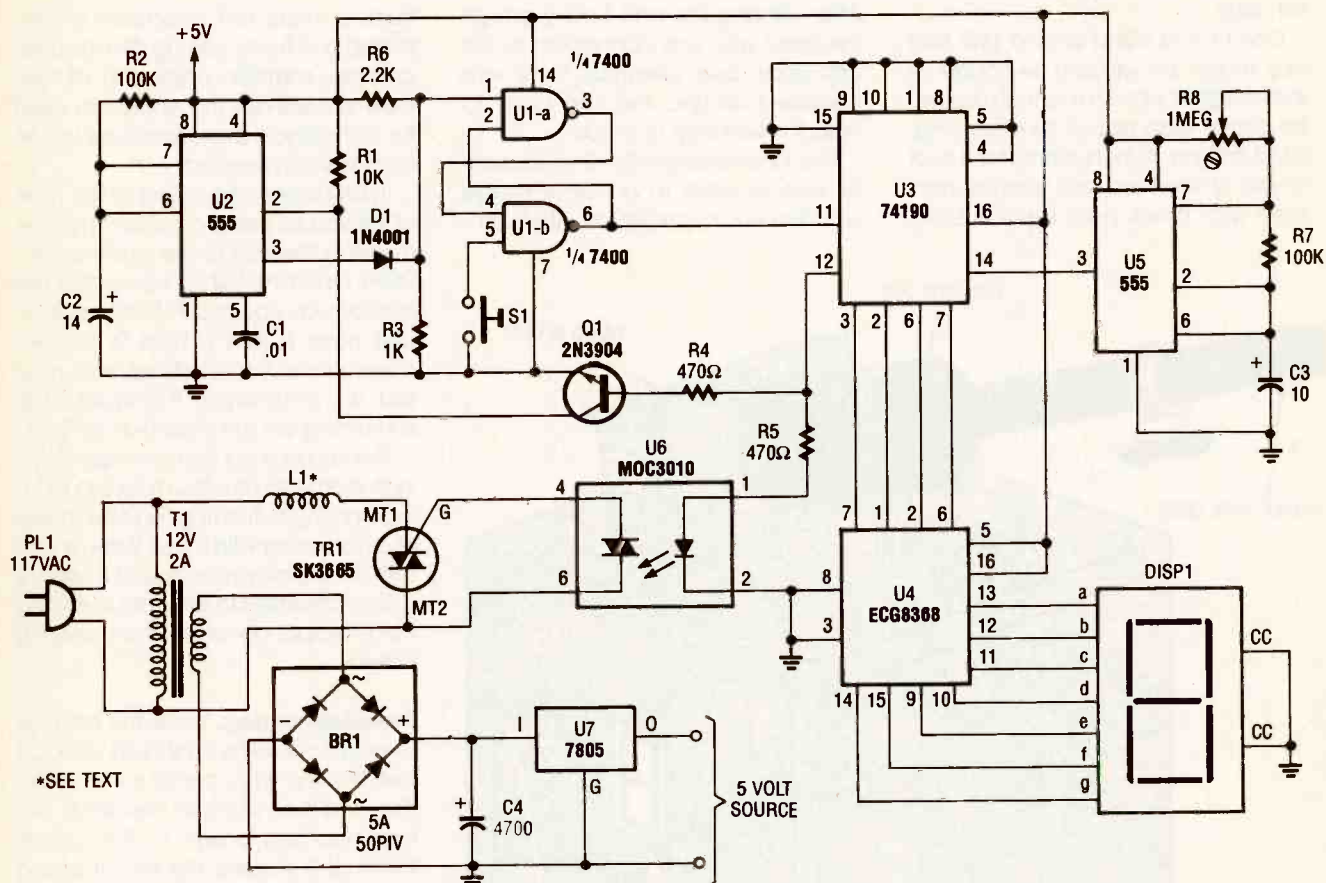


Fig. 1. The Electromagnetic Ring Launcher is comprised of four sub-circuits: a clock circuit (built around U5, a 555 oscillator/timer configured for astable operation), a count-down/display circuit (built around U3, a 74190 synchronous up/down counter with BCD outputs that is configured for count-down operation; U4, an ECG8368 BCD-to-seven-segment latch/decoder/display driver; and DISP1, a common-cathode seven-segment display), a trigger circuit (comprised of U6, an MOC3010 optoisolator/coupler with Triac-driver output; TR1, an SK3665 200-PIV, 4-amp Triac; and a few support components), and a reset circuit (composed of U1, a 7400 quad 2-input NAND gate; U2, a second 555 oscillator/timer configured for monostable operation; and a few support components).

PARTS LIST FOR THE ELECTROMAGNETIC RING LAUNCHER

SEMICONDUCTORS

U1—7400 quad 2-input NAND gate, integrated circuit
 U2, U5—555 oscillator/timer, integrated circuit
 U3—74190 synchronous up/down counter with BCD outputs, integrated circuit
 U4—ECG8368 BCD-to-7-segment latch/decoder/display driver, integrated circuit
 U6—MOC3010 optoisolator/coupler with Triac driver output, integrated circuit
 U7—7805 5-volt, 1-amp voltage regulator, integrated circuit
 Q1—2N3904 general-purpose NPN silicon transistor
 TR1—SK3665 200-PIV, 4-amp Triac

D1—1N4001 50-PIV, 1-amp rectifier diode
 BR1—50-PIV, 5-amp, full-wave bridge rectifier
 DISP1—Common-cathode, 7-segment LED display (see text)

RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)
 R1—10,000-ohm
 R2, R7—100,000-ohm
 R3—1000-ohm
 R4, R5—470-ohms
 R6—2200-ohm
 R8—1-megohm, trimmer potentiometer

CAPACITORS

C1—0.01- μ F, ceramic-disc

C2—14- μ F, 10-WVDC, electrolytic
 C3—10- μ F, 10-WVDC, electrolytic
 C4—4700- μ F, 35-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

T1—12-volt, 2-amp power transformer
 PL1—117-volt molded AC power plug with line cord
 Perfboard materials, enclosure (see text), aluminum ring (see text), #28 magnet wire, 3-inch length of 1/2-inch diameter paper tubing, 1-foot length of 1/2-inch diameter steel rod, heat-shrink tubing, heavy-gauge electrical wire, hook-up wire, electrical tape, solder, hardware, etc.

tion later.

Coil L1 is a hand-wound unit that was made by winding 1/4-pound of #28 magnet wire on a 1/2-inch diameter paper tube about 3 inches long, fitted onto a 1/2-inch diameter 1-foot length of steel rod that was first covered with black heat-shrink tubing.

After winding the coil, heavy gauge insulated wire was connected to the coil ends, and electrical tape was wrapped around the coil body to hold the windings in place.

The Electromagnetic Ring Launcher was housed in a home-made wooden enclosure (which with its pro-

truding metal rod resembles a battleship gun turret, see Fig. 2), however, any non-metallic enclosure of suitable size will do. The enclosure used for the author's prototype was made from 1/2-inch plywood.

In any event, regardless of the type of enclosure used, a cutout must be made in the side of the enclosure for DISP1. Once the cutout was made, the display was epoxied into place. You'll also have to drill a hole in the enclosure for switch S1. When your project is completed, it should look something like the illustration in Fig. 2.

The ring was cut from a length of 3/4-inch diameter aluminum tubing to 1/2-inch in length. The ring must be made of a non-magnetic metal such as aluminum. If a magnetic metal is used, it will be attracted to the core, nullifying the principle on which the project is based.

Troubleshooting. While the circuit is so easy to build that it should work just fine the first time, construction errors may find their way into the circuit. Before applying power to the circuit, thoroughly inspect the circuit board for construction errors—cold solder joints, misconnected components, shorts, etc.—that may prevent the circuit from operating. **Caution: AC line voltage is used in transformerless fashion in the trigger section of the circuit to supply the necessary burst of AC current to L1, therefore, caution must be exercised. Do not**

(Continued on page 109)

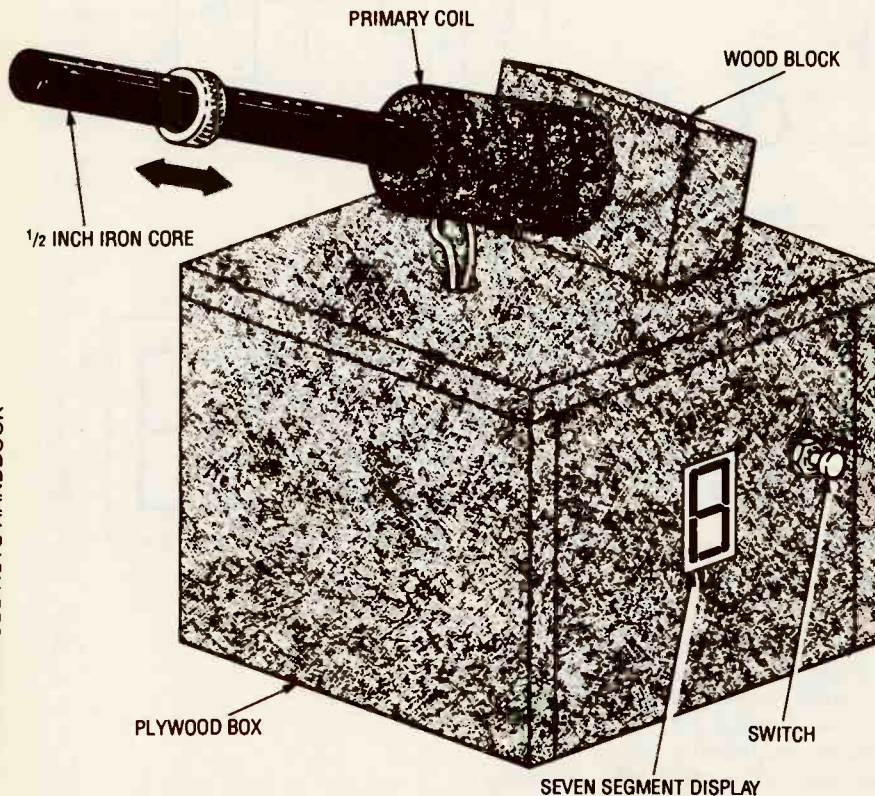


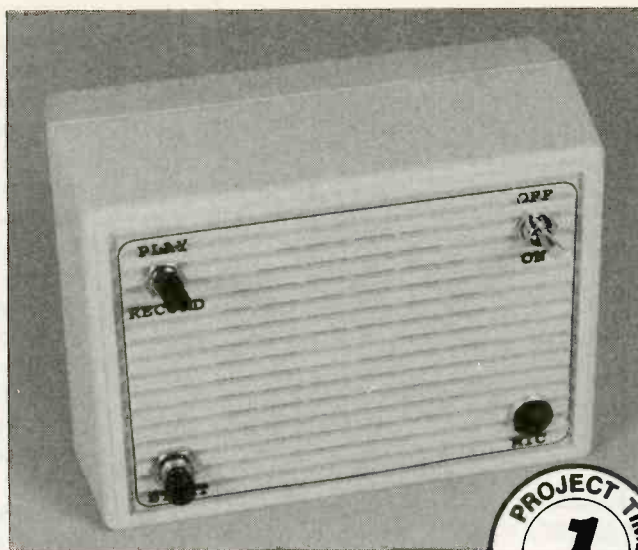
Fig. 2. When your project is completed, it should bare some remote resemblance to this illustration, with its gun-turret like core support from which to launch the ring. The ring—which must be made of a non-magnetic metal—was cut from a length of 3/4-inch diameter aluminum tubing to 1/2-inch in length.

If you are like many people, you probably own a telephone-answering machine so that you never miss an important phone message. But what about those important messages at home or work that don't come from the telephone? How often do you search for pencil and paper just to leave a family member or co-worker a short note? Or how frequently, when driving your automobile, do you think of something important that you need to be reminded of later? Wouldn't it be great if you could just press a button to record your thoughts and instantly recall them whenever you desire?

You can do that and more with the *Personal Message Recorder*, described in this article. It works like a conventional tape recorder except that it is completely solid state. It features instant playback because there is nothing to re-wind. In addition, it will hold messages for more than 10 years without any power!

How It Works. The project is based on the new analog storage technology. Current techniques for recording analog signals involve several steps. In general, the signal is first compressed (or encoded) and then converted to digital values by an analog-to-digital converter. The converted values are stored in a large digital RAM area. That memory area requires a battery to prevent data loss when power is removed.

When the signal is to be played back, the digital data is clocked out of the RAM to a digital-to-analog converter. Finally, the restored signal passes through an expander (or decoder) circuit and an output amplifier, which feeds the signal to a speaker. That traditional approach is very complicated. And even with sophisticated compression schemes, huge amounts of memory are required to



PERSONAL MESSAGE RECORDER

This state-of-the-art, solid-state recorder uses no tape and can store messages for up to 10 years.

BY DAVID WILLIAMS

store relatively small amounts of speech. Typically, a 32,000-bit RAM holds less than 2 seconds of speech.

The Personal Message Recorder is built around an ISD1016 CMOS voice messaging system, which does away with the cumbersome and expensive analog-to-digital and digital-to-analog conversion circuits. The ISD1016 made by Information Storage Devices, Inc., of Austin, TX uses CMOS EEPROM technology to directly sample, store, and playback analog signals. And since EEPROM storage is non-volatile, the ISD1016 holds its data indefinitely without power.

A functional block diagram of the ISD1016 is shown in Fig. 1. The ISD1016 contains all of the functions necessary for a complete message-storage system. The pre-amplifier stage accepts

audio signals directly from an external microphone and routes the signal to the ANA OUT (analog out) terminal. An automatic-gain control (AGC) dynamically adjusts the preamplifier gain to extend the input signal range. Together the preamp and AGC circuits provide a maximum gain of 24 dB. The internal clock samples the signal and, under the control of the address-decoding logic, writes the sampling to the analog-storage array. Eight external input lines allow the ISD1016's message space to be addressed in 160 equal segments, each with a 100-millisecond duration. When all address lines are held low, the storage array can hold a single, continuous, 16-second message.

The ISD1016 also includes control signals for cascading multiple chips in order to achieve longer recording and playback times. Additionally, the ISD1016 has an internal output amplifier that can drive an external speaker with up to 50 mW of power.

Figure 2 shows the complete schematic of the Personal Message Recorder. The circuit is very straight-

forward, since the ISD1016 takes care of most functions. However, there is a special addition to the POWER DOWN input (pin 24) of U1. As mentioned earlier, the ISD1016 is designed to allow cascading multiple chips for longer recording times. That's a useful feature, but it causes a slight problem in our application. If the internal memory becomes full during recording, an overflow condition is generated in order to trigger the next device. Once an overflow occurs, pin 24 must be taken high and then low again before a new playback or record operation can be started.

A separate reset switch could be used to clear any overflows, but that would make the operation awkward. Instead, transistor Q1 along with components C3, R5, and R6 form a one-

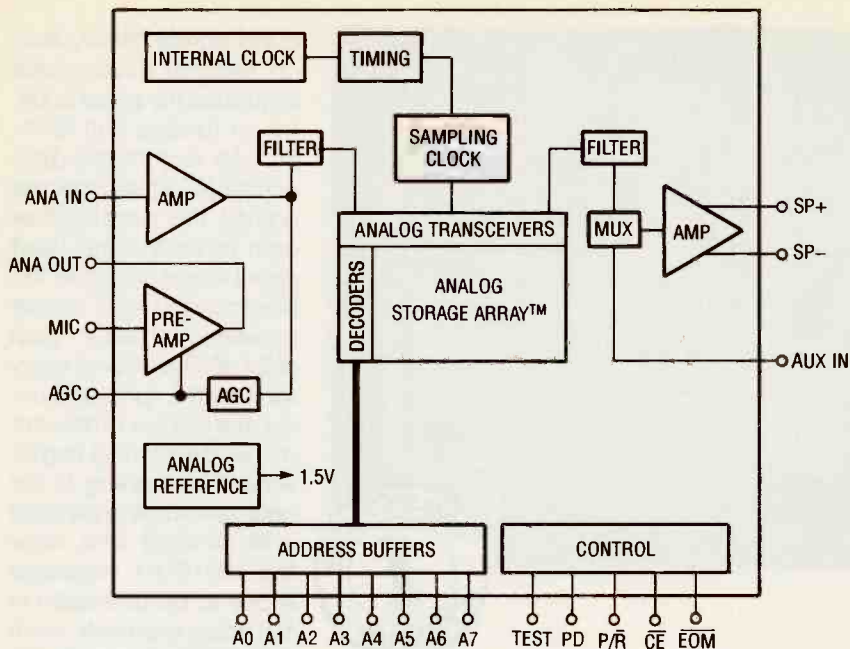


Fig. 1. This block diagram shows the internal structure of the ISD1016 voice-messaging system integrated circuit.

shot pulse generator that automatically clears any overflow condition each time the START switch (S1) is pressed. Switch S2 selects either the playback or the record mode. Switch S4—an 8-position (a-h) DIP switch—is included in the circuit to allow the circuit's record/playback time to be varied from 0 to 16 seconds, the maximum time being available when all 8 switch positions are close (or set to the on position). Resistor network R8 (a-h) is included in the circuit to provide a pull-up function for the address lines, thereby controlling U1's record/playback time.

Construction. Building the recorder is reasonably easy since the circuit contains few parts. However, since the ISD1016 has both analog and high-frequency digital signals within the same package, several precautions must be taken to assure good voice quality. First the analog components should be located close to U1, and all components-lead lengths must be kept as short as possible.

Also note that the ISD1016 has separate digital and analog power and ground pins. It is important to keep all four paths separate when wiring the circuit, and to tie the isolated power and grounds together at only at the +V and ground sides of C1/C7 parallel combination, respectively. Lastly, the microphone ground must be tied to analog ground (V_{SSA}) and never to digital ground (V_{SSD}).

The template of the circuit layout, shown half size in Fig. 3, incorporates all of those guidelines and will fit nicely into a Unibox plastic enclosure. Begin construction by referring to the parts-placement diagram shown in Fig. 4. Install the jumpers using 22-gauge bus wire. Next mount all of the resistors and install a 28-pin socket for U1. Then solder transistor Q1 and the SIP resistor network R8 (a-h), carefully observing the proper orientation of each. Install all of the capacitors and check the orientation of the polarized electrolytics.

The voltage regulator (U2) is mounted vertically with the metal tab facing away from U1. No heat sink is required in this application. Install the 8-position DIP switch (S4). The microphone (MIC1), switches (S1-S3), and the speaker (SPKR1) are mounted separately from the circuit board and are

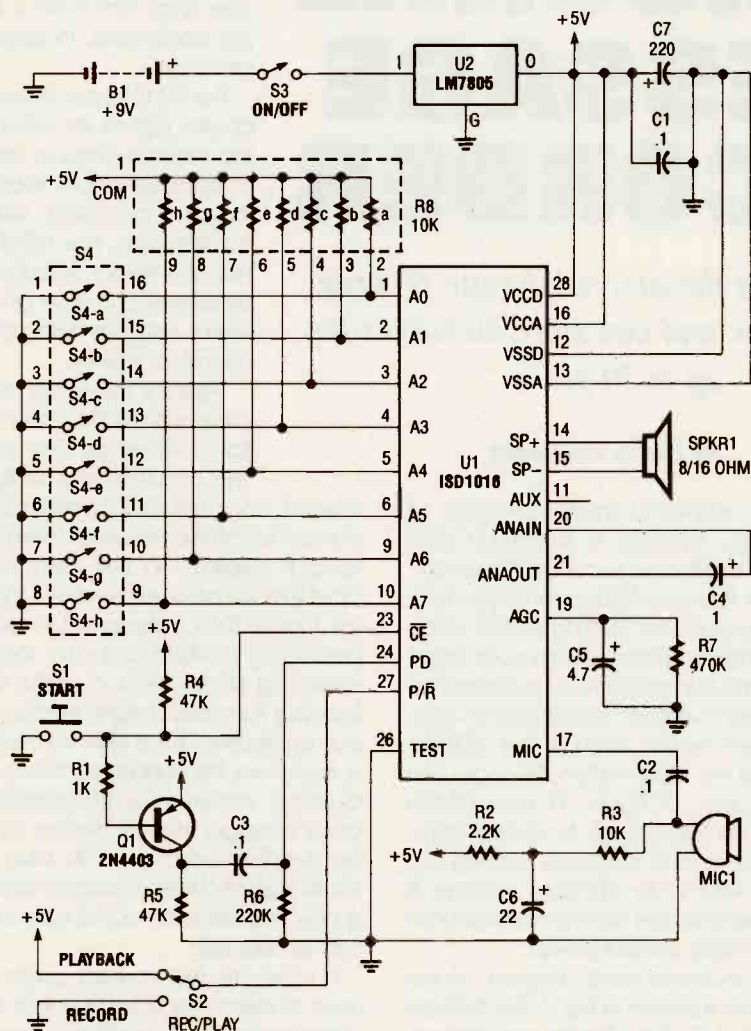


Fig. 2. The Personal Message Recorder is comprised almost entirely of the ISD1016, with a few additional components rounding out the system.

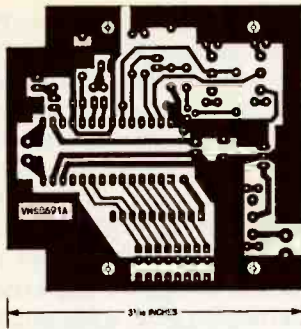


Fig. 3. Here is a half-size template of the author's printed-circuit artwork, which incorporates all of the guidelines/restrictions outlined in the body of the article.

wired according to Fig 4. Use 26–28 gauge hookup wire for the three switches and the speaker. Connect the microphone to the board using shielded wire only. Try to keep all lengths of wire between the board and the off-board-mounted components as short as possible, while allowing enough for the parts to mount to the cover of the enclosure without being pulled too taut. The wires of the 9-volt battery connector must be threaded through the battery com-

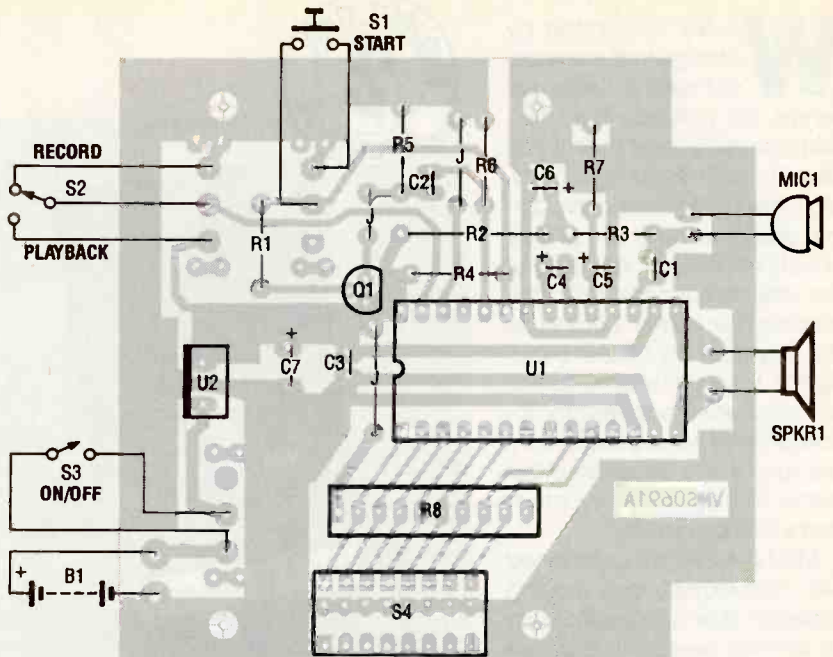


Fig. 4. Assemble the Personal Message Recorder using this parts-placement diagram as a guide. Start with the jumpers, followed by the resistors and a 28-pin socket for U1; then on to transistor Q1, the SIP resistor network R8, and the capacitors.

partment in the plastic case before soldering them to the circuit board. After attaching the battery connector. Mount the board in its case,

and install U1 in its socket, making sure that the IC is properly oriented.

The Unibox case already has mounting provisions for the speaker, but you will need to drill holes for the microphone and switches S1–S3.

PARTS LIST FOR THE PERSONAL MESSAGE RECORDER

SEMICONDUCTORS

- U1—ISD1016 single-chip voice messaging system, integrated circuit (Information Storage Devices, Inc.)
- U2—LM7805 5-volt, 1-amp, voltage regulator, integrated circuit
- Q1—2N4403 general-purpose PNP silicon transistor

RESISTORS

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

- R1—1000-ohm
- R2—2200-ohm
- R3—10,000-ohm
- R4, R5—47,000-ohm
- R6—220,000-ohm
- R7—470,000-ohm
- R8—10,000-ohm × 9 SIP resistor network

CAPACITORS

- C1–C3—0.1- μ F, ceramic-disc
- C4—1- μ F, 16-WVDC, electrolytic
- C5—4.7- μ F, 16-WVDC, electrolytic
- C6—22- μ F, 16-WVDC, electrolytic
- C7—220- μ F, 16-WVDC, electrolytic

SWITCHES

- S1—SPST momentary contact,

- pushbutton switch
- S2—SPDT toggle switch
- S3—SPST toggle switch
- S4—8-position DIP switch

ADDITIONAL PARTS AND MATERIALS

- MIC1—Electret microphone element
- SPKR1—8- or 16-ohm speaker
- B1—9-volt transistor-radio battery
- Printed-circuit materials, Unibox #188 plastic enclosure, 9-volt battery connector, shielded wire (see text), hookup wire, solder, hardware, etc.

Note: The following items are available from LNS Technologies, 20993 Foothill Blvd., Suite 307, Hayward, CA 94541-1511; Tel. 510-886-9296; A complete kit of parts, including all components, a PC board, and plastic case, along with complete assembly instructions (order part #VMS-KIT) for \$69.00; ISD1016 analog storage system (U1) for \$32.00. Add \$3.00 for shipping and handling to all orders. California residents please add appropriate sales tax.

Operation. Install a 9-volt battery and set all of the DIP switches to their on positions. That sets the starting address to zero and gives you up to 16 seconds of recording time. Flip S3 to ON and switch S2 to RECORD. Hold down switch S1, while speaking into the microphone, and when finished release S1.

It is not necessary to shout or to get close to the microphone while recording a message. The AGC circuit adjusts the gain of the preamp to produce sufficient signal strength for the rest of the circuit. Once a message is recorded, it is stored indefinitely, until changed by the user, even when the power is turned off. Subsequent pressing of the START switch (S1) while speaking into the microphone will automatically record over the previous recorded message.

To playback a message, flip S2 to the PLAYBACK position and momentarily press S1 (START). It is not necessary to hold S1 down during playback. In fact, pressing START during playback immediately re-starts the message from the beginning. ■

We are surrounded by energy that we cannot detect using our senses. For instance, the electromagnetic signals that come alive through the magic of radio have been passing through you and your home completely unnoticed. You are not aware of the electromagnetic radiation because the human body lacks the capacity to detect those signals; you can't see, hear, feel, or taste electromagnetic radiation (unless it is in the visible-light portion of the spectrum). The same is true of many other forms of radioactivity.

Most people are concerned with radioactivity and ionizing radiation due to its relationship to atomic weapons and nuclear power plants. When a nuclear power plant has an accident—such as the ones that occurred at Three Mile Island and Chernobyl—the media and a few anti-nuclear groups go into a *feeding frenzy*. That pushes public fears to the point where nuclear power plants are forced to shut down before they have started producing power. That fear helped prevent the opening of LILCO's Shoreham nuclear power station on Long Island, New York.

That fear, while well founded, overlooks the medical, scientific, and economic benefits that nuclear technology has offered humanity. No one is advocating that anyone treat atomic radiation or nuclear materials lightly—you should not—but it is not a technological monster either, considering that life on this planet has evolved in a naturally-occurring, radiation-rich environment. Yes, radiation permeates our very being. For example, radioactive material can be found in food we eat (potassium-40 and carbon-14) and in the soil (uranium-238 and thorium-232).

Radioactivity. What is radioactivity? Radioactivity (a term coined by Pierre and Marie Curie) is defined as the spontaneous emission of energy and/or particles from the atomic nucleus of certain elements. The energy emit-



Geiger Counter

This project can be used to detect and identify radiation sources in and around your home

BY JOHN IOVINE

ted can take the form of electromagnetic energy (called gamma rays), while the particles are typically alpha and beta particles.

Alpha particles are helium-4 nuclei, consisting of two protons and two neutrons. When an atomic nucleus emits an alpha particle, it changes into another nuclide with an atomic number of two units less and a mass number of four units less.

Beta particles, which can be either electrons or positrons (positive electrons), are more penetrating than alpha particles. But they can be stopped by thin sheets of metal (such as aluminum) or a few feet of air.

Gamma rays are typically deep-

penetrating emissions; *i.e.*, they can go through several inches of metal. Gamma rays are photons of energy (quanta) emitted from excited atoms. When an atom (such as Uranium-238) emits an alpha particle, it becomes Thorium-234. The Thorium atom at this point has excess energy. It is said to be in an excited state. But by emitting a gamma ray, it drops to its ground (unexcited) state.

Measuring Radiation. Radiation is measured in curies, a quantity described as the amount of radiation given off by one gram of radium; a quantity that's equal to 37,000,000,000 (3.7×10^{10}) atomic breakdowns per second. Because the curie is a rather large number, many radioactive sources are measured in millicuries or microcuries.

In order to detect radioactivity, you need an instrument specifically designed to detect such energy. There are a number of ways to measure radioactivity; scintillation, PN junctions, autoradiography, and gas-ionization. The Geiger-Muller (GM) tube, which works on the gas-ionization principal, can detect alpha, beta, and gamma radiation. If you are concerned about possible exposure to radiation, then perhaps the *Geiger Counter* described in this article can help to put your mind at rest.

Our Geiger Counter, which is based on the gas-ionization method of detection, will give visual and audible indications of local radioactivity. It can be used to detect nuclear radiation or contamination in and around your home, to prospect for uranium, and measure background radiation. In fact, it can even be used to detect large solar flares.

Figure 1A shows the basic operating principal of the GM tube. The tube consists of a cylindrical electrode (cathode) surrounding a center electrode (anode). The tube is evacuated and filled with a neon- and halogen-gas mixture. A voltage of 500 volts is applied across the tube through a 10-

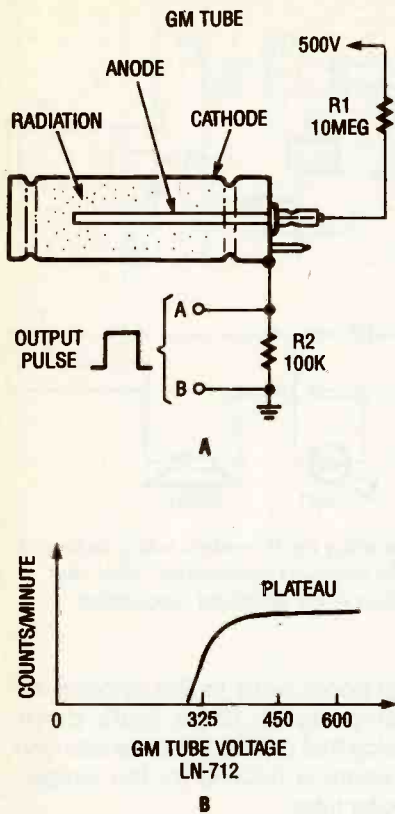


Fig. 1. The Geiger-Muller tube consists of a cylindrical electrode (cathode) surrounding a center electrode (anode). The tube is evacuated and filled with a neon- and halogen-gas mixture.

megohm, current-limiting resistor, R1. The tube has an extremely high resistance when it's not detecting radioactivity. When an atom of the gas is ionized by the passage of radiation, the free electron and positively ionized atom created move rapidly towards the anode and cathode of the GM tube, respectively. In doing so, they collide with and ionize other gas atoms, thereby creating a small avalanche effect.

The ionization causes the resistance of the tube to drop, passing a sudden surge of current that creates a voltage pulse across R2. The halogen gas quickly quenches the ionization, returning the GM tube to its high initial resistance and enabling it to detect another particle.

The number of pulses-per-minute that the GM tube generates rises with the voltage across its electrodes. (Fig. 1B). By increasing the voltage, a plateau is reached where the pulse rate stays pretty constant. The plateau range for the GM tube used in our Geiger Counter is between 400 and

600 volts with a recommended operating voltage of 500 volts. If too much voltage is applied to the tube, when the tube detects a radioactive particle the avalanche created will not be quenched, putting the tube in a state of continuous discharge that can damage it.

A Look at the Circuit. Figure 2 is a schematic diagram of the Geiger Counter. The circuit is built around a 4049 hex inverter (U1), a pair of 555 oscillator/timers (U2 and U3), two transistors, a Geiger-Muller tube, and a few additional support components. The first 555 (U2) is configured for astable operation. The output of U2 (a series of negative-going pulses) at pin 3 is fed to three parallel-connected inverters (U1-a, U1-b, and U1-c). The positive-going output pulses of the inverters are fed to the gate of Q1, causing it to toggle on and off in cadence with the applied signal.

The output of Q1, which is connected in series with the primary of step-up transformer T1, produces a stepped-up series of pulses in T1's secondary. The output of T1 (approximately 300 volts) is fed through a voltage doubler (consisting of D1, D2, C3, and C4), producing a voltage of around 600 volts. Three series-connected Zener diodes (D3, D4, and D5) are placed across the output of the voltage doubler to regulate the output to 500 volts. That voltage is fed through R4 (a 10-megohm current-limiting resistor) and J2 to the anode of the GM tube. The limiting resistor also allows the detection ionization to be quenched.

The cathode side of the tube is connected to ground through a 100k resistor, R5. When a particle is detected by the GM tube, the gases within the tube ionize, producing a pulse across R5. That pulse is also fed through C5 and applied to the base of Q2 (a

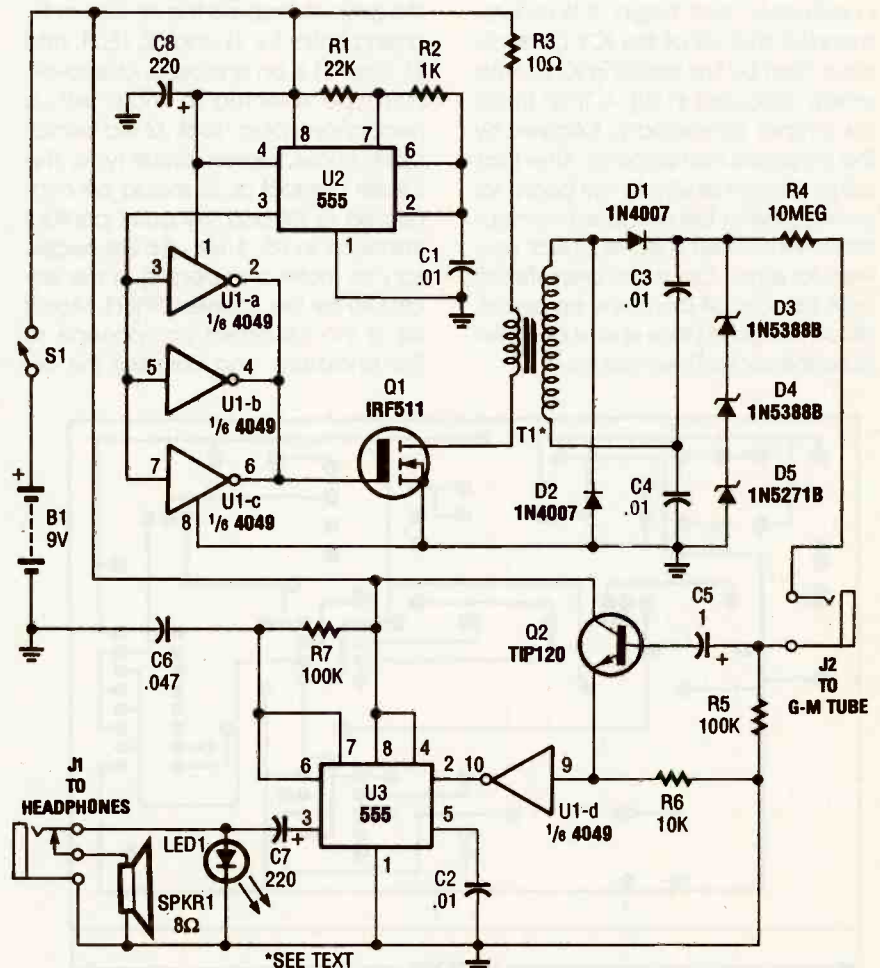


Fig. 2. The Geiger Counter is built around a 4049 hex inverter (U1), a pair of 555 oscillator/timers (U2 and U3), two transistors, a Geiger-Muller tube, and a few additional support components.

TIP120 NPN transistor), where it is amplified and clamped to 9 volts. The output of Q2 is inverted by gate U1-d, and then used to trigger U3 (the second 555, which is configured for monostable operation). The output of U3 at pin 3 causes LED1 to flash, and produces a click that can be heard through speaker SPKR1 or headphones.

The circuit is powered by a 9-volt alkaline battery and draws about 28 mA when not detecting radiation.

Construction. There is nothing critical about the circuit. In fact, if you are more comfortable with point-to-point wiring, there is no compelling argument against you going that route. The author's prototype of the Geiger Counter, however, was assembled on a printed-circuit board. A full-size template of the foil pattern is shown clearly in Fig. 3.

Once you've etched your printed-circuit board and gathered the parts, construction can begin. It is recommended that all of the IC's be socketed. Start by first installing IC sockets where indicated in Fig. 4. Then install the jumper connections, followed by the on-board components. After that, solder lengths of wire to the board for connection to the off-board components. When that is done, check your work for errors. Once you are satisfied that the circuit contains no errors, place the board to one side and prepare the project's enclosure.

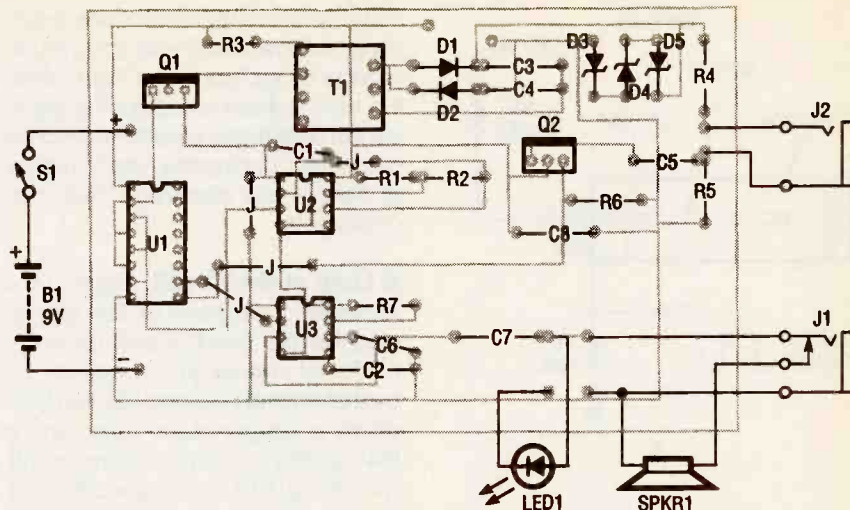


Fig. 4. Begin assembling the project by first installing the IC sockets where indicated, followed by the jumper connections, and then the on-board components. After that, connect lengths of wire to the board for connection to the off-board components.

Any plastic enclosure large enough to hold the circuit board and other components can be used to house the project. Prepare the enclosure by drilling holes for J1 and J2, LED1, and S1. Jack J1 is an enclosed, closed-circuit type selected to mate with a headphone plug. Jack J2 is a 1/8-inch open-frame, closed-circuit type. The center contact of J2 should be connected to R4 and the outer contact connects to R5. It will also be necessary to make an opening in the enclosure for the speaker, SPKR1. Mount all of the off-board components to the enclosure, and connect the cir-

cuit-board wires to the appropriate components. Once that's done, place that assembly to one side and prepare a housing for the Geiger-Muller tube.

Although the circuit is designed around the LN-712 Geiger-Muller tube, it is possible to use other Geiger tubes by altering the power-supply output accordingly. The power supply used in our circuit can be used to power any tube requiring up to 700 volts by eliminating or substituting a Zener diode of the proper rating. For instance, if you have a tube that requires a 300-volt source, simply remove one of the 200-volt Zener diodes and replace it with a jumper wire. Or if the tube requires a 600-volt source, remove the 100-volt Zener diode and replace it with another 200-volt unit. In addition, using another tube may require that the value of the current-limiting resistor (R4 in the schematic diagram) be scaled accordingly.

The GM tube is delicate and should be handled carefully. The GM tube has a thin mica window on the front end that allows alpha and beta particles to penetrate and be detected. That window is easy to break, rendering the tube useless. The author housed the GM tube in a plastic coin tube. The coin tube was prepared by drilling several tiny holes in the lid. Those holes allow alpha and beta particles to get to the mica window unimpeded.

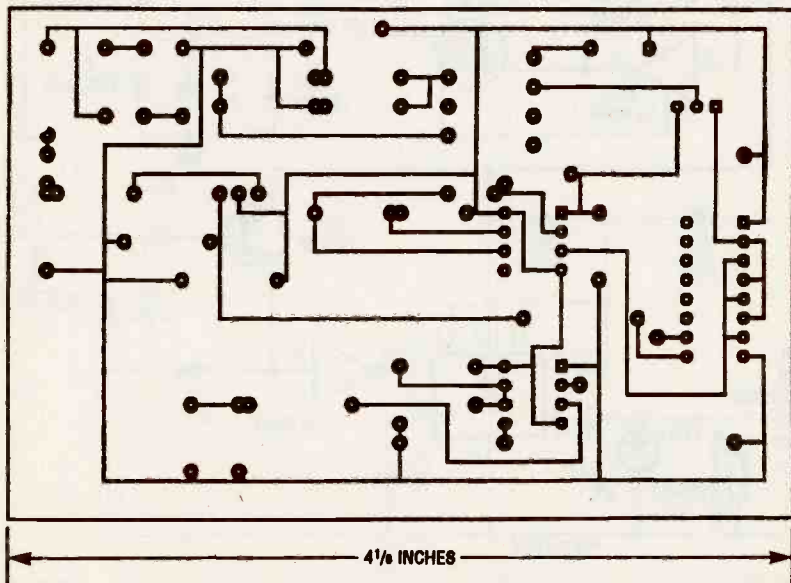


Fig. 3. The author's prototype was assembled on a printed-circuit board. A full-size template of the foil pattern is shown here.

In the bottom of the coin tube, the author drilled a hole just large enough to pass the end of a 3-foot length of two-conductor shielded cable through. The conductors within the cable are color coded, greatly simplifying the proper wiring of the GM tube. One end of the shielded cable was then connected to the GM tube and the other end to a 1/8-inch plug that connects the GM tube to the circuit board through J2.

Connect one conductor of the cable to the anode (center lead) of the GM tube, and connect the other end of the same conductor to the center contact of the plug. Connect the other conductor to the cathode (outer lead) of the Geiger-Muller tube, and the other end of that conductor to the outer contact of the plug, so that the cathode is tied to ground (through R5) when the GM tube is plugged in.

The GM tube was cushioned on the sides and bottom using soft non-conductive foam rubber. **Note:** If conductive foam is used, do not allow the

foam to touch the electrodes of the GM tube. That will put a short across the GM tube, rendering the unit inoperative. A small amount of velcro was then used to secure the GM housing to the case.

Checkout and Troubleshooting.

Before plugging in the GM tube, it's a good idea to see if the circuit is functioning properly. Turn on the circuit and measure the voltage from the D3/C3 junction to ground; it should be approximately 500 volts DC.

If the voltage is too low, or you get none at all, check the primary side of T1; There should be a pulsating DC signal across the primary of the transformer. Also check the orientation of the Zener diodes. Continue backtracking in that manner, checking the base of Q1. You should be getting a 5-kHz squarewave signal. Check pin 3 of U2 using a scope.

Once the circuit is working, power it down and plug in the GM tube. Then turn it on again, and note whether it begins to click. The author gets a

reading of approximately 11 pulses per minute from background radiation. As each particle is detected, the speaker will click and the LED will flash. If you have acquired some radioactive material (we'll present some sources shortly) bring the GM tube close to it to test for activity.

Radioactive Sources. An easy source of a radioactive material—approximately one microcurie of Americium 241—can be found in a ionization-type smoke detector. Americium is a strong alpha-particle source. To use the Americium as a source, it must be removed from the smoke detector. The alpha particles only travel an inch or so through the air so you'll have to get pretty close with the GM tube to detect anything.

To get to the radioactive source, first remove the plastic top of the smoke detector. The Americium is inside a small ventilated metal can. Remove the can with pliers. The Americium is embedded in a metal plate underneath the can. Remove the entire plate with the Americium from the detector. Leave the radioactive material attached to the plate, and use the material on the plate. Bringing the GM tube within 1/2-inch of the source, the reaction of the Geiger Counter will become furious.

A more reliable source of radioactive materials is the Nucleous Company (601 Oak Ridge Turnpike, Oak Ridge, TN 37830; Tel. 615-483-8405 or 800-255-1978). The company sells calibrated and uncalibrated radioactive materials for students, schools, and industry. (I purchased a Cesium-137 gamma-ray source for \$25.00. The material is rated at 5 microcuries with a 30-year half life. It was enlightening when I placed a 3/4-inch solid block of aluminum in front of the Cesium-137, and found there was no noticeable decrease in radiation.) ■

PARTS LIST FOR THE GEIGER COUNTER

SEMICONDUCTORS

U1—4049 hex inverting-buffer, integrated circuit
 U2, U3—555 oscillator/timer, integrated circuit
 Q1—IRF511 N-channel enhancement MOSFET
 Q2—TIP120 silicon NPN transistor
 D1, D2—IN4007 general-purpose silicon rectifier diode
 D3, D4—IN5388B 200-volt Zener diode
 D5—IN5271B 100-volt Zener diode
 LED1—Light-emitting diode (red)

RESISTORS

(All resistors are 1/4-watt, 5% units.)
 R1—22,000-ohm
 R2—1000-ohm
 R3—10-ohm
 R4—10-megohm
 R5, R7—100,000-ohm
 R6—10,000-ohm

CAPACITORS

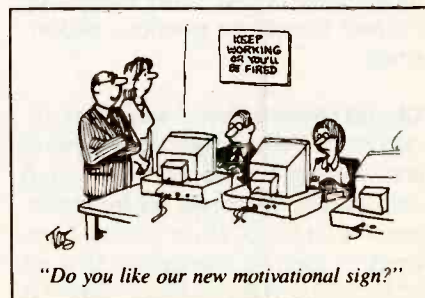
C1, C2—.01-μF, polyester
 C3, C4—.01-μF, 2000-WVDC, ceramic-disc
 C5—1-μF, 16-WVDC, electrolytic
 C6—.047-μF, polyester
 C7, C8—220-μF, electrolytic

ADDITIONAL PARTS AND MATERIALS

SPKR1—8-ohm speaker
 T1—6-volt to 330-volt, step-up transformer
 B1—9-volt alkaline battery
 S1—SPST toggle switch
 J1, J2—see text
 Printed-circuit materials, LN-712 Geiger-Muller tube (see text), enclosure, battery clip, etc.

Note: The following items for the Geiger Counter are available from the following vendors: The step-up transformer (T1), part # C-2B, is available from Allegro Electronics (3 Mine Mountain Road, Cornwall Bridge, CT 06754; Tel. 203-672-0123) for \$3.99, plus \$2.00 shipping and handling. Connecticut residents, please add appropriate sales tax.

The LN-712 Geiger-Muller tube is available from Images Company (P.O. Box 140742, Staten Island, NY 10314-0024; Tel. 718-698-8305) for \$48.00, plus \$3.00 shipping and handling. New York State residents, please add applicable sales tax.



An Enlarging Light-Meter for Photographic Printing

BY RUDOLF F. GRAF AND
WILLIAM SHEETS

Get perfect photographic prints every time with this easy-to-assemble darkroom accessory.



Using an enlarger light meter in the darkroom makes producing prints (both monochrome and color) easier. It also saves time, trouble, and money in otherwise wasted materials. While there are a number of such meters on the market, electronics enthusiasts who also dabble in photography can build a simple meter to do the job at very little cost. In this article we'll describe how you can build the *Enlarger Light Meter*, at a cost of \$25 or less depending on how well stocked your spare-parts bin is.

The light meter (which is essentially a comparator circuit designed specifically for photographic work) is not calibrated against any special standard. That makes it easy to build, set up, and use. All it does is compare the incident light striking a light-dependent resistor (LDR) with a level that has formerly been established—via a potentiometer and a rotary switch—so correct based on previous experience.

Circuit Description. A schematic diagram for the Enlarger Light Meter is shown in Fig. 1. Meter M1, a $\pm 50\mu\text{A}$ zero center D'Arsonval meter movement is driven by U1, a TL081 FET op-amp, through R3. The gain of U1 is set at 11 by R1 and R2, while capacitor C1

is used to restrict the bandwidth of U1 to 1.6 Hz. Power for the circuit is derived from a simple dual-polarity 12-volt power supply (consisting of T1, D3, D4, C2, and C3).

A light-dependent resistor (LDR), R16 (which is a semiconductor element whose resistance decreases as it is exposed to increasing illumination), is used as a light-sensing device. One end of R16 is connected to the negative supply rail through R12, while the other end is connected to pin 3 of U1, applying a negative current to U1. A variable (over a 4:1 range) positive current determined by the settings of R14 and S1 (and derived from the positive supply rail) is also fed to pin 3 of U1.

When the two currents (of opposite polarities) are equal, they cancel each other out, so effectively no current is applied to pin 3 of U1. With no current applied to pin 3, the output of U1 is zero, and meter M1 registers accordingly, indicating a null. However, when light striking R16 causes its resistance to decrease, the current through the device increases, making the negative current greater than the positive current. Under that condition, the negative current causes the output of U1 to swing negative, causing the meter's pointer to swing in the negative direction.

That indicates that the light intensity must be reduced by using a smaller lens opening on the enlarger (smaller f/stop). The opposite occurs if the light is too dim. Lamp I1, a 12-volt 60-mA "grain of wheat" unit, is used to illuminate the meter scale, while R15 is used to limit I1's illumination to a faint glow that is just bright enough so that the face of M1 can be plainly seen in a photo darkroom.

Resistors R3 and R4 should be selected for the meter used. With a dual supply of ± 12 volts, U1 produces an output voltage of 10 volts peak-to-peak. The resistance of R3 can be found by dividing the peak voltage (i.e., 10/2) by the full-scale meter current (in amps); i.e., $R3 = (10/2)/0.00005 = 100,000$ ohms. Resistor R4, the shunt resistor, should be selected to have a value equal to the meter's internal resistance—in our case, 220 ohms.

Building the Circuit. There is nothing critical about the construction of the Enlarger Light Meter. Most of the circuit was assembled on a couple of terminal strips, using point-to-point wiring techniques. Wire the circuit together using Fig. 1 as a guide. Note that R16 (the LDR), S1, R14, and M1 are not mounted with the other circuit elements. The LDR (which we'll get to a bit later) will be mounted

in its own enclosure and connected to the other circuit components through a length of twisted-pair wire. Meter M1, switch S1, and resistor R14 are all mounted at some convenient point on the circuit's enclosure. Note that the schematic diagram shows S1 as a seven-position switch; if a seven-position unit can not be located, a 12-position unit (with five positions left blank) will work just as well. Resistors R5 through R11 can be connected directly to S1's terminals and their free ends tied together, and then brought out to the appropriate point in the circuit.

Be careful when connecting the polarized components. Connecting them backwards could render the circuit inoperative at best, or in the worst-case scenario, destroy one or two components. Lamp I1 should be positioned somewhere behind the meter scale, and if possible, painted orange or red to reduce blue-light components emitted by the device; photo paper is sensitive to those light wavelengths. Transformer T1 is not critical; the only requirement is that the transformer be a 12-volt unit that is able to supply sufficient current to operate the circuit. The enclosure used to house this part of the circuit can be of any type that you choose.

As for the light-dependent resistor, R16, it should be mounted in separate housing; a plastic bottle cap with a hole drilled in its center is suitable. See Fig. 2. Begin by drilling a hole in the center of the bottle cap (or similar housing). Mount the LDR so that its lens is centered over the opening. Epoxy the LDR in place, clip off the excess leads so that they do not extend beyond the enclosure, and connect a two-foot length of twisted-pair wire to the LDR's leads. Attach a cover to the rear of the sensor enclosure and complete the project by connecting the twisted-pair wires from the sensor to the appropriate points in the circuit as shown in the schematic.

Checkout. Once the circuit is fully assembled, check for the usual construction errors; shorts, cold-solder joints, wiring mistakes, etc. If all looks okay, apply power to the circuit. Then check for +12 volts at the junction of C2 and D3 (a voltage between +10–+15 volts is okay) and for –12 volts (–10 to –15 volts) at the junction

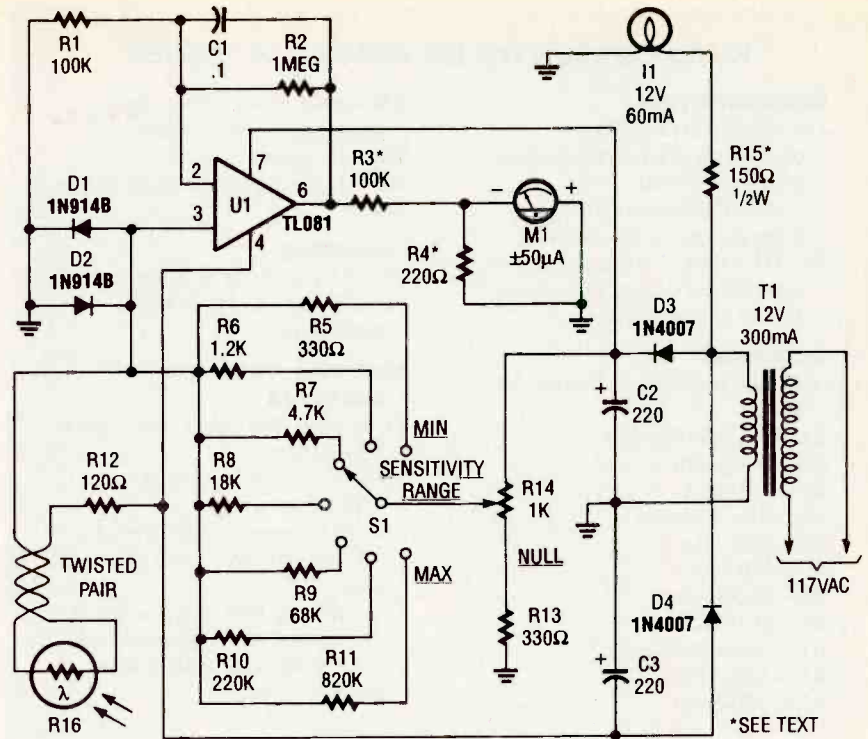


Fig. 1. As revealed by this schematic diagram, the Enlarger Light Meter is nothing more than a comparator, built around a TL081 op-amp.

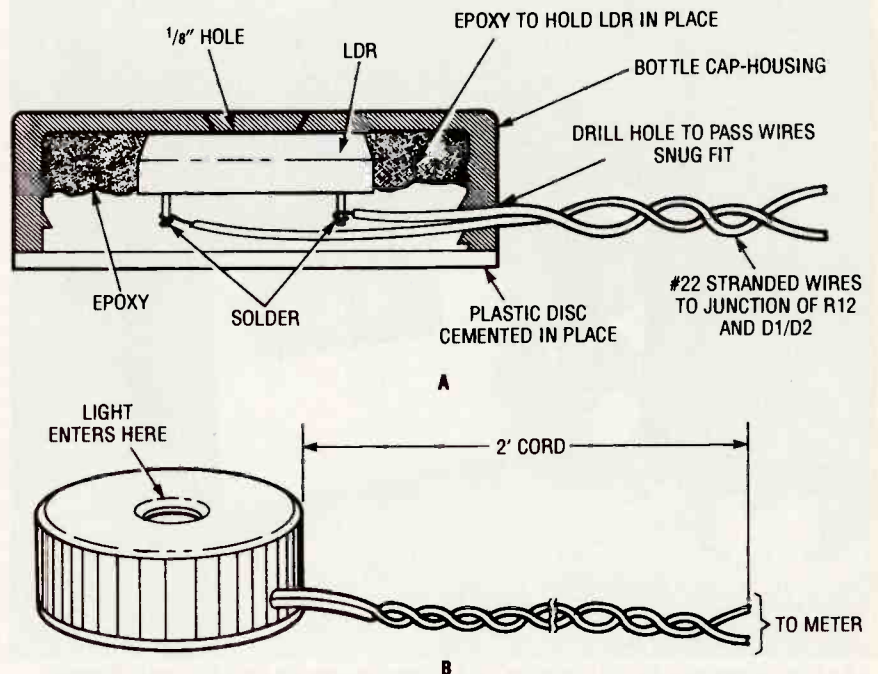


Fig. 2. The sensor (light-dependent resistor or LDR), R16, is housed in its own enclosure, and connected to the rest of the circuit via a two-foot length of twisted-pair wire. Shown here are the details for that assembly's preparation.

of C3 and D4. Next, with R16 shielded from light, set S1 to its maximum-sensitivity position. It should be possible to null, or a least move, the pointer of M1 by varying R14. Next, expose R16 to a dim light (a 7-watt night light about 3-feet away). Adjust S1 and vary R14. You

should find a setting of S1 and R14 where the meter nulls. If not, check your wiring.

Grounding pin 3 of U1 should null M1. That verifies that U1, the power supply, and M1 are operating properly. If that test works, but you cannot

PARTS LIST FOR THE ENLARGER LIGHT METER

SEMICONDUCTORS

U1—TL081, NTE857M (or equivalent) JFET-input op-amp, integrated circuit
D1, D2—1N914B or equivalent, general-purpose silicon diode
D3, D4—1N4007, or equivalent 1-amp, 1000-PIV general-purpose silicon rectifier diode

RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)
R1, R3—100,000-ohm
R2—1-megohm
R4—220-ohm
R5, R13—330-ohm
R6—1200-ohm
R7—4700-ohm
R8—18,000-ohm
R9—68,000-ohm
R10—220,000-ohm
R11—820,000-ohm
R12—120-ohm

R14—1000-ohm panel-mounted linear-taper potentiometer
R15—150-ohm, 1/2-watt
R16—Light-dependent resistor (see text)

CAPACITORS

C1—0.1- μ F, Mylar or ceramic-disc
C2, C3—220- μ F, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

T1—12-volt 300-mA or more, power transformer
M1— \pm 50- μ A zero center D'Arsonval meter
S1—SP7T rotary switch (see text)
I1—12-volt 60-mA "grain of wheat" lamp
Terminal strip (see text), enclosure, AC molded power plug with line cord, bottle cap, wire, solder, hardware, etc.

the enlarger settings (distance between lens and paper, *f*/stop, and exposure time). Next, place the negative used for the print in the enlarger, and duplicate the recorded settings. Place R16 on a part of the image that corresponds to a medium gray tone.

Use meter-range switch S1 to coarse null the meter (pointer at zero center). Then, use R14 to exactly null the meter. Note the meter settings and leave it that way. That calibrates the meter for your paper and print developing technique.

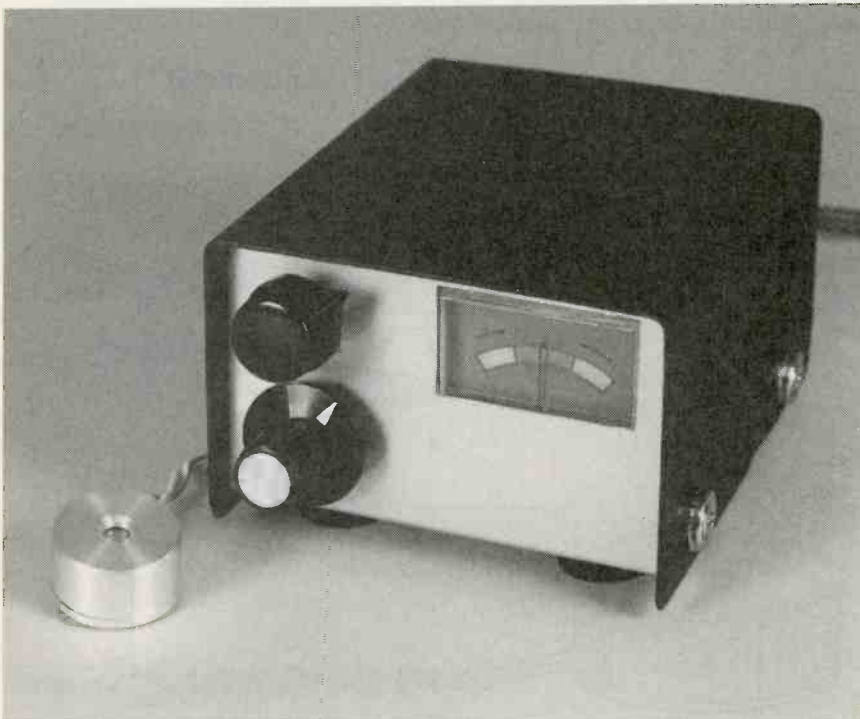
When you to make another print, simply insert the negative in the enlarger. Compose and sharply focus the picture, using the enlarger lens at maximum aperture, usually *f*/3.5 or larger. Place the light sensor in a part of the image that is to be a medium gray in the final print, preferably an area somewhere in the central portion of the picture. Try to avoid the corners or extreme edges if you can.

Now, without adjusting the light meter settings from those obtained from the first negative, adjust the enlarger lens aperture for a null on the meter. That will be the correct exposure setting. Use the same exposure time and developing method as you used for the first negative. Insert a sheet of photographic paper into the enlarger easel, and make the exposure. Develop the print. It should be correctly exposed.

You may also use a lighter gray tone or even total black as a reference point. The trick is to be consistent. A medium gray reference point was suggested because it seems to be the easiest to judge. Others prefer the darkest area (lightest gray or white on final print), which works equally well. It is simply a matter of preference.

While the meter is primarily intended for B/W printing, it may be also used for color, although it will give only the correct exposure; color balance is not measured. However, if you have predetermined the filter pack, the meter will work well for color. Use an area of the negative that is neutral or near neutral in color. In our experience, flesh tones work well. For landscapes, you can get good results if you use the sky areas as a reference.

That's all there is to it. Once this project is complete and operating, you should be able to obtain near perfect prints every time. ■



All of the electronics for the Enlarger Light Meter, except for the LDR, were housed in a small enclosure on whose front panel switch S1, potentiometer R14, and meter M1 are mounted. The LDR was housed in a separate enclosure about the size of a bottle cap, and connected to the circuit by wire leads.

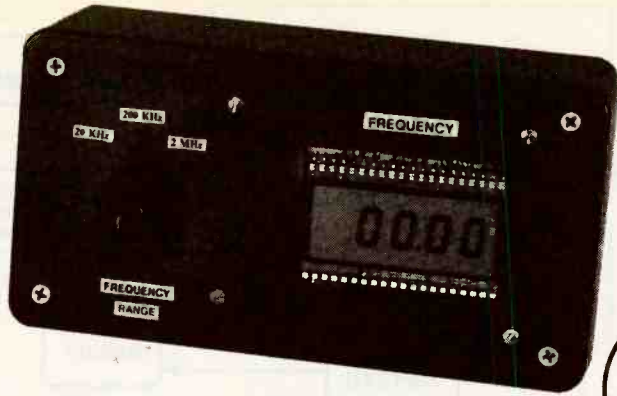
get the meter to null, check R16, its wiring, and the wiring of R14, R13, S1, and R5 through R12.

Use. Do not expose R16 to very bright light before attempting to use the light meter. Bright light reduces the re-

distance of R16, and it will take several minutes for it to recover, thereby throwing off your readings for the first few minutes.

Begin by first making a good print (monochrome or color) using your conventional technique, and record

Here is a chance for you to add an accurate, but inexpensive, digital frequency counter to your electronics arsenal



Portable 2-MHz Frequency Counter

BY ANTHONY J. CARISTI

Frequency counters have been available to electronics engineers and technicians for many years. But for the electronics hobbyist, particularly the newcomer, the cost of such frequency-measuring instruments—usually upwards of \$100 for a basic unit—can be prohibitive. Fortunately, even those on a meager budget can afford the *Portable Frequency Counter*. The counter is an easy-to-build, basic (no-frills) unit that can measure frequencies up to 2 MHz with a resolution of 1 Hz. That makes it a handy instrument for audio, ultrasonic, and low radio-frequency applications.

About the Circuit. Figure 1 shows a functional block diagram of the frequency counter. The counter is made up of several subassemblies: a crystal oscillator, a pair of divide-by-10 counters, a 16-stage binary counter, a trigger circuit, a latching circuit (RS flip-flop), an analog amplifier, a counter/display-driver circuit, and, of course, an LCD readout.

The crystal oscillator, which provides a timing reference, generates a high-frequency signal that is twice divided by ten to provide three selectable frequencies. The selected frequency is fed to the 16-stage binary counter (which further divides the selected frequency by 2^{16}). The output

of that binary counter is fed to the latching circuit as a stop (or reset) signal.

A low-frequency trigger oscillator periodically generates a start (or set) signal, which is also fed to the latch. The latch, in turn, outputs a pulse of known width (called a gate), which is fed to the counter/display driver and is used to initiate the measurement.

The input to the circuit (a signal of unknown frequency) is fed to an analog amplifier, which boosts the signal sufficiently to operate the input to the counter/display driver. The counter/display driver counts the number of pulses applied to its input during the time that the gate is active. The total number of pulses is then decoded and used to light the appropriate segments of a large $3\frac{1}{2}$ -digit LCD readout.

A Closer Look. Figure 2 is a complete schematic diagram of the frequency counter. The crystal oscillator, comprised of NOR gate U3-c and its associated components, is biased linearly by resistor R5, while crystal XTAL1 (connected from U3-c's input to its output), causes U3-c to oscillate at the crystal's series-resonant frequency. The output of U3-c is buffered by U3-a and divided along two paths. In one path, the signal is delivered to one terminal of S2-b (half of a double-

pole, three-throw switch); in the other path, the signal is fed to U6-a ($\frac{1}{2}$ of a CD4518 dual synchronous up counter), which is configured for divide-by-10 operation.

The output U6-a is also divided along two paths, with one path going to a second terminal of S2-b, and the other going to U6-b (also configured for divide-by-10 operation). Together, the two halves of the synchronous counter provide a total frequency division of 100. The output of U6-b is fed to a third terminal of S2-b, providing three selectable frequency ranges. Those selectable frequencies determine the gate time of the counter (10, 100, or 1000 milliseconds). The selected frequency is fed to U4, the first of two CD4040B ripple-carry binary counters. The output of U4 is fed to U5 (the second CD4040B ripple-carry binary counter). Together U4 and U5 provide a frequency division of 2^{16} , or 65,536.

The output of U5 is fed to pin 6 of U3-b, which with U3-a forms a bistable multivibrator (RS flip-flop), that is used to control the start/stop sequence of the counter. The RS flip-flop is reset by the output of U5 and set by the output of U1, a CMOS 555 oscillator/timer that is configured for low-frequency, astable operation. The set and reset inputs of the flip-flop are labeled "start" and "stop," respectively.

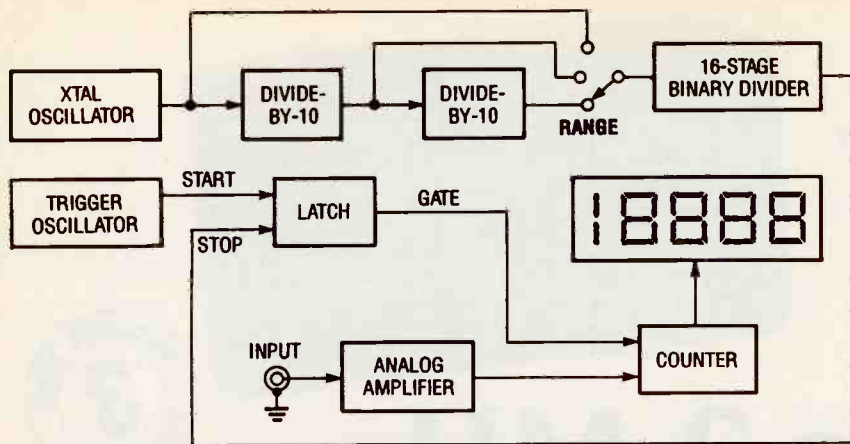


Fig. 1. The frequency counter is made up of several subassemblies: a crystal oscillator, a pair of divide-by-10 counters, a 16-stage binary counter, a trigger circuit, a latching circuit (RS flip-flop), an analog amplifier, a counter/display driver circuit, and, of course, an LCD readout.

The negative-going output of U1, which is used to initiate the count sequence to periodically update the frequency display, is inverted by U2-d before application to U3-a. (The inversion is accomplished by tying one input to U2-d high, and applying a low to the other pin. That forces the output of U2-d to go high, each time a U1 outputs a low.) The resulting positive-going pulse drives the output of U3-a at pin 3 low. That low, which is applied to pin 11 of both U4 and U5, causes U4 and U5 to begin the count sequence. The output of U3-a remains in a low state until the flip-flop is reset at the end of the count (65,535).

At the end of the count, pin 5 of U5 goes high. That high is applied to pin 6 of U3-b, forcing its output high, which divides along two paths. In one path, the signal is fed to pin 2 of U3-a, forcing its output high. That inhibits U4 and U5, resetting them to zero to await the next trigger pulse. In the other path, the signal (a positive-going pulse of precise width—10, 100, or 1000 milliseconds, depending on the selected clock frequency) is fed to pin 31 of U8 as a gate-control signal.

Switch S2-a (the second half of the DP3P switch) is used to set the decimal point for the higher frequency ranges (200 kHz and 2 MHz). Decimal-point activation is accomplished through two XOR gates (half of a CD4030B quad 2-input XOR gate, U2-a and U2-b), which are used as conditional inverters. (An XOR gate produces a logic 1 output only when the logic levels at its two inputs are different from each other.) Depending upon the setting of S2-a, the selected unit inverts the

no decimal point since the 4½-digit readout will display frequency directly in hertz. When the counter is set to the 20 kHz range, S2-a activates field-effect transistor (FET) Q1. Activating Q1 places C3 in parallel with C4, thereby lowering the operating frequency of U1 to about 0.5 Hz to accommodate the 1-second gate time that is required for the 20-kHz range.

The input frequency is fed through J1 to an analog amplifier, built around Q2 and Q3. Transistor Q2 (a FET that provides a high input impedance to the signal source) is used to drive Q3 (which is configured as a common-source amplifier). The total gain provided by Q2 and Q3 is sufficient to

PARTS LIST FOR THE PORTABLE FREQUENCY COUNTER

SEMICONDUCTORS

- U1—LMC555CN CMOS oscillator/timer, integrated circuit
- U2—CD4030B quad 2-input XOR gate, integrated circuit
- U3—CD4001B quad 2-input NOR gate, integrated circuit
- U4, U5—CD4040B 12-stage ripple-carry binary counter, integrated circuit
- U6—CD4518B dual decade counter/divider, integrated circuit
- U7—AN78L05 5-volt, 100-mA, voltage regulator, integrated circuit
- U8—ICM7224IPL counter/display-driver, integrated circuit
- Q1—BS170 N-channel enhancement MOSFET
- Q2—MPF102 (or SK9164) N-channel JFET
- Q3—2N3906 general-purpose PNP silicon transistor
- DISP1—4½-digit LCD readout (Digi-Key LCD-004 or equivalent)

RESISTORS

- (All fixed resistors are ¼-watt, 5% units.)
- R1, R2—220,000-ohm
 - R3—100,000-ohm
 - R4—470,000-ohm
 - R5—10-megohm
 - R6, R8—1-megohm
 - R7—10,000-ohm
 - R9, R10—1000-ohm

- R11—470-ohm
- R12—4700-ohm
- R13—47,000-ohm

CAPACITORS

- C1, C2, C5, C7—0.1-μF, ceramic-disc
- C3—2.2-μF, 10-WVDC, electrolytic
- C4—1-μF, 10-WVDC, electrolytic
- C6—270-pF, ceramic-disc
- C8—330-μF, 6-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

- B1—9-volt transistor radio battery
- XTAL1—3.2768-MHz crystal
- S1—SPST toggle or slide switch
- S2—DP3T rotary switch
- J1—Phono or BNC jack
- Printed-circuit materials, enclosure (Radio Shack 270-223 or similar), 9-volt battery connector, #24-gauge insulated stranded hook-up wire, solder, hardware, etc.

Note: The following parts are available from A. Caristi, 69 White Pond Road, Waldwick, NJ 07463. Digital and counter boards, \$11.95 each; U1, U2, U3, and U7, \$2.00 each; U4, U5, U6, \$2.75 each; U8, \$21.50. Please add \$3.00 postage/handling. New Jersey residents please add appropriate sales tax.

backplane signal, which is then fed to its connected decimal point when required.

The lowest range, 20 kHz, requires

drive U8 (an ICM7224IPL high-performance 4½-digit counter) with input signals as low as .25-volt rms.

Integrated circuit U8 contains a

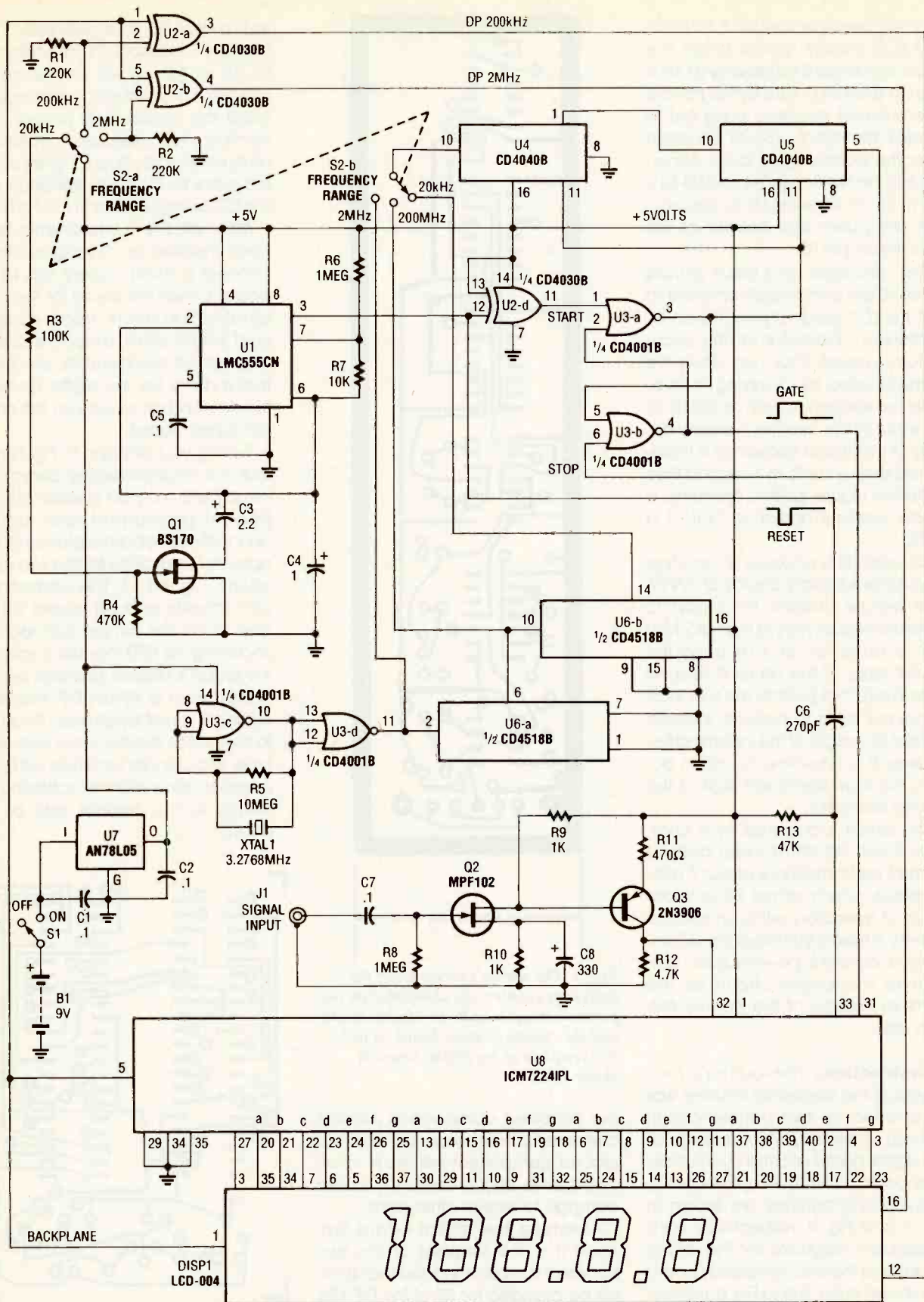


Fig. 2. The circuit contains a crystal oscillator that's built around U3-c and XTAL1, which provides the primary timing-reference signal. That signal is then divided twice to provide two additional timing references, giving the circuit three selectable timing references.

counter, decoders, output latches, and LCD display drivers. When the count sequence is initiated by U1, U8 is reset to a count of zero by the narrow, differentiated, negative pulse fed to its reset terminal, pin 33. At the same time, the positive gate pulse generated by the flip-flop (U3-a and U3-b) is fed to pin 31, allowing U8 to accumulate any pulses that appear at the clock input, pin 32.

The decoders and latch circuits within U8 are continuously enabled so that the LCD readout provides an instantaneous indication of the accumulated count. That can easily be demonstrated by applying a relatively low frequency, such as 100 Hz, to the input of the counter. A steady display of measured frequency is maintained during the 1/2 to 1-second time between trigger pulses, providing a digital readout similar to that of a DVM.

Counter U8 is capable of counting beyond its full-scale display of 19999. That feature enables the circuit to measure frequencies as high as 2 MHz with a resolution of 1 Hz using the lowest scale of the circuit (1 second gate time). That permits the four least significant digits to properly indicate the last four digits of the incoming frequency. If an overflow condition occurs, the most-significant digit of the display remains 1.

The circuit is powered by a common 9-volt transistor-radio battery. Current consumption is about 7 milliamperes, which allows 20 or more hours of operation using an alkaline battery. A fixed 5-volt regulator, U7, ensures a constant power-supply voltage to the entire circuit as the terminal voltage of the battery falls with use.

Construction. The author's prototype of the frequency counter was assembled on two printed-circuit boards, which the author refers to as the digital board and the counter/display board. Full-size templates of the circuit-board patterns are shown in Fig. 3 and Fig. 4, respectively. Parts placement diagrams for the digital board and the counter/display board are shown in Fig. 5 and Fig. 6, respectively.

When assembling the boards, be sure that all parts are correctly placed, paying special attention to

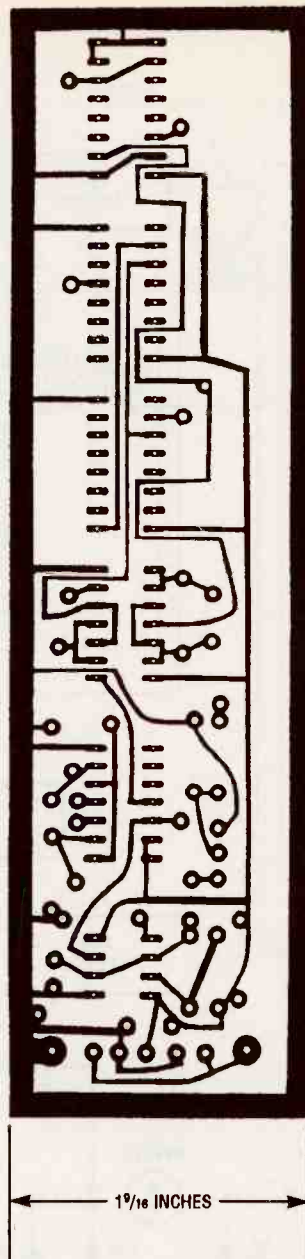


Fig. 3. The author's prototype of the frequency counter was assembled on two printed-circuit boards; the digital board and the counter/display board. A full-size template of the digital board is shown here.

the polarized components. Double check to be sure, since just one misplaced component will result in an inoperative circuit and may cause damage to itself or other parts.

Assemble the digital board first, since it is the simplest of the two boards. It is recommended that sockets be provided for all of the DIP IC's. Sockets are worth the small extra expense should the circuit ever need servicing. Start by installing the appropriate size IC sockets at the locations

indicated in Fig. 5. Do not install any of the IC's in their sockets until instructed to do so (which will be during the checkout procedure). Don't forget to install the board's only jumper connection, which stretches from pin 6 of U3 to pin 5 of U5. Figure 7 gives pinout diagrams for the three transistors and the LCD readout listed in the Parts List.

After all the components have been installed on the digital board, connect a 9-volt battery clip to the board. Check the board for the usual construction errors; solder bridges, cold solder joints, misconnected or misoriented components, etc. Once that is done, lay the digital board to the side and go to work on the counter/display board.

Turning your attention to Fig. 6, note that the counter/display board's assembly is a two-part operation; component placement and jumper connections. Separate placement diagrams are provided for the two operations; Fig. 6A for the component placements and off-board wiring, and 6B for the jumper connections. Socketing the LCD module is optional. If a socket is desired, one can be fabricated from a 40-pin DIP socket by cutting it in half lengthwise. If you opt to socket the display, use a wire-wrap type, since longer terminals will be required to allow room for soldering the socket to the copper side of the board.

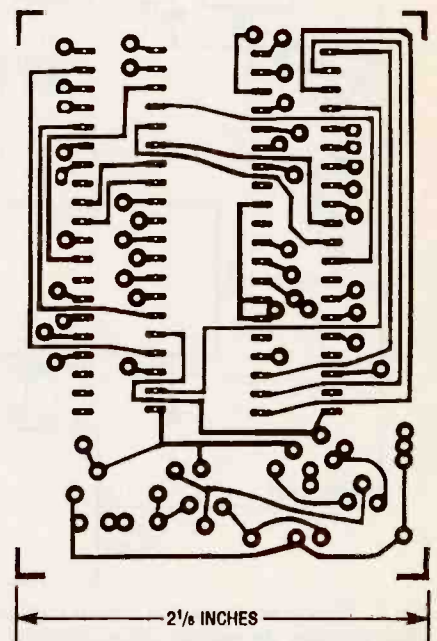


Fig. 4. Here's the full-size template for the counter/display board.

Begin the display-board assembly by first installing a 40-pin socket at the position labeled U8. Then install all the board-mounted components, as shown, with the exception of the display (DISP1), which is indicated in Fig. 6A by a dashed line. Because the display (or a cut socket as mentioned) is to be mounted to the foil side of the board, it must be installed last.

Once the board-mounted components (with the exception of DISP1) have been installed, connect the jumpers as shown in Fig. 6B. Be very careful—there are 19-jumper connections, making it very easy to misconnect one or two. After installing the jumpers, connect lengths of insulated hook-up wire (5- or 6-inch lengths should be sufficient) to the points indicated for connection to the digital board. Use shielded microphone wire (near C7) for connection to the input jack, J1. Shielded microphone wire is specified for that connection to help prevent unwanted

as not to touch the component connections from the parts mounted to the other side. It is necessary to handle things that way to provide sufficient room for soldering. Mounting the display in that manner allows the board assembly to be mounted directly to the panel of the selected enclosure so that the readout can be viewed through a rectangular opening.

In any event, do not install the display until the rest of the board has been completely assembled, and checked. Visually check your work, and then do a continuity check for possible shorts, opens, bad solder joints, and misconnected jumper wires. That precaution is necessary because if the display board has an assembly or wiring defect, it may be necessary to remove the LCD module in order to repair the fault. If you find no defects in the assembly or the wiring, install the display.

Once that's done, begin preparing

enclosure). The display board may be attached to the cover of the enclosure using suitable hardware.

In the author's prototype, the range switch (S2) was mounted to the front panel of the enclosure, just to the right side of the counter/display board. The power switch and input jack were mounted to a side panel of the enclosure. It is best to mount J1 as close to the board's input as possible to reduce the length of the wire that connects J1 to the circuit board.

Once the project is completed, inspect it thoroughly for any possible wiring mistakes or bad solder joints. It is far easier to correct a fault at this time rather than later on if you discover that your counter does not work.

Checkout. Checking out the counter will require at least a digital voltmeter or VOM with an input resistance of 1 megohm or more. A signal source, such as an audio or RF oscillator, or a function generator, can be used to

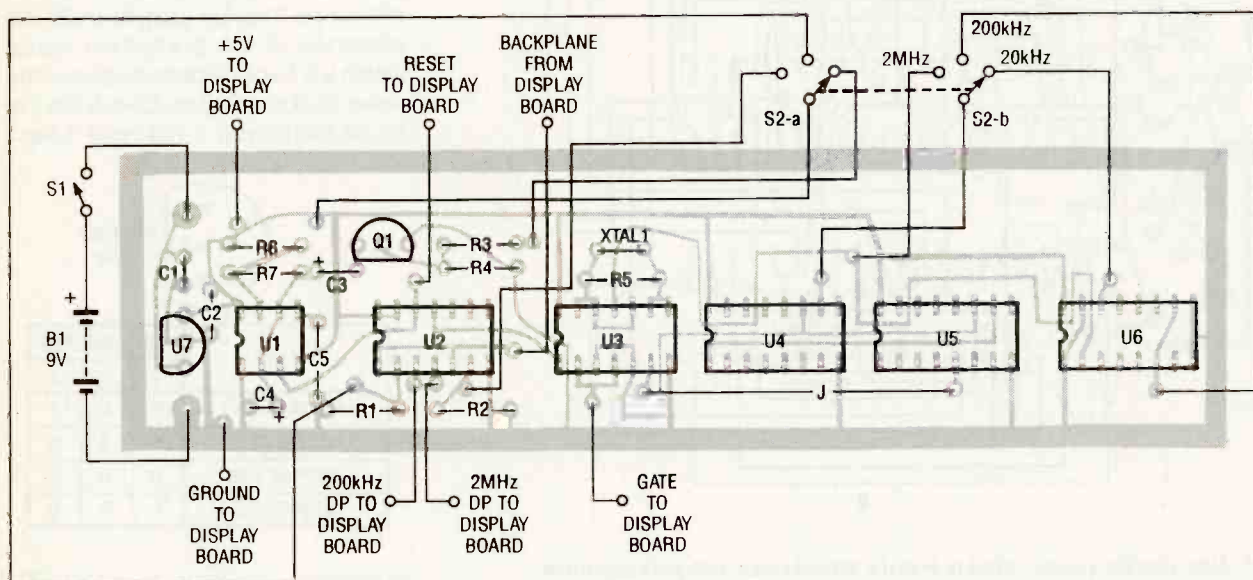


Fig. 5. Assemble the digital board first, guided by this parts placement diagram. It is recommended that sockets be provided for all of the DIP IC's, and make sure that all parts are correctly placed, paying special attention to the polarized components.

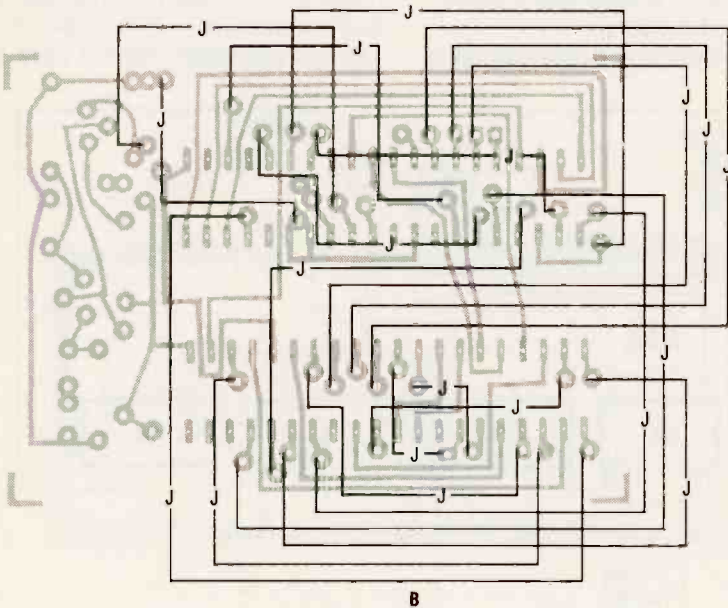
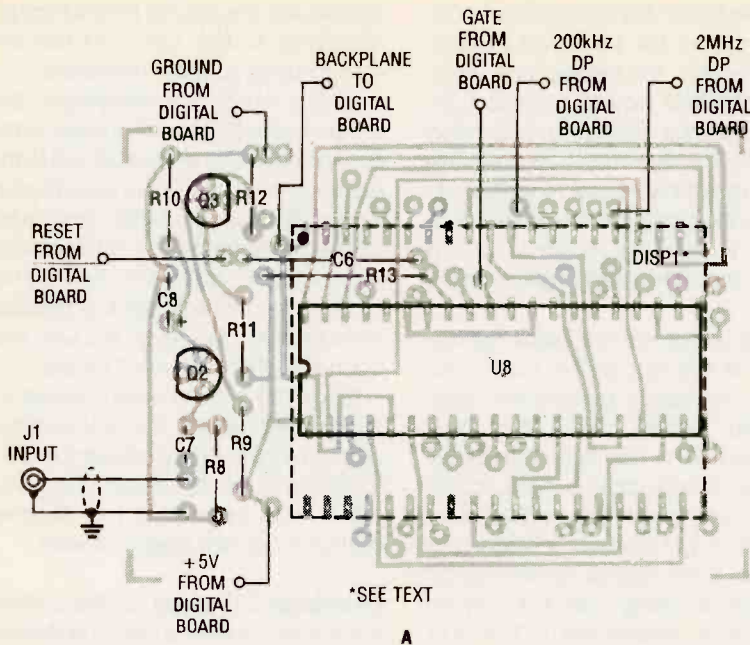
pickup from the high-frequency circuits in the unit. It's a good idea to label each wire as it's installed in order to avoid confusion later when the wires are connected to the digital board.

Once all components, jumper connections, and lengths of wire are in place, mount the display (or a cut socket as mentioned) to the foil side of the board with enough elevation so

the enclosure. The digital board was designed to fit into the enclosure—which has molded PC slots—that is specified in the Parts List. As for the display board, it will be necessary to cut a 1 $\frac{3}{8}$ - by 2 $\frac{1}{8}$ -inch rectangular opening into the cover through which to view the readout. Try to keep the display board more-or-less centered, top-to-bottom, to one side of the lid (which serves as the front panel of the

provide an input signal to check the operation of the counter on all ranges. If necessary, a general-purpose oscilloscope may be required to troubleshoot the circuit in the event that it malfunctions.

At this point, there should be no IC's occupying the DIP sockets. Connect a fresh 9-volt battery to the battery connector. Turn on the power and measure the regulated DC voltage at the



to 2 MHz. With no signal applied to the input jack, apply power to the circuit and observe the display. After the power has been on for at least a second, you should get a 000.0 indication. Set the range switch to 200 kHz. This time the display should read 00.00. Set the range switch to 20 kHz, and the display should now show 0000.

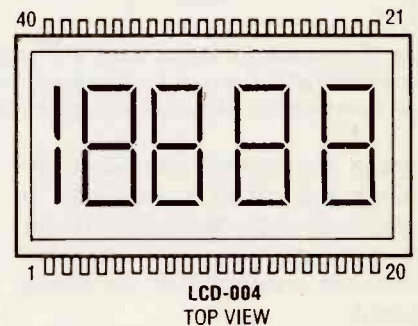
If the unit does not give the correct displays, troubleshoot the circuit before proceeding. The display should indicate the probable area of fault. For example, if the digits are activated, but do not form perfect zeros, the fault probably lies with the wiring of the associated segments that are incorrect. The same comment holds for the decimal points. If the display is totally blank, check that the LCD module is installed correctly.

A totally blank display can also be caused by lack of backplane signal generated at U8 pin 5. Check the wiring associated with pin 5 to be sure that it is not open, or shorted. An oscilloscope may be used to verify the presence of the backplane signal, which is a 5 volt peak-to-peak square-wave of about 200 Hz. Check pin 1 of U5 for the proper 5-volt input. Check



DEVICE	PIN FUNCTION		
	1	2	3
AN78L05 (U7)	O	G	I
BS170 (Q1)	D	G	S
MPF102 (Q2)	S	D	G
QN3906 (Q3)	E	B	C

A



B

Fig. 7. Here are the pinout diagrams for the three transistors and the LCD readout listed in the Parts List.

(Continued on page 107)

Fig. 6. Note that the counter/display board's assembly is a two-part operation; component placement (A) and jumper connections (B). Socketing the LCD module is optional. If a socket is desired, one can be fabricated from a 40-pin DIP socket by cutting it in half lengthwise.

output of U7. A reading of +4.75 to +5.25 volts is normal. If an incorrect voltage is indicated and the battery is delivering at least 7 volts to the circuit, troubleshoot the circuit and repair the fault before proceeding with the checkout.

Check the orientation of U7. With the battery disconnected, measure the resistance between the +5-volt bus and ground to make certain that there is no short circuit in the wiring. A

normal indication is 1000 ohms or more. Any reading that's much lower than that indicates a short or defective component. After the fault has been located and corrected, and the 5-volt regulated supply is operating properly, continue with the checkout.

Remove power from the circuit, and insert the IC's into their respective sockets. Be careful to orient each properly, and make sure that they are properly seated. Set the range switch

Today's consumers are offered an ever increasing variety of wireless gadgets, many of which operate in the 46- and 49-MHz FM bands. Walkie-talkies and cordless telephones are but two examples of that. Operating those gizmos is usually very easy. But simply operating them teaches you relatively little about what makes them tick. One way to learn about how such devices work is to build, maintain, and repair a few of those wireless "thingamajigs."

In this article, we are going to show you how to build a low-power transmitter that can be used with any compatible receiver: cordless telephones, walkie-talkies, baby monitors, etc. The 49-MHz FM Transmitter described in this article, which is powered from a standard 9-volt battery, is capable of outputting 16 mW (milliwatts) of RF power. The circuit contains a voltage-controlled crystal oscillator (VCXO) to

Build a 49-MHz FM Transmitter



Learn some of the principles behind wireless communications by building this simple FM transmitter

BY DAN BECKER



back network made with a conventional inductor would have a Q (quality factor) well below 100, allowing oscillation over a wide band of frequencies. That would make the output signal very unstable. To increase the oscillator's tuning sharpness (Q) and, by extension, its frequency stability, a quartz-crystal resonator is used. Inductor L represents the net result of three separate components: crystal XTAL1, tuning coil $L1$, and varactor diode $D1$.

The operation of a quartz crystal is best explained by a simplified equivalent circuit, like the one shown in Fig. 3. That model consists of a series-resonator network made up of C_m , L_m , and R_m , with a parallel capacitor, C_o , shunting the crystal's terminals. At the crystal's series-resonant frequency, the equal and opposite reactances of C_m and L_m cancel each other out, leaving the equivalent series resistance R_m .

However, our Colpitts oscillator requires an inductor between $C16$ and $C17$. Therefore, as with any series-resonant circuit, as the applied signal increases in frequency, inductive reactance dominates. Therefore, the crystal resonator is manufactured so that the desired operating frequency is slightly above the crystal's series-resonant frequency. That provides the needed inductor, but one with a Q of several thousand, which sharply tunes the feedback network to a single frequency.

Refer back to Fig. 1. In order to generate an FM signal, it is necessary to modulate the oscillator's frequency. The audio signal from the microphone is used as the modulating source. Diode $D1$, with a junction capacitance that's inversely proportional to the voltage between its anode and cathode, provides a convenient mechanism for varying the

ensure RF-carrier stability. That helps to prevent signal drift.

In a frequency-modulated (FM) transmission, the RF carrier frequency (49.890 MHz in our case) must deviate (vary) in direct proportion to the amplitude of the audio or voice signal.

Circuit Description. Figure 1 is a schematic diagram of the 49-MHz FM Transmitter. The circuit consists of an audio amplifier, a low-pass filter, three RF stages, and a regulated-DC power supply.

The audio picked up by the microphone (MIC1) is fed to U2-a (half of an LM358 dual op-amp), which is configured as a non-inverting audio amplifier, the gain of which (approximately 500) is determined by $R1$ and $R28$. Capacitor $C6$ modifies the gain of the audio amplifier, effectively turning it into a high-pass filter. That results in a 13-dB gain at 100 Hz that increases 6-dB-per-octave to yield 33 dB at 1000 Hz.

In order to keep the audio bandwidth below 20 kHz (± 10 kHz), the output of U2-a is fed to a low-pass filter, consisting of $R7/C9$. Together the low-pass filter and audio amplifier yield an overall cutoff frequency of about 4 kHz. The resulting signal is then coupled through $R8$ and $R9$ to the base of Q1—a buffer stage built around a 2N3904 general-purpose NPN transistor that's configured as a boot-strapped voltage follower. The output Q1 is fed back via $C11$ to the $R8/R9$ junction; that prevents Q1 from loading the low-pass filter.

The output of Q1 (taken from its emitter) is fed through $R10$ (which provides a means of adjusting the peak deviation) to a crystal-controlled Colpitts oscillator comprised of Q2, $L1$, $D1$, XTAL1, and several support components. Figure 2 shows a simplified schematic diagram of a Colpitts oscillator. In that circuit, capacitors $C16$ and $C17$ and inductor L provide feedback to Q2's input. However, a feed-

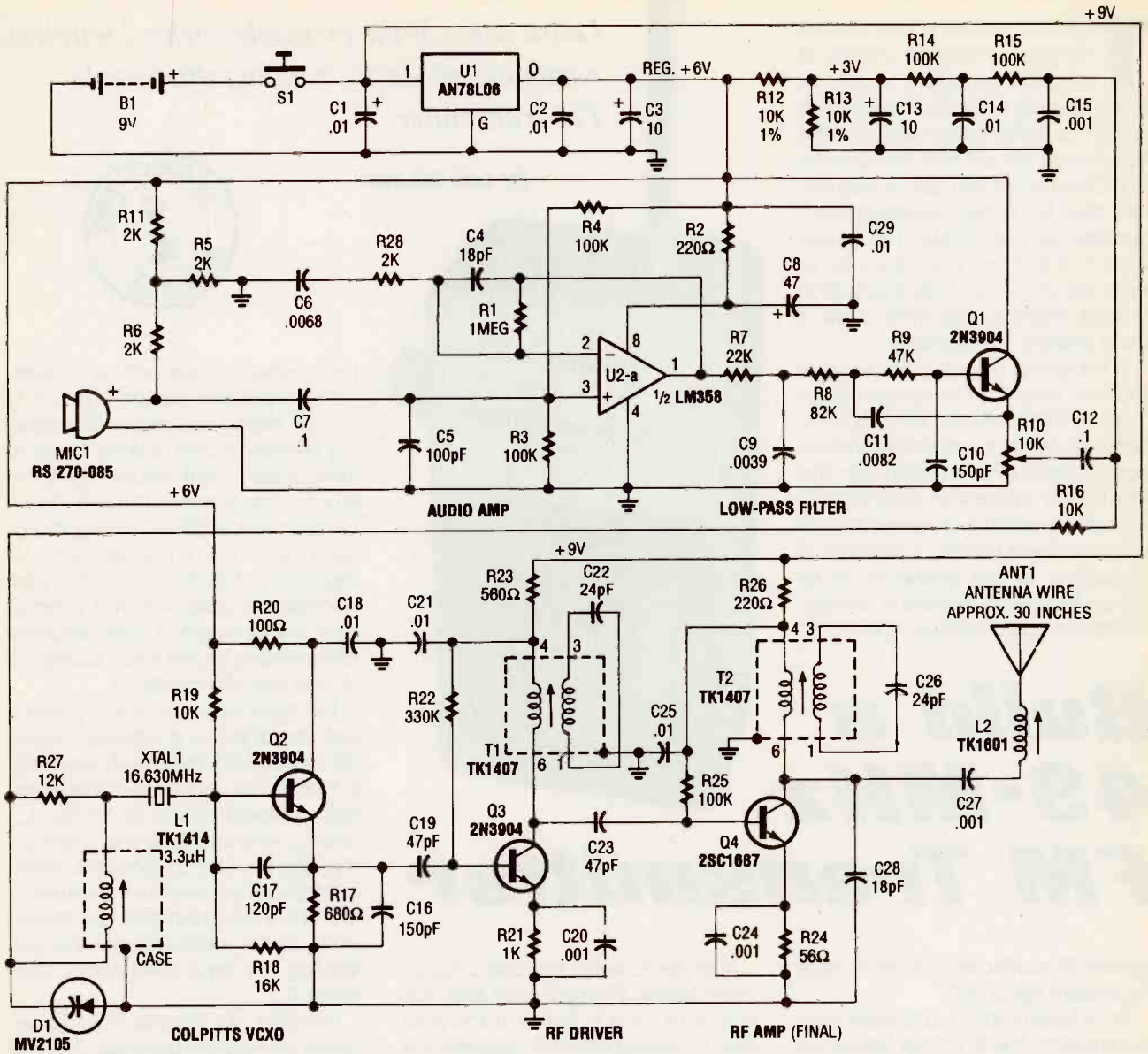


Fig. 1. The 49-MHz FM Transmitter consists of an audio amplifier, a low-pass filter, three RF stages, and a regulated-DC power supply.

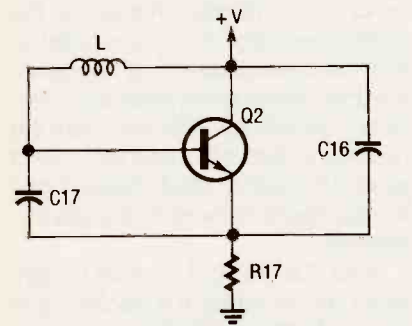


Fig. 2. Shown here is a simplified schematic diagram of a Colpitts oscillator. In that circuit, capacitors C16 and C17 and inductor L provide feedback to Q2's input. Inductor L represents the net result of three separate components: crystal XTAL1, tuning coil L1, and varactor diode D1.

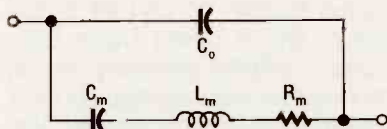


Fig. 3. The operation of a quartz crystal is best explained through this simplified equivalent circuit, consisting of a series-resonator network made up of C_m , L_m , and R_m , with a parallel capacitor, C_o , shunting the crystal's terminals.

resonant frequency of the oscillator's feedback network.

However, since D1 lowers the net inductive reactance of the crystal, L1 is included in the circuit to compensate for the loss. Inductor L1 can also be used to adjust the oscillator to the

desired center frequency. Resistor R27 lowers the Q of L1, preventing spurious oscillations that may be caused by L1 resonating with the crystal's shunt capacitance.

Voltage divider R12/R13, along with a pair of low-pass filters (consisting of R14 and C14, and R15 and C15), set D1's quiescent point to 3 volts; that yields a junction capacitance (which varies by about 2-pF/volt of audio signal) of approximately 16 pF. Thus the audio-signal frequency modulates the oscillator. Because it is easier to vary the frequency of a 16-MHz crystal oscillator than that of a 49-MHz crystal oscillator, the circuit operates on the third sub-harmonic of the output fre-

quency. For example, if a 49.890-MHz transmitter signal is desired, a 16.630-MHz crystal would be selected. Because Q2's output is rich in harmonics, the next stage is tuned so that it amplifies only the third harmonic (49.890 MHz) and ignores the 16.630-MHz fundamental frequency.

Since the third harmonic produces three times as much deviation as the oscillator's fundamental frequency, varying the fundamental frequency by ± 1.67 kHz yields a ± 5 kHz deviation at 49.890 MHz. That greatly reduces the demand on our reactance modulator. The output of oscillator is fed to the emitter-base junction of Q3 (an RF driver stage) through C19. By making C19 small (47 pF), Q3's low input impedance does not load or detune the oscillator. Resistors R21-R23 set Q3's quiescent DC emitter current to a fraction of a milliamp. However, drive from Q2 automatically increases that current to a few milliamps, producing significant RF-power gain. Capacitors C20 and C21 bypass RF current to prevent degenerative feedback.

A resonant tank circuit, comprised of T1 and C23, filters Q3's highly distorted collector current by creating a high impedance at 49-MHz, but a low impedance at the oscillator's fundamental and second harmonic. That allows Q3's collector to drive Q4 with a reasonably clean, 49.890-MHz signal through C23. The next RF-output stage, built around Q4, works pretty much like the Q3 driver stage. However, DC bias resistors R24-R26 are noticeably smaller than their Q3 counterparts. That causes a larger DC emitter current, and results in greater RF gain.

As with Q3, a resonant-tank circuit (consisting of T2 and C26) filters Q4's somewhat-distorted collector current. A reasonably clean output signal is taken from Q4's collector, and used to drive the antenna. The antenna-loading coil, L2, is used to tune out capacitive reactance, allowing Q4 to see a more resistive load. Capacitor C27 blocks Q4's DC collector voltage, while coupling its RF output to the antenna. Capacitor C28 improves the impedance match between Q4's output and the antenna, in addition to suppressing any spurious VHF emissions.

Power for the circuit is supplied by a

PARTS LIST FOR THE 49-MHZ FM TRANSMITTER

SEMICONDUCTORS

- U1—AN78L06 6-volt, 100-mA, low-power voltage regulator, integrated circuit
- U2—LM358N low-power dual op-amp, integrated circuit
- Q1, Q2, Q3—2N3904 general-purpose NPN silicon transistor
- Q4—2SC1687 RF-amplifier, NPN silicon transistor
- D1—MV2105, 15pF at 4-volts, varactor tuning diode (Motorola)

RESISTORS

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

- R1—1-megohm
- R2, R26—220-ohm
- R3, R4, R14, R15, R25—100,000-ohm
- R5, R6, R11—2000-ohm
- R7—22,000-ohm
- R8—82,000-ohm
- R9—47,000-ohm
- R10—10,000-ohm, trimmer potentiometer
- R12, R13—10,000-ohm, 1%
- R16, R19—10,000-ohm
- R17—680-ohm
- R18—16,000-ohm
- R20—100-ohm
- R21—1000-ohm
- R22—330,000-ohm
- R23—560-ohm
- R24—56-ohm
- R27—12,000-ohm
- R28—2000-ohm

CAPACITORS

- C1, C2, C14, C18, C21, C25, C29—0.01- μ F, ceramic-disc
- C3, C13—10- μ F, 16-WVDC, tantalum
- C4, C28—18-pF, ceramic-disc
- C5—100-pF, ceramic-disc
- C6—0.0068- μ F, metallized-film
- C7, C12—0.1- μ F, metallized-film
- C8—47- μ F, 16-WVDC, electrolytic
- C9—0.0039- μ F, metallized-film
- C10, C16—150-pF, ceramic-disc
- C11—0.0082- μ F, metallized-film
- C15, C20, C24, C27—0.001- μ F, ceramic-disc
- C17—120-pF, ceramic-disc
- C19, C23—47-pF, ceramic-disc
- C22, C26—24-pF, ceramic-disc

ADDITIONAL PARTS AND MATERIALS

- L1—TK1414 3.3- μ H, 7.96 MHz Toko coil
- L2—TK1601 1.6- μ H, 25.2-MHz Toko antenna-loading coil
- T1, T2—TK1407 0.41- μ H, 49-MHz Toko RF transformer
- MIC1—Electret microphone element
- XTAL1—16.630-MHz, 32-pF parallel-resonant crystal
- B1—9-volt alkaline transistor-radio battery
- S1—SPST momentary contact pushbutton switch
- Printed-circuit materials, antenna (27-inch whip or length of #22 wire), enclosure, 8-pin DIP socket, wire, solder, hardware, etc.

9-volt battery (B1). Alternatively, the circuit can be operated from any 9-volt DC source that's capable of supplying about 20 mA or so.

When S1 is pressed, 9-volts DC is applied across C1 to voltage regulator U1. Capacitor C1 protects U1's input from stray RF and voltage spikes. Integrated-circuit U1 regulates its 9-volt input to deliver 6-volts DC to all of the circuit except for the RF driver and final stages. If a regulator were not used, the RF carrier frequency could drift or change as the battery voltage decreased with age. Capacitors C2 and C3 minimize the noise and voltage spikes that are often generated by low-cost voltage regulators like U1.

Construction. The author's prototype was assembled on a printed-circuit board that measures about

11 $\frac{1}{2}$ by 2 inches. A full-size template of the printed-circuit artwork is shown in Fig. 4. Once you've etched your own board and gathered the parts listed in the Parts List, construction can begin. Most of the specified component values are not critical; so if your junkbox contains a reasonably close value to the one specified, use it. If you have a reasonably well-stocked parts bin, you probably already have more than half (if not all) of the passive components.

A parts-placement diagram for the printed-circuit board is shown in Fig. 5. It is recommended that an IC socket be provided for U2. Before you begin assembling the project, it is important that you decide at what frequency the circuit is to operate. The frequencies shown in Table 1 correspond to the 46- and 49-MHz cordless-tele-

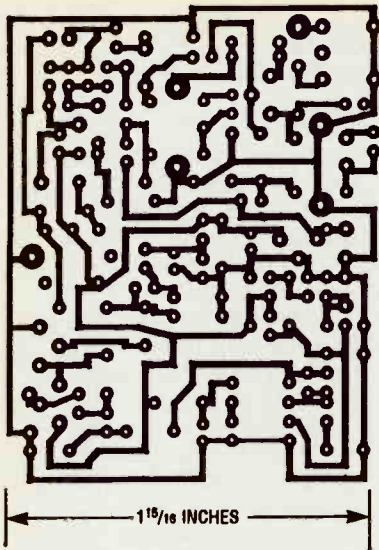


Fig. 4. The author's prototype was assembled on a printed-circuit board that measures about 1¹⁵/₁₆ by 2 inches. This full-size template of the printed-circuit artwork is provided so that you can etch your own printed-circuit board.

phone channels. However, many of those frequencies are also used by walkie-talkies, baby monitors, and numerous other wireless and experimental devices. To determine the required crystal frequency for the transmitter, divide the given channel frequency by three.

Once you've decided on the frequency of operation for your transmitter and obtained the required crystal, assembly can begin. Start by installing an IC socket where U2 is indicated in Fig. 5, and then install the passive components surrounding the socket. When assembling the circuit, mount all of the components close to the circuit board to keep lead length (and thus its reactance) to a minimum. Note: Because of the density in component placement, most of the resistors are mounted vertically.

Also note that except for the three electrolytic and the two metallized-film capacitors, all of the capacitors are low-voltage ceramic-disc units. After the passive components have been installed, mount and solder the semiconductors in place. Connect the positive lead of the battery connector in series with a SPST switch, making sure that that subassembly has sufficient (but not over abundant) lead length to reach the switch's mounting location. Connect that sub-assembly to the points on the board

shown in Fig. 5. Finally, connect lengths of wire to the board where MIC1 and ANT1 are indicated.

The next step is to prepare the enclosure. Any enclosure of sufficient size can be used to house the 49-MHz FM Transmitter; just remember that the enclosure should have sufficient room to accommodate the circuit board as well as the off-board components (S1, ANT1, B1, and MIC1).

The first step in preparing the enclosure is to select a site on or within the enclosure for the off-board com-

TABLE 1—FREQUENCY ALLOCATION

CHANNEL	BASE TRANSMITTER (MHz)	HANDSET TRANSMITTER (MHz)
1	46.610	49.670
2	46.630	49.845
3	46.670	49.860
4	46.710	49.770
5	46.730	49.875
6	46.770	49.830
7	46.830	49.890
8	46.870	49.930
9	46.930	49.990
10	46.970	49.970

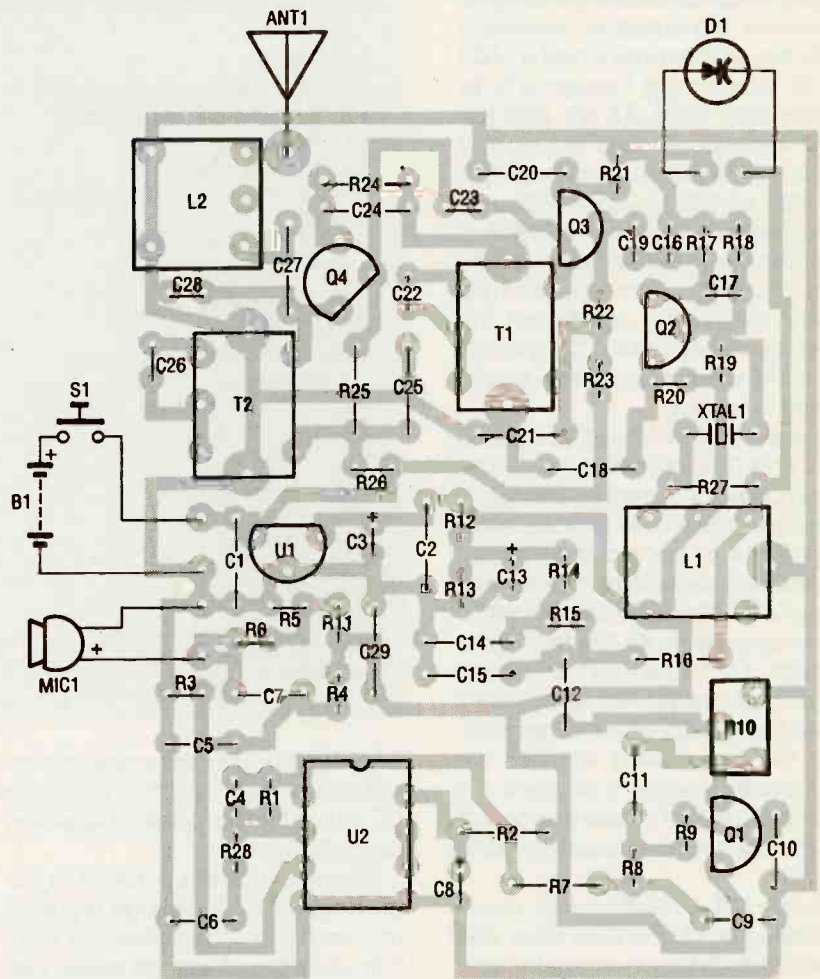


Fig. 5. Assemble the printed-circuit board using this parts-placement diagram as a guide. It is recommended that an IC socket be provided for U2. Before you begin assembling the project, however, it is important that you decide on what frequency the circuit is to operate and to select a crystal accordingly.

ponents—S1, MIC1, and ANT1. Drill holes at the selected sites for the components that will be located there. Mount the off-board components to the enclosure, and connect them to the circuit using the previously installed hook-up wire.

Note: If you intend to power the circuit from an alternate power source

(a wall adapter, for example), install a 10- μ H miniature RF choke in series with each supply lead, and then connect the positive lead in series with an SPST switch.

If you intend to use a telescoping whip antenna, be certain that it includes mounting hardware. Most

(Continued on page 106)



Telephone Ring Converter

BY DEAN F. POETH, II K8TM

This one-evening project alters the ringing sound of your phone so you can distinguish it from any other phone in the room.



Most companies use the same type of telephone for all of their employees, all of which sound the same when they ring. The result? Every time a phone rings, two or three people can be seen running back to their office to see if it is theirs. You only have three rings to get the call, or it switches to the department secretary. If it wasn't so darn frustrating, it would be comical.

You can put a stop to all that undignified exercise by building the Telephone Ring Converter. It is a simple one-evening project that will change the ring of your telephone to an electronic warble (usually found on expensive multi-line telephones). The pitch of the warble signal is adjustable, so you can change the note of your telephone to make it sound distinct from your neighbors'. The project can also be used to indicate that there is an incoming call in places where you don't have a phone (such as a workshop).

How it Works. The schematic diagram for the ring converter is shown in Fig. 1. The circuit is based on the TCM1506 ring detector/driver integrated circuit. It is a monolithic IC specifically designed to replace the telephone's mechanical bell. The chip is powered and activated by the telephone-line ring voltage, which may vary from 40–150 volts rms at a frequency of from 15 to 68 Hz. No other source of power is required.

Again referring to Fig. 1, C1–C5 are placed in parallel to form a 0.5- μ F capacitor that conducts the AC ring voltage to pin 1 of the TCM1506, but blocks any DC component. Of course, those capacitors can be replaced by a single 0.47–0.5- μ F capacitor provided it has at least a 400-WVDC rating. Resistor R1 is in series with the capacitor network and is used to dissipate power from any high-voltage transient that might appear across the line. The diluted AC voltage that reaches pin 1 on U1 powers the chip.

Capacitor C6 is used to prevent "bell tapping." That is an annoying ringing of the bell that occurs when a phone on the same line is used to dial an outgoing call. The capacitor prevents the short dial pulses from triggering the ring detector, but still allows the much longer ring signal to activate it.

Potentiometer R2 is used to vary the tone of the ring signal from below 100 Hz to over 15 kHz. Potentiometer R4 is the volume control; adjusting that potentiometer to its lowest resistance will mute the piezo element (BZ1).

When a ring signal is present on the phone-line, it powers U1. The IC then generates a tone (with a frequency determined by R2 and an amplitude set by R4) that is reproduced by BZ1.

Construction. Construction is straightforward and the parts layout is not critical. Any point-to-point wiring

technique will do. However, a printed-circuit board was used in the prototype to speed-up construction and to prevent wiring errors. If you wish to make a printed-circuit board, use the foil pattern shown in Fig. 2.

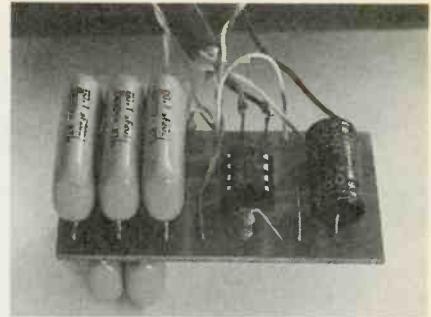
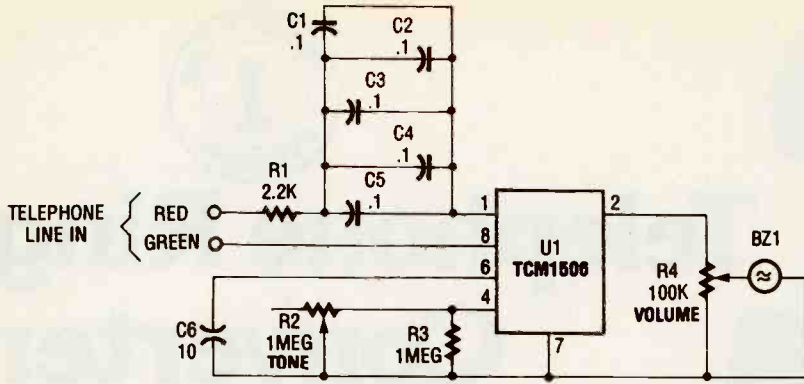
If you plan to use the foil pattern, take a look at the parts-placement diagram shown in Fig. 3. As you can see, to obtain the 0.5- μ F capacitance five 0.1- μ F capacitors are wired in parallel; however, note that capacitors C2 and C4 are mounted on the foil side of the board to save space.

Regardless of the wiring technique you use, a socket is recommended for the IC to prevent heat and static damage while soldering. It's also a good idea to leave the integrated circuit in its conductive packing until you are ready to install it.

Once you've mounted all the on-board components, attach leads to the off-board components as needed and solder the leads to the appropriate points on the board. Those points are shown in Fig. 3.

You will now have to attach a modular extension cord to the circuit board. The one you use will depend on whether you wish to use the project to change the pitch of a phone or just to act as an annunciator where there is no phone.

To use the project along with a phone, you will need a telephone extension cord with a dual-female end. That will permit you to connect it to the



To minimize the surface area of the PC board, capacitors C2 and C4 have been placed on the foil side of the board. Soldering them in is a little tricky, but it saves a lot of space.

Fig. 1. The Ring Converter circuit is incredibly simple thanks to the ring detector/driver IC, which does all the work. It even runs off the ring signal making a separate power supply unnecessary.

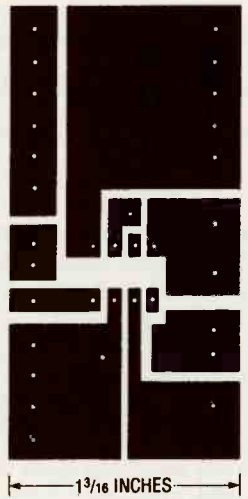


Fig. 2. If you wish to build a Ring Converter on a piece of printed-circuit board, use this pattern to etch the foil.

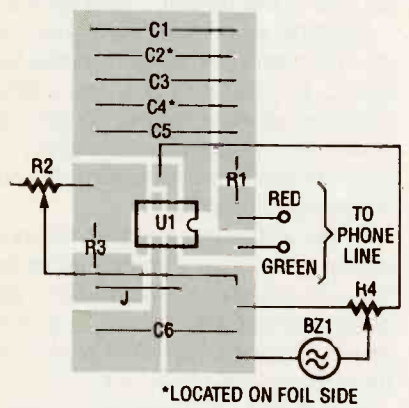


Fig. 3. Use this parts-placement diagram as a guide when mounting components on the circuit board. Note that you will need to attach leads to the two potentiometers (R2 and R4) to connect them to the board.

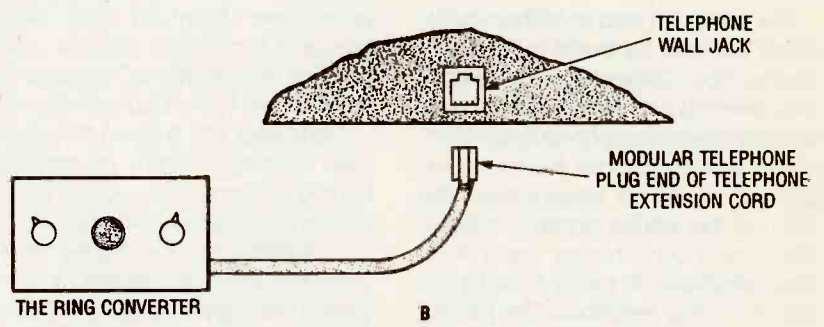
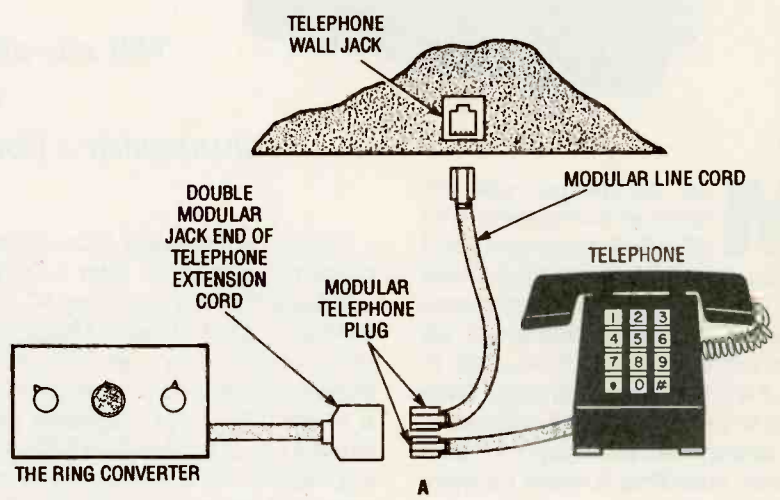


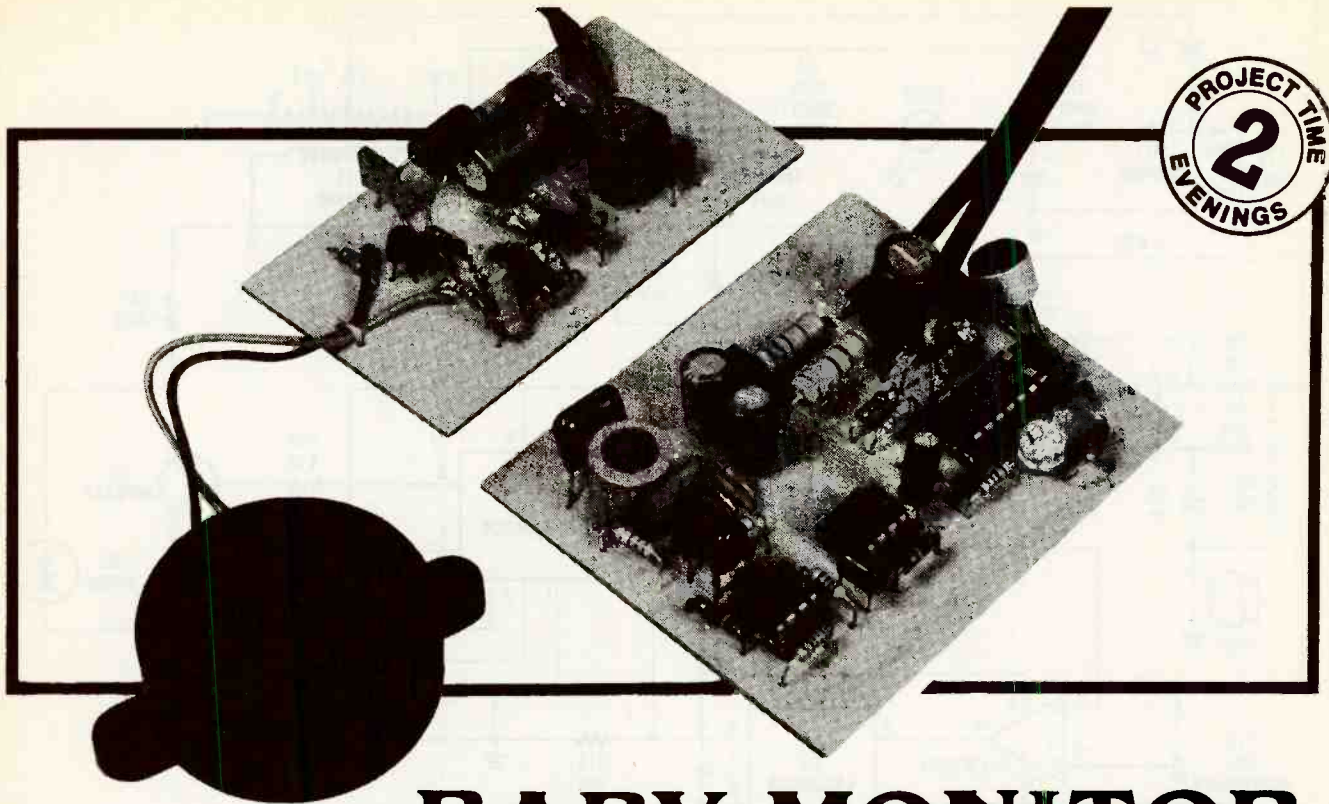
Fig. 4. You will have to wire an appropriate cable to the Ring Converter depending on whether you will use it with a nearby phone (A), or in a remote location as an annunciator (B).

vided you have a modular crimping tool, you can kill two birds with one stone: Just buy a modular extension cord that has a dual-female connector at one end and a male connector at the other. Cut the extension in half, strip the cut end of the half sporting the dual connector, and attach the green and red leads to the circuit board. Take the half with the male connector and add another male connector to the cut end. Once you've tested the unit (more on that

shortly) you can connect the project following Fig. 4A.

To use the project as a simple annunciator in a location without a phone, you just need a male plug on one end of a length of telephone wire. If you wish, you can use a telephone extension cord with one end snipped off. Connect the leads at the free end to the circuit, and once you've tested the unit, plug it into a wall jack as shown in Fig. 4B.

(Continued from page 112)



BY ANTHONY J. CARISTI

BABY MONITOR

Anyone who has been blessed with a new infant knows how important it is to keep a constant watch on your progeny. That's especially true when the baby is fast asleep in his or her crib; a time when one must be particularly vigilant. The circuit described in this article—dubbed the *Baby Alert*—is a simple electronic project that allows you to monitor the baby's room without having to be within earshot.

The project consists of a carrier-current transmitter and a receiver. The transmitter, which plugs into any AC outlet in the baby's room, generates an electronic signal when the baby cries. That signal is sent through the AC line and is picked up by the receiver, which can be plugged into any outlet within the home. Transmitter portion of the project is sensitive enough to detect sound that cannot easily be heard through a closed bedroom door, so even faint cries can be detected. It is also useful at night when you're asleep and may not easily hear the baby cry. If desired, multiple receivers can be placed at various locations throughout your home and be simultaneously active.

Keep a constant "watch" on your progeny from anywhere in your home with this carrier-current system

The Baby Alert can also be a valuable aid to the hearing impaired. Or it might be used to monitor an area for sound, perhaps as part of a security system—any sound made by an intruder would activate an alarm. It might also be used to extend the range of the doorbell (sort of a doorbell relay station).

Transmitter Operation. Figure 1 shows a schematic diagram of the transmitter portion of the project. Operating power for the circuit is derived directly from the AC line. DC power to operate the circuit is generated in two stages, one for an RF power-amplifier stage, and the second for the remainder of the circuit.

The AC line voltage is applied to D1, which half-wave rectifies the AC input. The resulting DC voltage (approximately 30 volts under load) is fed across an RC filter (comprised of R1 and C1) and used to operate amplifier, Q1. The second stage of the

power supply (composed of LED1, R2, D2, D3, C2, and C3, which forms a regulated +13.6-volt, center-tapped supply) feeds the remainder of the circuit. LED1 is connected in series with R2 and is used as a visual power-on indicator for the transmitter.

An electret microphone element (MIC1) is used as the pick-up. The output of the microphone is AC coupled through C5 to U1-a (a non-inverting op-amp with a gain of about 100). The output of U1-a at pin 1 is AC coupled through C4 to the non-inverting input of U1-b (which provides an additional gain of 48) at pin 5. The output of U1-b at pin 7 is then fed through D4 and R10, and across R11 and C6 to the inverting input of U1-c, which is configured as a voltage comparator. The non-inverting input of U1-c is biased to a positive voltage that is set by SENSITIVITY-control R19. This represents a threshold voltage at which the output of U1-c switches from high to low.

During standby, the output of U1-c

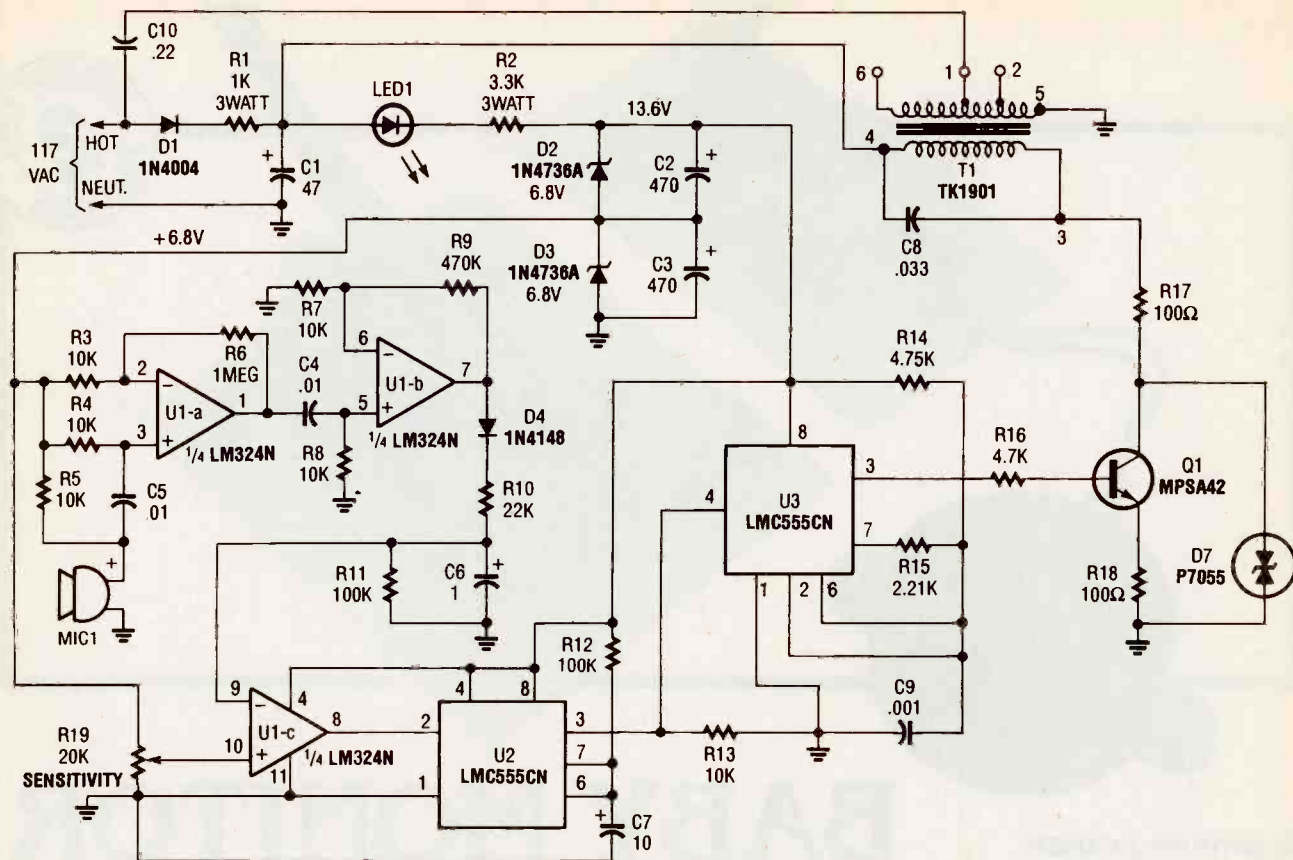


Fig. 1. The Baby Alert transmitter is built around an LM324 quad op-amp (U1), two LMC555CN CMOS oscillator/timers (U2 and U3), and a few support components.

at pin 8 is held at about 12 volts when the voltage developed across C6 is less than the bias-voltage setting at pin 10. When a sound of sufficient intensity and duration is detected, the voltage at pin 9 of U1-c exceeds the threshold level (set by R19), causing U1-c's output at pin 8 to go low. That low is applied to pin 2 of U2 (a 555 oscillator/timer that's configured as a monostable multivibrator). That causes the output of U2 to go high for about one second, as determined by the time constant of R12 and C7. The output of U2 at pin 3 is applied to pin 4 of U3 (a second 555 oscillator/timer that is configured for astable operation, with a frequency of about 125 kHz). That causes U3 to oscillate, producing a near squarewave output that is used to drive Q1 into conduction. The output of Q1 is applied across a parallel-tuned circuit composed of T1's primary and C8. The tuned circuit, in turn, reshapes the 125-kHz signal, causing a sinewave-like signal to appear across both the primary and the secondary of T1.

The signal appearing at T1's sec-

ondary (about 1 or 2 volts peak-to-peak) is impressed across the AC power line, and is then distributed throughout the building without affecting other electrical appliances connected to the line. Transient suppressor D7 is included in the circuit to help protect Q1 from voltage spikes that might appear across the power line and be coupled to the circuit through T1.

Receiver Operation. Refer to Fig. 2, the schematic diagram of the Baby Alert receiver. Power for the receiver, as with the transmitter, is derived from a traditional half-wave rectifier (D5). The resulting DC voltage is regulated to 27 volts by D6 and R20, and then filtered by C11 to provide a relatively clean, DC power source for the circuit. A light-emitting diode, LED2, connected in series with R20 provides a visual indication that the circuit is powered and ready to receive a signal.

The 125-kHz signal is plucked from the AC line and coupled through R21 and C12 to a parallel-tuned LC circuit,

consisting of C13 and L1. That LC circuit passes 125-kHz signals while attenuating all others. The 125-kHz signal is fed through C14 to the base of Q2 (which is configured as a high-gain linear amplifier), which boosts the relatively low amplitude of the 125-kHz signal. The RF output of Q2 is AC coupled to the base of Q3 through C15. Transistor Q3 acts as both an amplifier and detector. Since there is no bias voltage applied to the base of Q3, it remains cut off until driven by the amplified 125-kHz signal. When Q3 is forward biased, its collector voltage rises.

Capacitor C16, connected across Q3's collector resistor, filters the 125-kHz signal so that it is essentially DC. When the voltage at the collector of Q3 rises, Q4 is driven into conduction. That causes current to flow into piezo buzzer BZ1, producing a distinctive audio tone that alerts anyone within ear-shot that the baby needs attention.

Construction. The author's prototype was assembled on a pair of printed-circuit boards. Full-size tem-

plates of the two circuit-board layouts are shown in Figs. 3 (the transmitter) and 4 (the receiver). You may etch your own boards using the templates or obtain a set from the source given in the Parts List. Once you have a set of boards, assemble the transmitter and receiver boards guided by Fig. 5 and 6 (respectively).

It is recommended that sockets be used for all IC's; it is well worth the additional cost should the circuit ever require troubleshooting. Be very careful to orient all polarized components—such as transistors, diodes, integrated circuits, and electrolytic capacitors—as shown in the parts-placement diagram. A single mis-oriented component will render the circuit inoperative and may cause damage to itself, or to other components.

Resistors R1 and R2 in the transmitter and R20 in the receiver normally operate at temperatures that are very warm to the touch. Be sure that those components are allowed sufficient clearance from all other components, the sides and top of the enclosure, and the board itself. Capacitors C8 and C9 in the transmitter and C13 in the receiver are tuning components (which are part of frequency-selective networks). Because of that, use only the component types specified in the Parts List. Ordinary ceramic capacitors are not temperature stable and should not be used in place of the specified parts. The same consideration holds true for R14 and R15 in the transmitter. Use only metal-film resistors where directed; carbon types are not stable with temperature and should not be used in those locations.

Transistor Q1 and some of the capacitors used in both the transmitter and the receiver have higher voltage ratings than ordinarily found in solid-state circuits. Be sure to use parts that have the specified voltage rating. Note that U2 and U3 (in the transmitter) are the CMOS version of the common 555 oscillator/timer. Use only the specified parts; the ordinary 555 may not operate properly at the specified transmitter frequency (125 kHz).

Before mounting T1 to the transmitter board, use an ohmmeter to identify the primary, which is connected to terminals 3 and 4 and electrically isolated from the secondary. Secondary terminals 1 and 5 are used in this cir-

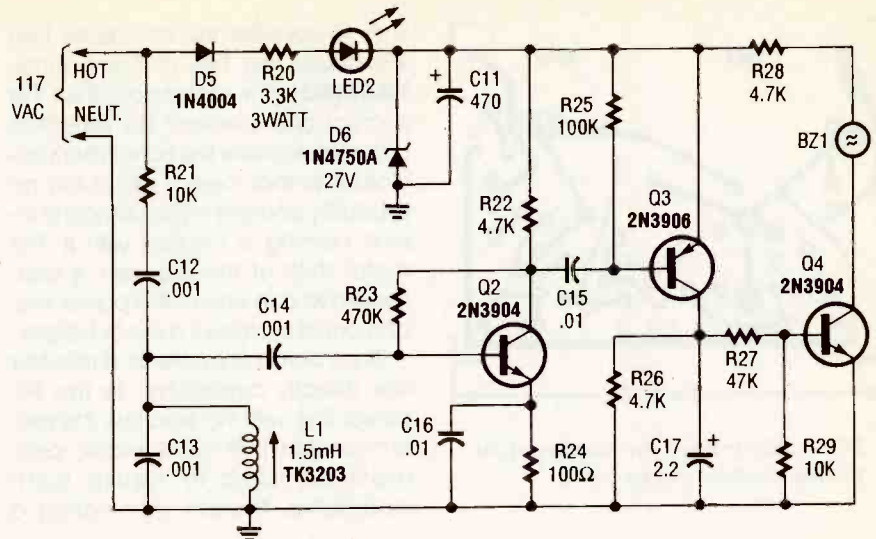


Fig. 2. The Baby Alert receiver is comprised of three transistors—Q2, which is configured as a high-gain linear amplifier; Q3, which serves as both an amplifier and detector; and Q4, which is essentially used as a switch—and a few additional components.

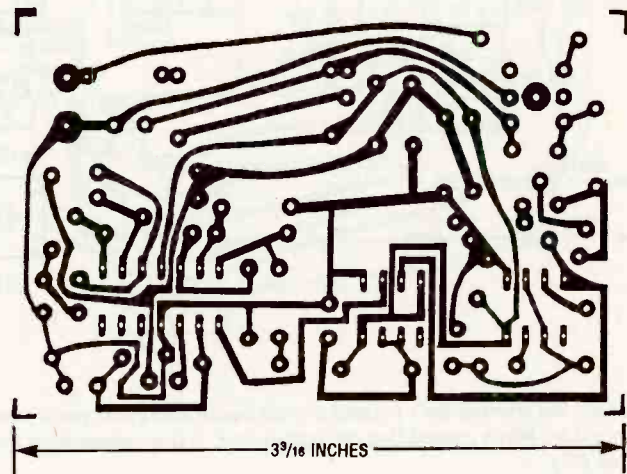


Fig. 3. Here is a full-size template of the transmitter's printed-circuit board.

cuit; 2 and 6 are not. When you have completely assembled the boards, examine them very carefully for cold solder joints; they appear as dull blobs of solder. Correct any joint that is suspect. Also check for opens and inadvertent short circuits between adjacent traces. Most problems can be attributed to faults such as those; it is far easier to correct them at this stage rather than later.

Both the transmitter and the receiver are powered directly from the AC line without transformer isolation. AC power receptacles have two power leads, one "hot" and the other "cold" (sometimes called neutral) that are generally color-coded black and white, respectively. The cold lead is essentially at ground potential, while

the hot lead is 117 volts above ground.

It is recommended that only polarized power cords, either 2- or 3-conductor types, be used for both circuits. The larger spade of a polarized plug is neutral and smaller one is hot; the same hold true for three-conductor plugs, with the third terminal being Earth ground. In any event, connect the hot and neutral leads of the power cord to the points indicated in the parts-placement diagrams (Figs. 5 and 6). Secure the cord so that the exposed ends cannot move and accidentally touch your body or anything else.

Enclosure. Once the leads of the power cords have been connected to the transmitter and receiver, it is

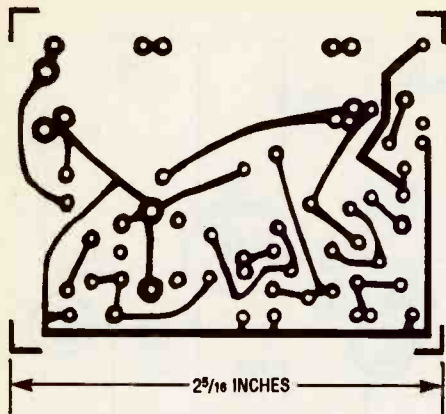


Fig. 4. This is a full-size template of the receiver's printed-circuit board.

time to consider the enclosures that will house the two circuit boards. **WARNING:** It is mandatory that the microphone element be mounted completely inside the transmitter's enclosure so that there is absolutely no possibility of anyone (including the infant) coming in contact with it. The metal shell of the element is connected to one side of the power line, and could represent a shock hazard.

Since both transmitter and receiver are directly connected to the AC power line with no isolation, it is recommended that 100% plastic cabinets be used to house both assemblies, thereby eliminating a

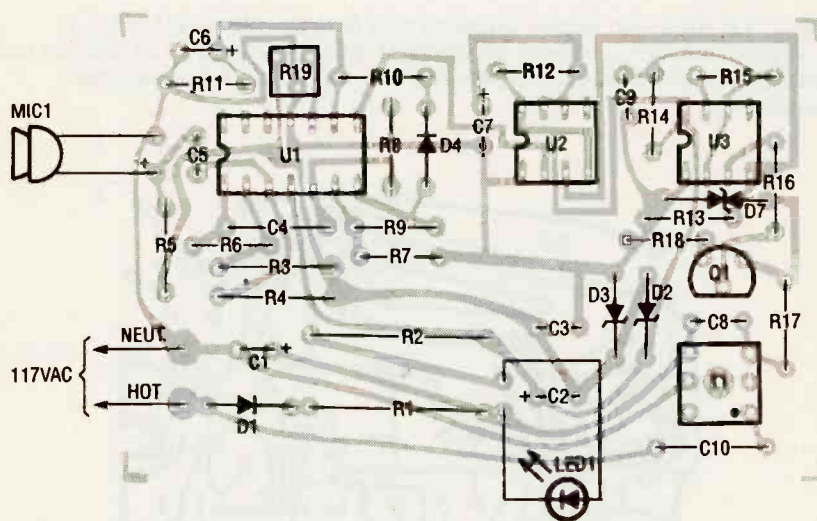


Fig. 5. Assemble the transmitter's printed-circuit board using this parts-placement diagram as a guide. When assembling the transmitter, it is recommended that sockets be used for the IC's.

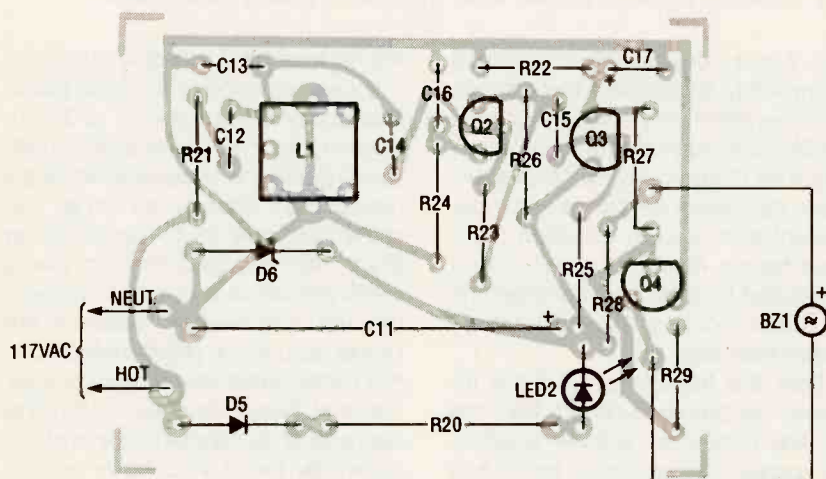


Fig. 6. Use this parts-placement diagram as a guide to assembling the receiver's printed-circuit board. It is important that only polarized power cords, either 2- or 3-conductor types, be used to connect either circuit board to the AC line. The larger spade of a polarized plug is neutral and smaller one is hot; in a three conductor plug, the third terminal is Earth ground.

PARTS LIST FOR THE BABY ALERT TRANSMITTER

SEMICONDUCTORS

- U1—LM324N quad op-amp, integrated circuit
- U2, U3—LMC555CN CMOS oscillator/timer, integrated circuit
- Q1—MPSA42 or equivalent high-voltage NPN silicon transistor
- D1—1N4004 1-amp, 400-PIV silicon rectifier diode
- D2, D3—1N4736A 6.8-volt, 1-watt, Zener diode
- D4—1N4148 general-purpose silicon diode
- D7—P7055 transient suppressor (Digi-Key)
- LED1—Light-emitting diode, 2-volt, 20-mA

RESISTORS

- (All fixed resistors are 1/4-watt, 5% carbon units, unless otherwise noted.)
- R1—1000-ohm, 3-watt, metal-oxide
 - R2—3300-ohm, 3-watt, metal-oxide
 - R3—R5, R7, R8, R13—10,000-ohm
 - R6—1-megohm
 - R9—470,000-ohm
 - R10—22,000-ohm
 - R11, R12—100,000-ohm
 - R14—4750-ohm 1/4-watt, 1% metal-film
 - R15—2210-ohm, 1/4-watt, 1% metal-film
 - R16—4700-ohm
 - R17, R18—100-ohm
 - R19—20,000-ohm, PC-mount potentiometer

CAPACITORS

- C1—47- μ F, 100-WVDC, electrolytic
- C2, C3—470- μ F, 10-WVDC, electrolytic
- C4, C5—0.01- μ F, 50-WVDC, ceramic-disc
- C6—1- μ F, 10-WVDC, electrolytic
- C7—10- μ F, 16-WVDC, electrolytic
- C8—0.033- μ F, 50-WVDC, metallized-film
- C9—0.001- μ F, 50-WVDC, metallized-film
- C10—0.22- μ F, 250-WVDC, metallized-film

ADDITIONAL PARTS AND MATERIALS

- MIC1—Electret microphone element (Radio Shack 270-090)
- T1—125-kHz matching transformer (Toko Coil, Digi-Key catalog #TK1901 or equivalent)
- Printed-circuit materials, enclosure, IC sockets, polarized AC power plug with line cord, wire, solder, hardware, etc.

PARTS LIST FOR THE BABY ALERT RECEIVER

SEMICONDUCTORS

Q2, Q4—2N3904 general-purpose NPN silicon transistor
 Q3—2N3906 general-purpose PNP silicon transistor
 D5—1N4004 1-amp, 400-PIV. silicon rectifier diode
 D6—1N4750A 27-volt, 1-watt Zener diode
 LED2—Light-emitting diode, 2-volt, 20-mA

RESISTORS

(All fixed resistors are 1/4-watt, 5% carbon units, unless otherwise noted.)
 R20—3300-ohm, 3-watt, metal-oxide
 R21, R29—10,000-ohm
 R22, R26, R28—4700-ohm
 R23—470,000-ohm
 R24—100-ohm
 R25—100,000-ohm

R27—47,000-ohm

CAPACITORS

C11—470- μ F, 35-WVDC, electrolytic
 C12—0.001- μ F, 200-WVDC, ceramic-disc
 C13—0.001- μ F, 50-WVDC, polyester-film
 C14—0.001- μ F, 50-WVDC, ceramic-disc
 C15, C16—0.01- μ F, 50-WVDC, ceramic-disc
 C17—2.2- μ F, 10-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

L1—1.5-mH inductor (Toko Coil, Digi-Key catalog #TK3203 or equivalent)
 BZ1—Piezo buzzer (Radio Shack

273-065 or similar)

Printed-circuit materials, enclosure, polarized AC power plug with line cord, wire, solder, hardware, etc.

Note: The following parts are available from A. Caristi, 69 White Pond Road, Waldwick, N.J. 07463: Transmitter: printed-circuit board, \$9.95; LM324 quad op-amp (U1), \$2.50 each; LMC555CN oscillator/timer (U2 and U3), \$2.50 each; TK1901 125-kHz matching transformer (T1), \$8.75 each; MPSA42 high voltage transistor (Q1), \$2.25 each; set of 2 metal-film resistors, \$1.25
 Receiver: printed-circuit board, \$9.95 each; TK3203 1.5-mH inductor (L1), \$7.75 each. Please add \$3.00 per order for postage and handling. New Jersey residents please add appropriate sales tax.

possible shock hazard. Low-priced plastic enclosures are readily available from electronics parts suppliers such as Radio Shack. Using a 100% plastic enclosure eliminates the need to ground the chassis, so a 3-conductor power cord is not necessary. If you use a 3-conductor cord and house the circuits in plastic enclosures, tape the ground conductors of the cords so that they cannot short to anything else.

On the other hand, if you choose to house either unit in a metallic or partially metallic enclosure (something that is not recommended), it will be necessary to use a 3-conductor line cord and tie the metal chassis, or the metal portion of the enclosure, to Earth ground.

Prepare the transmitter enclosure by drilling a series of very small holes

in the enclosure to allow sound to reach the element. It will also be necessary to drill holes in both enclosures for the LED indicators. Also you have to drill holes in the receiver enclosure to allow sound from the piezo buzzer to escape; keep in mind that no metal part or wire of the piezo element may be left exposed. No power switch is required for either unit, since current draw is extremely low. However, you always have the option of installing switches if desired.

Transmitter Checkout. Electrical checkout will require the use of a DVM or VOM; an oscilloscope may be necessary for troubleshooting if the circuit is non-functional due to improper assembly or one or more defective components. The transmitter must be checked first. Once its operation is

verified, it can be used to check the receiver's operation. For the initial test remove the IC's from their sockets before powering the circuit. **Caution:** As with any electronic project that is connected directly to the power line, using an isolation transformer is the best way to test the circuit, and one *must* be part of the test setup when checking the project with an oscilloscope.

A simple, low-cost way to obtain line isolation is to use two step-down transformers, with equal ratings, connected back-to-back (the two secondaries connected to each other) as shown in Fig. 7. If line isolation is not used, use only a voltmeter for testing; connect the meter to the circuit before plugging the transmitter line cord into the AC receptacle. Do not touch any part of the circuit or meter with your body when power is on. Voltage measurements are made with the negative or common lead of the voltmeter connected to circuit ground (the negative side of C1), unless otherwise specified.

With all IC's removed from the transmitter board, apply power to the circuit. The LED should light. Measure the voltage across C1. The voltage across C1 should be about 80 volts DC. Measure the voltage across C2, and across C3; about 6.8 volts DC across each capacitor is the reading you

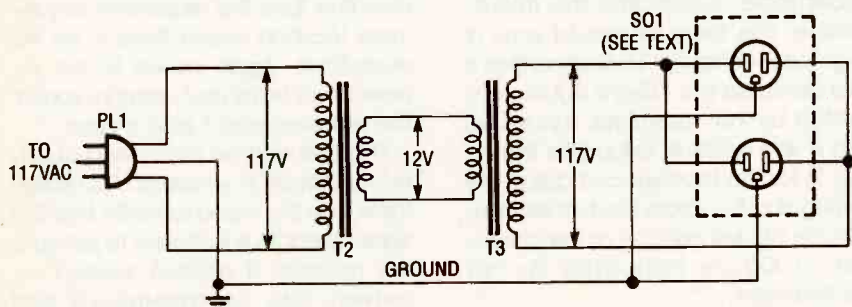


Fig. 7. Using an isolation transformer is the best way to test the circuit, and one must be part of the test setup when checking the project with an oscilloscope. You can use this simple, low-cost setup to obtain line isolation.

should get. Measure the voltage at pin 10 of the U1 socket. Adjust R19 for a reading of about 1 volt DC.

If you do not get the correct readings across the capacitors or at pin 10 of U1, disconnect the line cord and troubleshoot the circuit until the fault is found and corrected. Check the orientation of D1–D3, C1–C3, and LED1. Use an ohmmeter to verify that each blade of the line cord plug is connected to the proper part of the circuit as illustrated in the schematic diagram and the parts-placement diagram. Measure the resistance across C1–C3 to be sure that there is no short circuit on either the high-voltage bus or regulated-voltage bus.

When power-supply operation has been verified, and R19 has been set to 1 volt, disconnect power from the transmitter and insert the IC's into their respective sockets, being careful to observe proper orientation. Be sure that none of the IC pins are inadvertently bent under the body of the chip. Connect the voltmeter across C1. Apply power to the circuit and note the meter reading; again it should be about 80 volts.

Speak loudly into the microphone and observe that the reading decreases to about 40 volts as long as the microphone picks up sound, then returns to 80 volts when the room is silent. Note that LED brightness decreases significantly when the circuit is activated, as Q1 diverts current from the rest of the circuit. Failure to obtain the above results indicates that U1–U3 or Q1 is not operating. Isolate the fault by first measuring the voltage at pin 7 of U1, while speaking into the microphone. A normal indication is a voltage exceeding 1 volt that responds to the intensity of the sound.

If that measurement is normal, measure the voltage at pin 8 of U1. A normal indication is about 12 volts when the circuit is dormant, and about zero when speaking into the microphone.

The operation of U2 can be verified by measuring the voltage at its output terminal, pin 3. A normal indication is zero volts when the circuit is dormant and about 12 volts when activated during the 1-second pulse time of the one-shot multivibrator. An oscilloscope (with line isolation) may be used to verify that U3 is operational by examining its output waveform at pin

3. A normal indication is a near squarewave of about 13 volts peak-to-peak when the circuit is activated by sound. If U3 is normal, check pin 1 of T1 for a 125-kHz sinewave of about 1 or 2 volts peak-to-peak. Both top and bottom slugs of T1 may be adjusted for maximum amplitude.

When the transmitter is operating properly, the upper and lower slugs of T1 may be adjusted for maximum amplitude of the 125-kHz sinewave appearing at pin 1 of T1. Use the proper plastic tuning tool to avoid damage to the slugs. An oscilloscope is best for that adjustment. A normal indication is a 2-volt peak-to-peak sinewave.

When you are satisfied that the circuit performs properly, R19 may be adjusted for more or less sensitivity as desired. Use the LED as an indicator of circuit operation as sound reaches the microphone. The circuit is most sensitive when the voltage at pin 10 of U1 is near zero. It is best to use only as much sensitivity as necessary to avoid false alarms.

Receiver Checkout. Be sure to observe all safety precautions as described previously.

Connect a DC voltmeter across C10, and apply power to the receiver. The LED should light. Note the meter reading; a normal indication is about 26 to 28 volts DC. If you do not get the proper reading, disconnect the power and troubleshoot the circuit. Start by checking D5, D6, LED2, and C11 for correct orientation. Using an ohmmeter or continuity checker, verify that each blade of the line cord is connected to the proper points.

When the power supply is operational, plug the receiver's power cord directly into a duplex AC receptacle. Plug the transmitter's power cord directly into the other side of the same receptacle. Speak into the microphone. The receiver should emit a high-pitched sound, indicating that it has detected the 125-kHz signal generated by the transmitter. If possible, use a line isolation setup (like that in Fig. 7) for the receiver and adjust L1's tuning slug to obtain the highest amplitude 125-kHz voltage at the collector of Q3 as indicated by an oscilloscope.

Note the audio level that is required to operate the receiver. If more or less sensitivity is desired, adjust R19 in the

transmitter accordingly. Remember, use only as much sensitivity as necessary to avoid false alarms. If the receiver does not operate as described, check Q2, Q3, Q4, and their associated components. Check BZ1 to be sure that it's connected to the circuit with the correct polarity. The best way to troubleshoot the receiver is to power both receiver and transmitter through the same line-isolation transformer and use an oscilloscope to trace the 125-kHz signal from C13/L1 through Q3's collector.

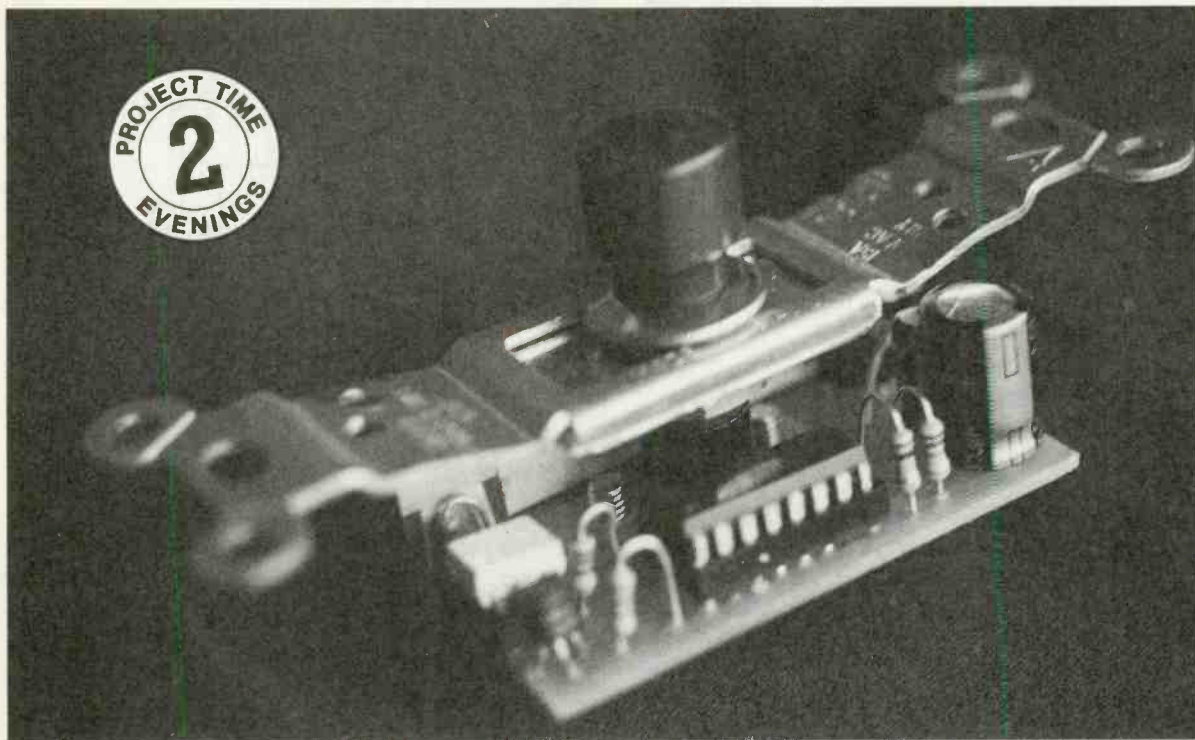
With both transmitter and receiver plugged into the same duplex receptacle, the signal at the junction of C13 and L1 should be about a 1-volt peak-to-peak, 125-kHz sinewave riding on a relatively small 60-Hz waveform. At Q2's collector the signal should be amplified to about 6 volts peak-to-peak as Q2 saturates.

The tuning slug of L1 should be adjusted to obtain the maximum amplitude signal voltage at Q2's collector. That adjustment is best performed if the transmitter is relocated to a remote location to attenuate the RF signal through the AC-line wiring. When so attenuated, the RF input to the receiver at the junction of C13 and L1 may be only about 0.1 volt peak-to-peak.

With an RF amplitude of several volts peak-to-peak at Q2's collector, the output of Q3 at its collector should rise to 15 volts or more as Q3 responds to the drive signal from Q2. Finally, Q4 should be driven into conduction, causing the piezo buzzer to operate.

Final Checkout. To check the range of the Baby Alert, connect the transmitter to an AC-power receptacle at its permanent location. Have an assistant stand by the transmitter to speak into the microphone at your direction. Take the receiver to any remote location where there is an AC receptacle. Apply power to the receiver and have your assistant speak. The receiver should emit a tone.

That test can be performed at any remote location where an AC receptacle can be found to verify that the signal strength is sufficient to activate the receiver. If desired, several receivers can be assembled and placed inside and even outside your home so that you'll never be totally out of touch with your offspring. ■



Automatic Porch-Light Control

Automate the operation of any light so it turns itself off and saves you money.

The price of electricity has gone up yet again! Have you ever known it to come down? And yet we waste so much. Why, only the other day I went out to get the morning paper, and the porch light was still on. Must have been on all night. I started thinking "Why can't my wife remember to turn it off after . . ." and then I remembered I left the light on. It was then I decided to build a circuit that would automatically turn off the light. Before presenting the circuit, let's look at some of the design criteria I dealt with.

Designing the Circuit. Of course I wanted a circuit that could be turned on manually, but would turn off automatically. For that reason I decided the circuit should replace the existing porch-light switch, so it had to be small enough to fit in a standard junction box. It would also have to draw its power from the existing wiring. That presented me with a problem: The switch junction box in question was

BY DAVID PONTING

not wired with both the hot and neutral powerlines. It just had an incoming hot wire and a switched hot wire going to the lamp. So my circuit would have to operate without benefit of the neutral line.

My solution was to place a resistor in series with the switch, and place the automatic control circuit in parallel with the resistor. With the switch in the "on" position and a good bulb in the porch-light fixture to complete the circuit, current flows through the resistor. The voltage drop produced across the resistor by the current provides power for the control circuit.

However, I had to determine the optimum value for the resistor: If it was too large it would make the porch light dim, if it was too small the voltage drop would not be sufficient to power the circuit. Furthermore, I had to determine if a resistor with sufficient wattage to handle the bulb's current would be physically small enough to

fit in the junction box, but run cool enough to prevent damaging the other components.

The first task was to determine the current flow through the bulb. To figure that I assumed I'd be working with at most a 100-watt bulb operating off a 120-volt supply. The current would equal the wattage divided by the voltage, which comes out to 0.83 amp. Now I needed to find the value of resistance that will yield a voltage drop sufficient enough to power the control circuit. Taking a guess that I needed about 12 volts and dividing that by 0.83 amps yielded a resistance value of about 15 ohms. Now I turned my attention to figuring out the wattage of the resistor. Multiplying the voltage drop times the current indicated I'd need a 40-watt resistor—a suitable size. The resistor would generate some heat, but since it would only be on for a couple of minutes at a time, it would not harm the other components in the junction box.

An additional concern of mine was

if the resistor value would still be suitable when operating with a smaller wattage bulb, say 40 watts. Let's go through the math again to see. The wattage over the voltage equals the current, so if we divide 40 by 120, we get 0.333 amp. Now, what voltage will be dropped by the 15-ohm resistor when it carries 0.333-amps? Multiplying resistance times current, the answer is 5 volts—still a usable value. Of course, at the reduced current level the resistor's 10-watt rating is more than sufficient.

Just to check out these theoretical figures, I ran a series of tests using mock circuits. To summarize the test results, I discovered that 40-watt bulbs are not made with the same degree of accuracy as the larger wattage bulbs. However, the circuit should work just fine regardless of that variance.

The rather lengthy activation time (2 minutes) presented me with another hurdle to overcome. Two minutes is pretty long in electronic terms. A resistor/capacitor-based timing circuit would require a large, leaky capacitor. The capacitor would waste a little energy and may be too large to fit easily and safely into a standard junction box. Obviously an RC circuit wouldn't do. Let's take a look at the actual circuit to see how I avoided using such a timing scheme.

The Control Circuit. The Automatic Porch-Light Control circuit is shown in Fig. 1. The hot lead in the switch box is connected to one side of the pushbutton switch, S1. The switch runs to R1, the 15-ohm, 10-watt resistor that is connected to the bulb via the house wiring. When the pushbutton is pressed it completes the circuit lighting the bulb. The small voltage drop across R1 is full-wave rectified by the bridge, BR1, and the pulsating DC out of the bridge is smoothed by C1 and limited to 6.2 volts by the Zener diode, D1. That voltage acts as the supply for U1, a CMOS 4020 counter/divider.

That IC has two inputs, a clock input (pin 10) and a master-reset input (pin 11). Let's consider the master-reset input first. Counting only occurs when the master reset is low. When the master reset is high, the counter is reset to zero, its outputs go high, and it will not count. However, to ensure that the counter starts at zero it is necessary to reset the counter with a positive pulse.

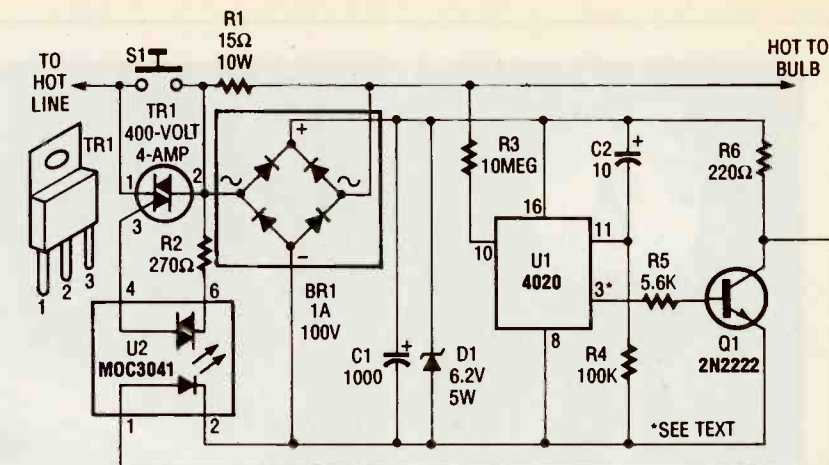


Fig. 1. The Automatic Porch-Light Control Circuit holds a Triac on until a 4020 divider counts a number of 60-Hz powerline pulses.

That pulse is produced by C2 and R4. Before the pushbutton is pressed there is no voltage across C2 so it is fully discharged and the master-reset pin is low. When the pushbutton is pressed, C2 pulls the master-reset pin high as it begins to charge. That resets the counter. Once C2 is mostly charged there isn't much current flow through R4, so the resistor pulls the master-reset pin low. At this point the counter/divider begins to count.

What the counter/divider counts are the clock pulses into pin 10. These pulses are derived straight from the switched side of the hot line, which, as you know, operates at 60 Hz. The current flow into pin 10 is strongly attenuated by the 10-megohm resistor, R3.

The counter/divider contains a number of different stages connected one after another and each stage divides the pulses it receives by two. So the first stage divides the 60-Hz signal to produce a 30-Hz square-wave. That signal is divided to produce a 15-Hz squarewave, and so on. The output of a number of these stages are available via pins on the IC package. The control circuit uses the output at pin 3. The signal at that output has a period of about 136½ seconds (i.e. a little bit over 2 minutes 16 seconds).

If you think that leaves the light on for too long, then use the output from pin 2, its period is half that of pin 3. Similarly, the output of pin 1, is half that of pin 2.

Getting back to the circuit, when the counter/divider is counting if the output pin is low, which holds Q1 off. The LED in the optocoupler receives current from R6, so the optocoupler

PARTS LIST FOR THE AUTOMATIC PORCH-LIGHT CONTROL

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)

- R1—15-ohm, 10-watt
- R2—270-ohm
- R3—10-megohm
- R4—100,000-ohm
- R5—5600-ohm
- R6—220-ohm

SEMICONDUCTORS

- U1—4020 14-stage ripple counter, integrated circuit
- U2—MOC3041 optocoupler, integrated circuit
- Q1—2N2222 NPN transistor
- TR1—4-amp, 400-PIV, Triac (isolated tab)
- BR1—1-amp, 100-PIV, bridge rectifier
- D1—6.2-volt, 5-watt, Zener diode

ADDITIONAL PARTS AND MATERIALS

- C1—1000-μF, 10-WVDC, electrolytic
- C2—10-μF, 50-WVDC, electrolytic
- S1—Pushbutton switch (Radio Shack 275-609)
- One 16-pin, and one modified 8-pin IC socket (see text), 8-32 hardware, switch-box fixing bracket (see text), blank switch-box panel, wire, solder, etc.

activates the Triac, TR1, completing the circuit to the bulb so it remains lit when S1 is released. When the time period passes and pin 3 goes high, transistor Q1 switches fully on so its collector is grounded. That shorts the op-

tocoupler's LED, turning off the Triac and extinguishing the light.

Safety Tips. Before we get to the construction details a word or two of caution is in order. When building the circuit keep in mind that when the circuit is active both AC legs of the circuit are hot. That is, of course, no different from the switch inside any switch-box in the house: hot is always present on one side of the switch, and appears on the other side when the switch is closed. Nevertheless, when testing this circuit board, **the utmost care must be exercised to see that no part of the board is touched.** Once the device is in its switch-box, it is no more dangerous than the standard switch it replaces, but until then handle it with caution.

On a different note, when you look around for a Triac try to get one with an isolated tab. That will prevent the tab from shorting the AC powerline should it come in contact with one of them. Also make sure the pushbutton switch you use can handle powerline voltages at currents up to about 1 amp. The switch recommended in the Parts List has not only a more than adequate rating for the circuit, but it also has an ideal length, allowing all the fitted components on the PCB to be clear of the switch's mounting bracket (which we'll discuss in a moment).

Preliminaries. Although very cautious point-to-point wiring will work, I recommend that you build your Auto-

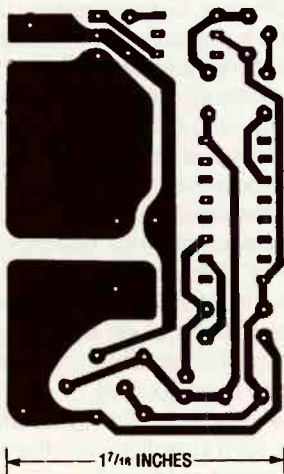


Fig. 2. Using this foil pattern to make a PC board is recommended. It will virtually eliminate the possibility of wiring errors.

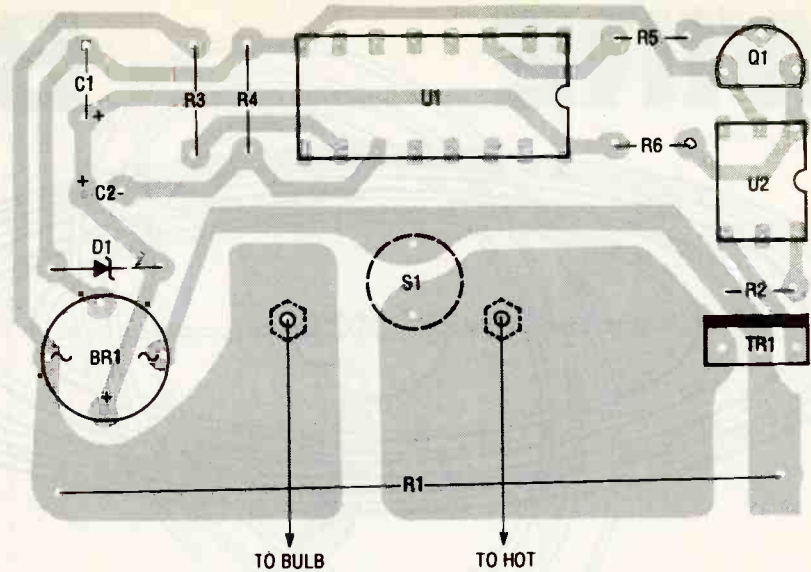


Fig. 3. Stuff the board as shown here. Note that the switch and nuts are mounted on the foil side of the board.

matic Porch-Light Control on a printed-circuit board made from the foil pattern shown in Fig. 2. Remember that if you want a different delay time, alter the foil pattern or circuit board to accommodate the delay you want as outlined earlier.

Some special steps must be taken for drilling the circuit board. For example, the flat terminals on the pushbutton switch have to be soldered to the PCB, so narrow slots have to be made in the board to accept them (see Fig. 3 for their position). These are best achieved by drilling a standard PCB size hole (about 1 mm), drilling two more holes adjacent to the first, and joining them together by carefully filing with a small needle file.

Also be sure to make two holes in the board large enough to accommodate 8-32 bolts. These holes should be located on the board where the terminal connections for the hot and bulb wires are to be made. Once the board is drilled, pass an 8-32 screw through each hole from the component side and fasten them with matching nuts. Solder the nuts to the foil being careful not to bind the screws to the nuts. Remove the screws for now, and the circuit board is ready.

Prior to stuffing the board you will need to modify some of the parts, so let's discuss that now. Do not solder anything to the circuit board until you are told to do so.

The body of the switch has to pass through a bracket that will hold it (and therefore the PCB) to the junction box.

You can take the retaining bracket from a plain wall switch, either a new one or the one you're replacing. If you want to use the bracket from the switch you're replacing, there are some instructions for safely removing the switch from the junction box given later (see the section entitled "Testing the Unit"). Once you have the switch, remove the bracket by carefully drilling out the rivets that hold it in place.

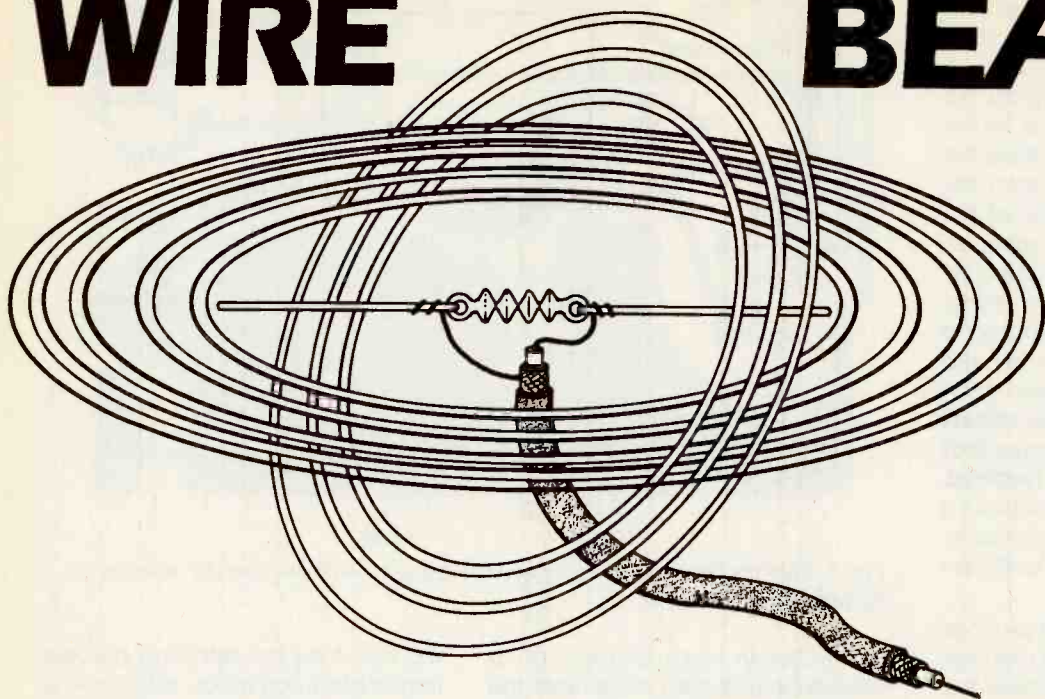
The pushbutton switch can now be passed through the central hole of the bracket (where the lever of the removed switch was). It may need a small rectangular piece of aluminum as a washer to hold it in the middle of the hole. Now finger-tighten the switch in position with its own washer and nut. When fixed in this way, the switch should be rotated so that its two contacts run parallel to the bracket's longer dimension. Hence, when the PCB is finally soldered to the switch, the board will have its longer dimension parallel to the bracket as well. Now securely tighten the switch to the bracket.

Drill a hole in the center of the blank switch box panel so that the button on the switch can come through. The switch recommended in the Parts List has a removable button, so you only have to drill a hole large enough to accommodate the shaft of the switch. Later, when the switch and switch box panel are in place, you just have to pop the button back on the shaft of the switch and it will hide the hole.

(Continued on page 106)

WIRE

BEAMS:



Gain on the Cheap

Nothing can give your ham rig better bang per buck or labor than a good antenna.

BY JOSEPH J. CARR, K4IPV

Antenna design is a perennial topic for radio buffs. Whether you are a shortwave listener, amateur-radio operator, scanner monitor, or a citizen's bander, the antenna is probably the most important aspect of your set-up. While a great deal can be done to improve receivers, transceivers, and transmitters, for the radio buff's dollar there is nothing that will produce as much benefit per nickel as a good antenna system. And the antenna need not be terribly expensive. While a multi-kilo-buck rotatable beam antenna is certainly a wonderful thing to have, not all of us can afford such an antenna or have the space to put one up. In some areas, a really nice commercial antenna isn't even legal because of local zoning regulations, etc.

Fortunately, wire antennas can be built for less than commercial antennas. They can be installed in areas where a tower cannot, or where one

would be prohibitively expensive to install. A wire antenna is also well worth considering because it provides convenience and low cost, and some designs can provide a surprising degree of gain and directivity.

Gain and Directivity. Gain and directivity are the two interrelated aspects of antenna design that make a good antenna so important to a radio system. These two concepts are essentially the same because antennas obtain "gain" by focusing the RF energy into limited directions rather than all directions. Gain is measured by comparing the strength of a signal radiated by an antenna in each direction to the signal strength that would be produced by an ideal isotropic radiator (*i.e.*, a uniform sphere). The signal produced by such an ideal antenna could be viewed as an ever-expanding series of spheres with the antenna at the center (something like

the layers of an onion). The larger a sphere's radius, the greater its surface area. Since all the spheres should have the same amount of RF energy but different surface areas, signal strength is measured in milliwatts per square centimeter (mW/cm^2).

A directional antenna focuses all of its energy into a limited direction, so more energy is found in each unit of area along that direction. In other words, the signal strength in mW/cm^2 increases along that direction. Because of its inherent directivity, such an antenna provides the following:

- Increased received signal strength from distant transmitters (*i.e.*, makes a received signal louder).
- Freedom from strong interfering signals from directions not the same as the signal of interest.
- Increased transmitted signal strength at distant locations (*i.e.*, makes your signal louder).
- The Law of Reciprocity makes the

antenna perform during reception as it does on transmission, so the same design can benefit both types of user.

The first two items on the list benefit all users of radio equipment, while the final one helps CB'ers and hams. The first benefit (i.e., making distant signals stronger) is probably not the advantage it seems at first blush except to a small percentage of radio amateurs. Increasing the received strength of "Radio Zlotplatz" is only of marginal benefit if it is already audible at your location and your receiver has both an automatic gain control and reasonable selectivity. The gain is of use, however, when attempting to listen to stations that are so weak that they are near the noise threshold. Increasing antenna gain may well bring such a station up enough to hear audibly without also increasing the overall noise as much as would a pre-amplifier.

So what use is a gain antenna if a random length of wire tied to a convenient tree will give us a strong enough signal? Recall that gain and directivity are merely restatements of the same thing. The selectivity of your receiver will help eliminate adjacent channel interference. You can narrow the passband down, use "single signal" techniques (where appropriate) and otherwise shunt unwanted adjacent channel signals off to oblivion.

Co-channel interference is a different matter. If the offending signal is on the same channel, then the receiver will "hop around" trying to eliminate it. But, if the offending signal is coming from a different direction than the desired signal, it is possible to place the low-gain "null" of the directive antenna in that direction. Thus, the offending signal is attenuated by the antenna's directionality.

The trick of using an antenna to select signals is well known to those who use rotatable antennas. What is perhaps a less popular fact is that you can derive the same benefit from a judiciously placed fixed antenna. For example, an "east coaster" might want to aim an antenna so that it picks up shortwave transmissions from Africa, South America, Europe, or Oceania, while at the same time eliminating signals from other regions (you might be surprised by what's buried underneath the North American Service of Radio Moscow). The null could

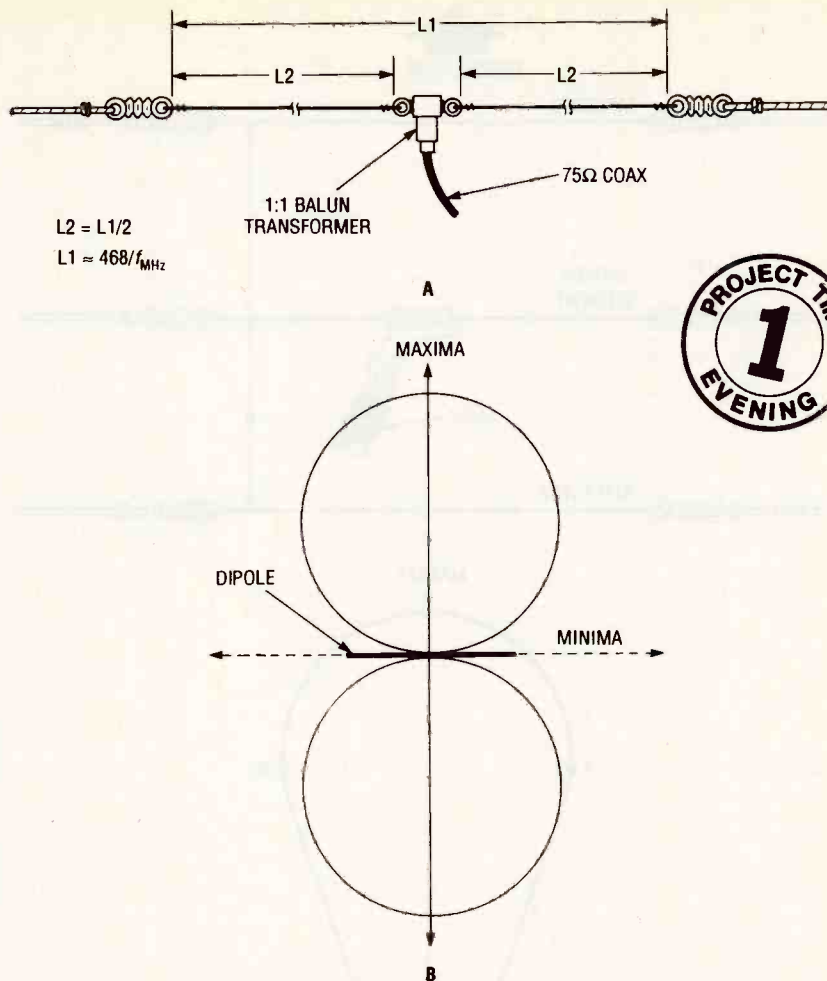


Fig. 1. In "A" is a simple half-wavelength dipole antenna. Ideally it should produce a radiation pattern like the one shown in "B."

be placed in the direction of the offending signal (or cacophony of signals), even though the main lobe (i.e., direction of maximum gain) is not directly on the area of interest.

The phenomenon is not limited to shortwave listeners and hams. Indeed, scanner users and FM-band DX'ers may have even greater need for directivity and gain. If you are far removed from a station, then the gain feature of an antenna may be attractive to you as well. Or, if you want to listen to a distant station on the same channel as a stronger, nearby station, then directivity may be just what you need. A friend of mine used to listen to a bluegrass music station 90 miles away with usable, if noisy, reception... until another station occupied the same channel closer in. Fortunately, the new station was about 40 miles distant in a different direction, so a gain antenna with a good directivity did the trick. Before we discuss the various antennas you can use to im-

prove your own set-up, another topic deserves attention: Safety!

Rules to Follow. Erecting antennas can be a dangerous affair. Every year the radio community is saddened by stories of people who were killed or seriously injured in the act of erecting antennas. The most serious threat comes from foolishly attempting to erect a wire antenna by tossing it over AC power lines. While it may be tempting to do so, especially when the most convenient support structures are on opposite sides of the power line, this feat **must never be attempted!** The argument that both antenna and power wires are insulated does not help, for insulation can and does deteriorate and falls apart with remarkably little force. It is never safe to do that trick, so **don't**.

Also, keep in mind where the antenna will go if it breaks. Look around the yard and determine whether or not it will be capable of "wind-whipping"



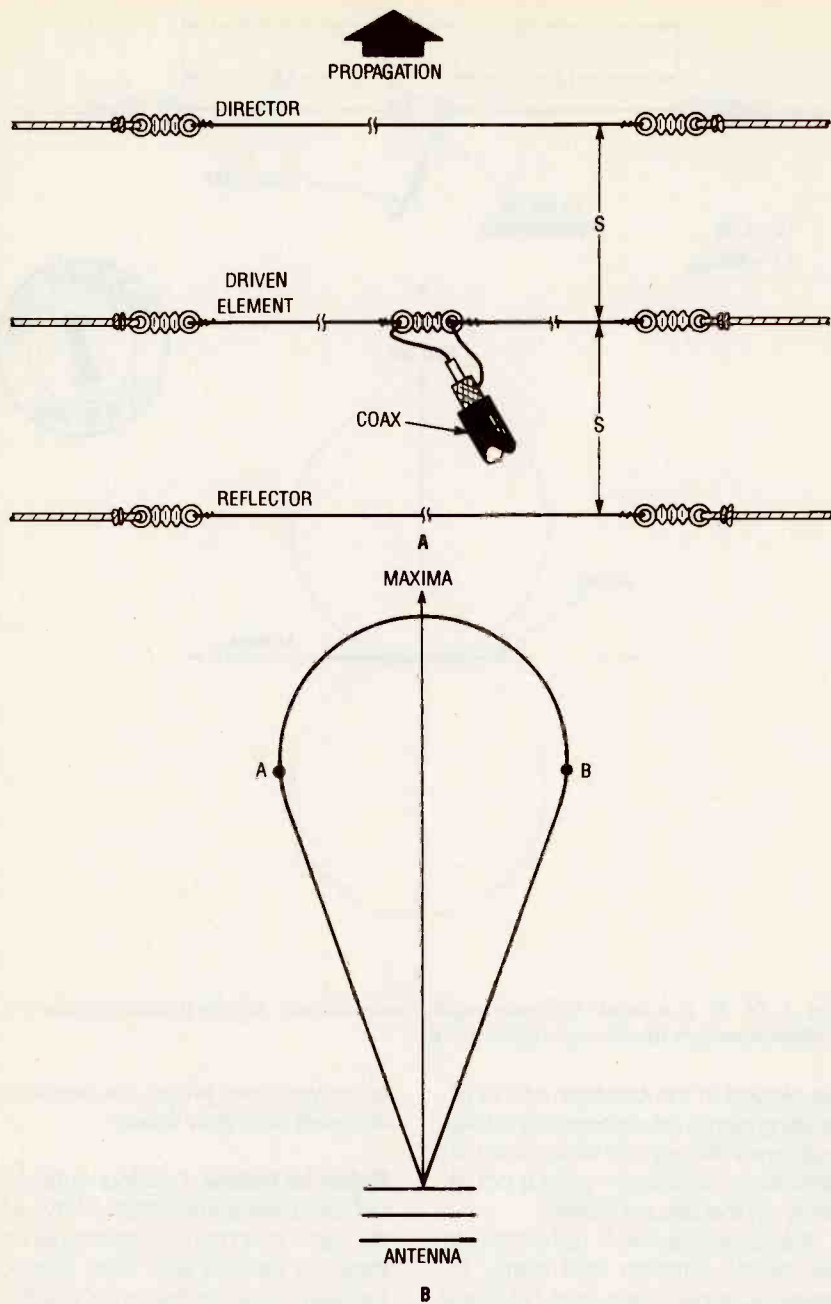


Fig. 2. You can improve the performance of a dipole by adding director and reflector elements that force the RF energy to move in a given direction,

into a power line, or if it will become a hazard on a path or sidewalk, or if it will crash into a window or vehicle (insulators and baluns will break glass when wind whipped).

Use properly designed insulators, not *ad hoc* substitutes, for the end and center insulators. The rope should be sufficiently strong to hold the antenna under all wind conditions, and should be tied to a spring or counterweight to permit some give. Use good quality No. 12- or No. 14-gauge wire. Copperweld is a steel core, copper-clad wire intended for this purpose.

Finally, when erecting the antenna, especially if standing on a ladder, be aware of where the wire is at *all* times. It can easily become entangled in your feet or ladder support, and cause a serious fall. Always work with another person so that help is near at hand; young readers should work with a knowledgeable adult until they are also experienced in the antenna-erection process. Wire antennas seem very easy to erect alone, but that's a fool's game from a safety perspective. With these important points covered, let's get to those antennas.

The Half-Wavelength Dipole Antenna. Although disdained by the technically sophisticated (without good reason), and despised by owners of super-arrays, the "lowly" dipole (Fig. 1) is the least expensive and most common form of directional wire antenna. It is a horizontal half-wavelength radiator fed at its center. Although the feedpoint impedance varies with height above ground, the dipole usually makes a good impedance match for 75-ohm coaxial cable. The overall length of the antenna (L_1) can approximately be found by using the equation in Fig. 1 where L_1 is in feet, and f is the frequency of interest in megahertz. The length is only approximate because local conditions can conspire to alter the electrical length a bit, so some tuning must be done on any antenna once it is erected. The length of each element (L_2) is about one-half of L_1 as shown.

The ends of the dipole are supported by end insulators and lengths of rope. The rope can be attached to trees, masts, buildings, or other structures. The feedpoint of the dipole can be constructed with another end insulator such that the center conductor of the coaxial cable is connected to one L_2 radiator element, while the shield is connected to the other radiator. A better result, and a more consistent pattern, will result if the coaxial cable is connected to the antenna through a 1:1 balun (which stands for *balanced-unbalanced*) transformer. They are readily available from radio-supply outlets, or can be homemade from toroidal transformer cores following instructions given in various texts (see the boxed copy entitled "For Further Reading" appearing with this article).

Figure 1B shows the radiation pattern for the dipole antenna. This view is from above. Note that the pattern is a figure eight with the main-lobe maxima perpendicular to the radiator element. The minima, or nulls, are the directions of minimum gain and are in line with the radiator element. In other words, if you want to null a station to the west or east, and receive along a north-to-south line, then run the antenna east to west. The antenna pattern in both the horizontal and vertical directions is best for most applications when the antenna is at least one half-wavelength from the ground, and is

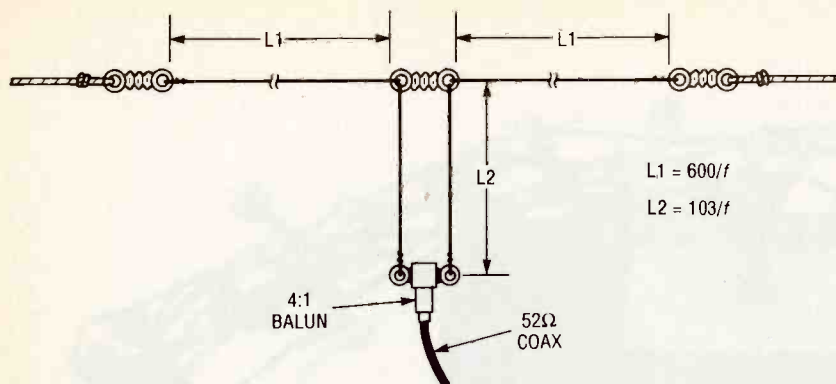


Fig. 3. The double-extended Zepp antenna is similar to a plain dipole, but it has a matching section and a balun at its feed point.

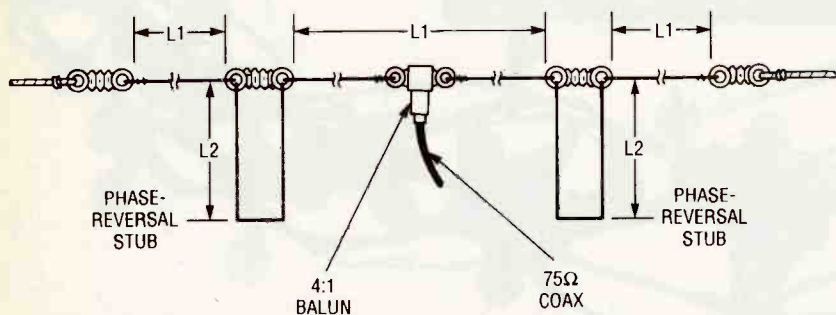


Fig. 4. The collinear Franklin-array antenna, shown here, can be extended to contain any number of elements. The number is only limited by the weight your rope can handle.

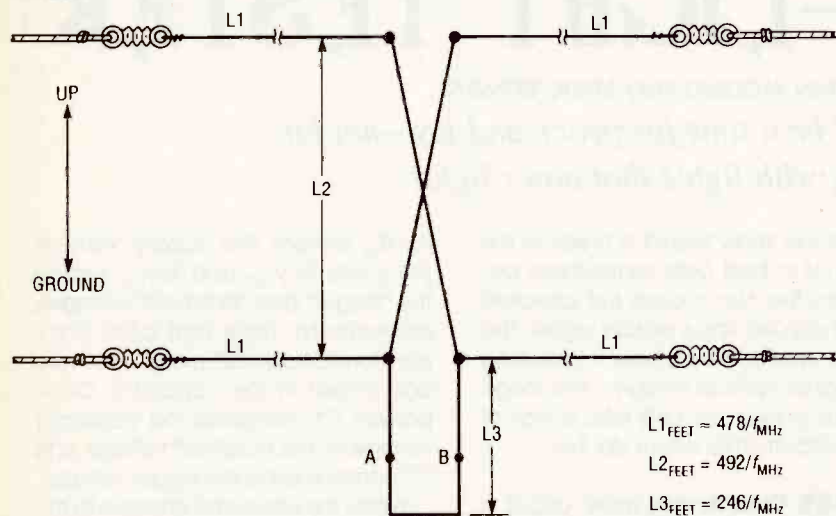


Fig. 5. The lazy-H antenna consists of two dipoles pointed in opposite directions. The feed points for the antenna (points A and B) need to be determined by experiment.

preferably several wavelengths above ground (which is nearly impossible on lower frequencies).

The dipole is the easiest directional antenna to build and use, and it is also the most well behaved when it comes to tuning. It has a gain of approximately 1.7 decibels (dB) above the ideal isotropic radiator mentioned above.

Wire Yagi Beam Antenna.

The Yagi antenna is a directional beam antenna that is made from dipole elements (see Fig. 2A). Most of the large rotatable antennas used on shortwave and VHF bands are basically tubing-based versions of the Yagi concept. The pattern for the Yagi beam antenna is monodirectional, as shown in Fig. 2B. This pattern is, incidentally, idealized and doesn't show sidelobes and backlobes that represent wasted energy, but hopefully those are kept low

enough to not be a problem. The beamwidth of the antenna is the angle between points "A" and "B" where the gain falls off - 3 dB from the gain at the maxima.

It is possible to make a fixed Yagi beam antenna from wire and insulators, as shown in Fig. 2A. The driven element is a half-wavelength dipole similar to the one in Fig. 1A; its approximate length (before tuning) is found from the equation for L1 presented earlier. The driven element can be fed either directly as shown, or through a 1:1 balun transformer to 52-ohm (not 75-ohm) coaxial cable. The element in the direction of maximum radiation is called a director, and is about 4% shorter than the driven element. Similarly, a reflector is behind the driven element and is about 4% longer than the driven element. Although the antenna in Fig. 2A has one director and one reflector, it is possible to use any number of reflectors and directors (and each one narrows the beamwidth and therefore increases the gain of the antenna).

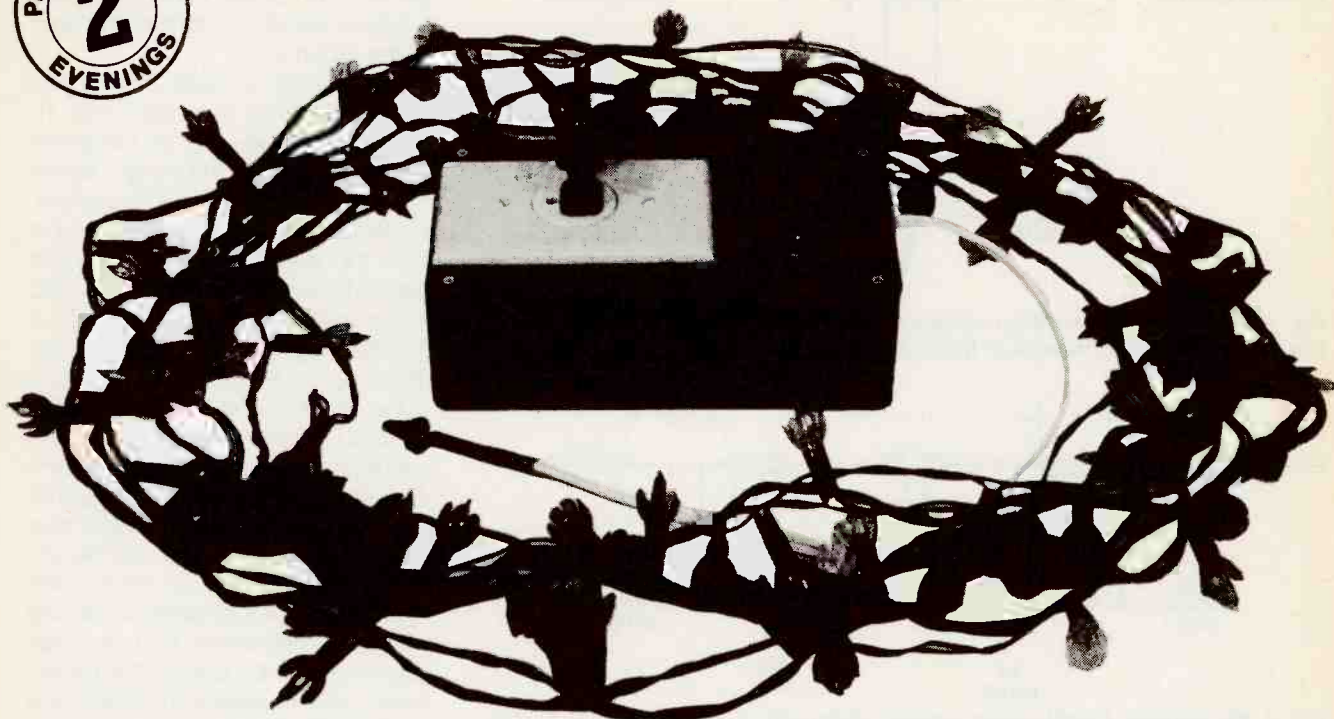
The spacing (S) between elements can vary from approximately 0.15 wavelength to 0.25 wavelength, or 0.3L1 to 0.5L1 to use the half-wavelength element lengths as a frame of reference (many builders try to make the spacing 0.2 wavelengths). The spacing is difficult to maintain, especially as the wind blows... but it is not strictly necessary to always have the spacing exact.

Double-Extended Zepp Antenna.

The double-extended Zepp antenna, shown in Fig. 3, provides a gain of about 2 dB at right angles to the antenna wire plane. It consists of two sections of wire, each one of a length based on the desired frequency of use as shown in the figure.

The D.E. Zepp antenna can be fed directly with 450-ohm twin-lead (available from Wire Antenna Supplies Radio Works, P.O. Box 6159, Portsmouth, VA, 23703), especially if a balanced antenna tuner is available at the receiver or transmitter end. Alternatively, it can be fed from a matching section of twin lead (or parallel line) as shown if coax is preferred. Use the equation shown in the figure to determine the length of the matching section (L2).

(Continued on page 104)



HOLIDAY-LIGHT TESTER

BY JOHN YACONO AND MARC SPIWAK

Christmas should be a time for peace and joy—not for wrestling with lights that don't light!

Many of you are probably familiar with what's involved in finding one burned-out light bulb in a long string of them. It's really frustrating when you have to pull each bulb and replace it with a known-good one, just to find the one bad one. And if you're lucky, you'll find the bad bulb and the string will come to life. If you're not lucky, there's a break in the wire somewhere in the loop, and you won't find it by checking the bulbs.

If you've ever had that problem, or if you regularly repair anything with many lights wired in series, then you'll certainly appreciate this neat little gadget: the *Christmas-Tree Light Tester*. It points you in the direction of the bad bulb by plugging into any socket in the string and seeing which of two LED's light up. Which LED lights depends on the direction from which power is being supplied to the LED's. Should you get to a point where the LED's indicate a change in direction

then you know there's a break in the wire or a bad bulb somewhere between the two sockets just checked and you also know exactly where. The tester also comes in handy for testing strings of lights on vanity mirrors, stage props, and so on. Let's take a look at the circuitry that lets us do this.

A 555 Circuit. The tester circuit is based on a 555 oscillator/timer. However, the IC is used in a non-standard configuration, so let's consider how a 555 timer works in a more common circuit before seeing how it's used in our tester.

A 555 wired for astable operation is shown in Fig. 1. If you apply power to the circuit, capacitor C starts to charge through R_A and R_B , and the output is high. The FET in the 555 can initially be ignored as it is off. The rate of charge is thus determined by the values of R_A , R_B , C, and V_{CC} .

The resistor network composed of

R_{11} – R_{13} divides the supply voltage (V_{CC}) into $\frac{1}{3}V_{CC}$ and $\frac{2}{3}V_{CC}$ (called the "trigger" and "threshold" voltages, respectively). Note that both comparators (C1 and C2) monitor the voltage stored in the capacitor. Comparator C1 compares the capacitor voltage to the threshold voltage and C2 compares it to the trigger voltage.

When the capacitor charges to the threshold voltage, C1 momentarily goes high, toggling the flip-flop. That causes the internal FET to start draining the charge off the capacitor via R_B (without any of the discharge current flowing through R_A), and the output terminal goes low. The rate of discharge is thus determined by R_B , C, and V_{CC} (but not R_A). Once the capacitor voltage drops to the trigger voltage, C2 is triggered and toggles the flip-flop. The FET then turns off, the output goes high, and the capacitor begins to charge again.

There are a few interesting facts

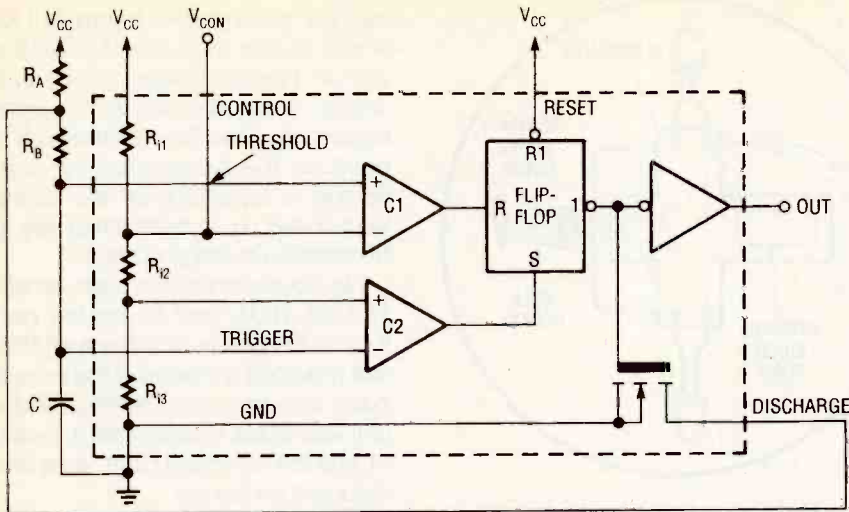


Fig. 1. A 555 oscillator/timer wired for astable operation. Capacitor C charges through R_A and R_B . The rate of charge is thus determined by the values of R_A , R_B , C , and V_{CC} .

about that process. First, the time that it takes for the capacitor to charge from $\frac{1}{3}V_{CC}$ to $\frac{2}{3}V_{CC}$, which is the time the output remains high, is given by:

$$t_h = 0.693(R_A + R_B)C$$

The time it takes for the capacitor to discharge from $\frac{2}{3}V_{CC}$ to $\frac{1}{3}V_{CC}$, which is also the length of time the output is low, is given by:

$$t_l = 0.693(R_B)C$$

Note the absence of R_A in the last equation. That's because only R_B is in the discharge path. That prevents us from attaining a 50% duty cycle (t_h can't equal t_l). Some may propose doing away with R_A , but that would short the power supply through the discharge pin at the beginning of the discharge cycle. However, there is another method for obtaining a 50% duty cycle—by putting a diode pointing down (cathode toward the capacitor) in parallel with R_B , and setting R_A equal to R_B . In that way, R_B is bypassed during charging, but it is still in the discharge path. That technique is used in our circuit, as you'll see in a minute.

The Tester. In the tester (shown in Fig. 2), a battery (B1) is the power supply for the circuit. The 555 oscillator/timer is connected to R1, R2, and C1 so that it produces a train of pulses at its output (pin 3), however its operation has been modified by the addition of D1 as described earlier. The reason for that will become clear as we proceed. The highs and lows produced

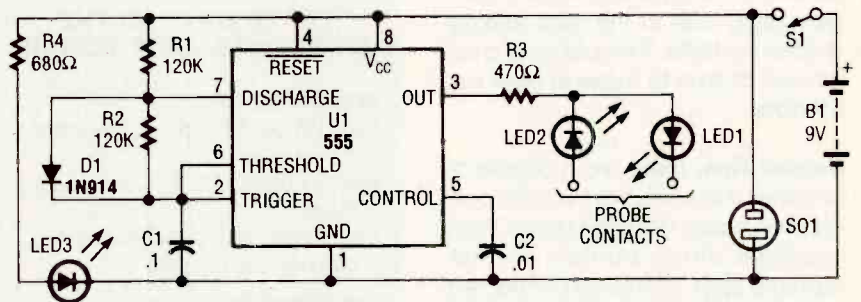


Fig. 2. The 555 oscillator/timer produces a train of pulses at its output, which are presented to LED1 and LED2 via R3.

by the 555 are applied to LED1 and LED2 via R3. The two LEDs have been installed in the base of a Christmas bulb (in place of the incandescent bulb) so that the free end of each LED replaces one of the evicted bulb's contacts.

To help explain how the circuit is used, imagine that the AC plug for a string of lights has been inserted in SO1 and one of the bulbs in the string (let's say the center-most one) has been replaced by the probe so that LED1 is touching the ground side of the bulb's socket and LED2 is touching the positive side of the socket.

With such a setup in mind, if all the bulbs in the string of lights are good, both LEDs will light—LED1 will light when U1's output goes high and LED2 will light when U1's output goes low. However, if any bulb in the path between LED1 and ground is bad (open), LED1 will not light, indicating that the faulty bulb lies in that side of the circuit. On the other hand, if any bulb in the path between LED2 and the positive side of the battery is bad,

LED2 will not light, indicating a problem in that part of the circuit.

Effectively, since a darkened LED indicates the troubled side of the circuit, by placing the probe in the middle of a faulty "sub-string" of lights, you immediately cut the number of suspect bulbs in half. You can repeat that process to cut the remaining number in half, again by re-installing the dislocated bulb and moving the probe to a socket mid-way between the previous location and the end of the string in the direction of the fault. By repeatedly cutting the number of suspect bulbs in half (by moving to the center of the troubled area over and over), you will eventually dislocate the bad bulb, which will cause both LEDs in the probe to light.

Based on some simple math, the strategy provides quite a time savings. Take for example a string of only twenty bulbs. Instead of replacing all twenty bulbs one at a time, you need only perform (at worst) four tests and without exposure to lethal AC power! With larger strands, the tester gives you even more of an edge.

Some of you may be wondering why we chose to use a 555 oscillator/timer, instead of two separate current loops under direct power. The reason is to conserve battery life. The string of lights will quickly gobble-up battery power during normal testing. By using the 555, the battery is only connected to the good section of bulbs 50% of the time until you displace the defunct bulb. All in all, that about doubles battery life.

The reason for designing the circuit for 50% operation, as opposed to some other duty cycle, is to ensure that both LEDs will have equal time to light. That is very important when the probe is placed so that there are a large number of bulbs in the path of

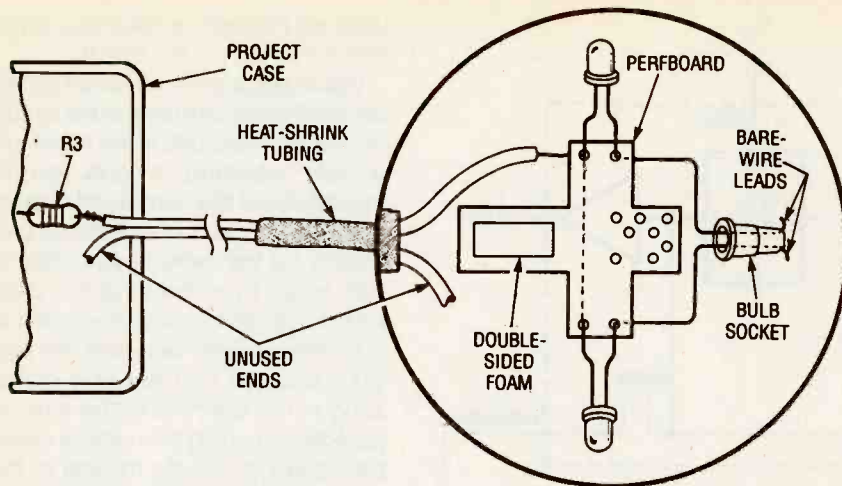


Fig. 3. The probe is made from a T-shaped piece of perfboard. One lead from each LED replaces the original bulb leads in the bulb base.

just one of the LED's: Since that LED will glow dimly due to the total resistive drop of the bulbs, it should be lit a fair amount of time to make its glow noticeable.

Helpful Tips. There are a couple of practices that will make troubleshooting even easier. First of all, most Christmas-light strings contain several separate serial circuits all connected in parallel. To ease troubleshooting, you should mark all of the bulbs in the faulty serial circuit so that you can concentrate on them alone. The best way to do that is to plug the string into an AC source and mark the base of each darkened bulb; remember, however, that you're fooling with AC (albeit it for a short time and with the protection of insulation).

Second, if neither LED in the probe lights in the course of testing, chances are you've installed the probe backwards (with LED1 connected to the positive side of the battery and LED2 connected to ground). If so, pull the probe out, flip it around, and reinstall it. If that doesn't work, there's more than one out-to-lunch bulb, and you have placed the probe between the two bad bulbs. You can find the first bad bulb by working your way toward it (half a suspect area at a time). For example, say you next test a point half-way between the completely powerless socket and the wall plug. If one of the LED's lights, you've passed one of the bad bulbs. You then back up to a socket half-way between the one you're in and the one that provided no illumination.

PARTS LIST FOR THE CHRISTMAS-LIGHT TESTER

SEMICONDUCTORS

- U1—555 oscillator/timer, integrated circuit
- LED1, LED2, LED3—Light-emitting diode
- D1—1N914 small-signal general-purpose silicon diode

ADDITIONAL PARTS AND MATERIALS

- C1—0.1- μ F ceramic-disc capacitor
- C2—0.01- μ F ceramic-disc capacitor
- R1, R2—120,000-ohm, $\frac{1}{4}$ -watt, 5% resistor
- R3—470-ohm, $\frac{1}{4}$ -watt, 5% resistor
- R4—680-ohm, $\frac{1}{4}$ -watt, 5% resistor
- SO1—Single AC socket
- S1—SPST switch
- B1—9-volt transistor-radio battery, Perfboard material, Christmas bulb base, heat-shrink tubing, project box, wall-socket faceplate, battery clip, double-sided foam, stand-offs, wire, solder, hardware, etc.

However, if both LED's are still dark, even though the probe is inserted with the right polarity, then you haven't moved far enough (you are still between the bad bulbs). Once the first corrupt bulb is found, use the normal procedure to find the second bulb.

Getting It Together. Because there aren't very many parts required for the tester, we decided to build the circuit on a piece of perfboard using point-to-point wiring. For very complicated circuitry, it might pay to spend

the time making a PC board, but for simple circuits, it's quicker to do it this way. And the light-tester circuit truly is simple—there are only seven parts mounted on the board. Wherever a point on the board must be connected to something off the board, we installed a 6-inch length of wire to be trimmed to length later on.

We mounted all of the parts, except S1, LED1-LED3, and R4 on the perfboard. The power-on indicator (LED3) was mounted on the lid of the project case, and its current-limiting resistor (R4) was wired in series with it. Switch S1, and the AC socket (SO1), were also mounted on the lid.

In order to be able to plug into a string of lights, we used the plastic base of a spare Christmas light bulb to make a "probe." Normally, a bulb is inserted into the base, and its leads protrude from two holes at the bottom. The bulb's leads are bent up around the sides of the base to hold it in place. To remove the bulb from the base, simply bend the leads out straight and pull out the bulb.

To make the probe, we used a T-shaped piece of perfboard and mounted the direction-indicators (LED1 and LED2) on it. Figure 3 shows the probe's details. One lead from each LED (the cathode of LED1 and the anode of LED2) replaces the original bulb leads. The leads are bent out of the end of the bulb base in the same way as the original bulb leads. The other two LED leads are twisted together and soldered to the wire that connects the probe to the light-tester circuit board. (Actually it's soldered to one end of R3, which is mounted on the board.)

As you can see from Fig. 3, we used two conductor wire for the probe lead, even though only one conductor is needed. The reason we did that is to secure the probe onto the wire more securely. Although shrink-wrap tubing holds the probe together, it's actually two pieces of double-sided tape or foam that secure the probe to the wire.

A simple circuit demands a simple case. There are no particular requirements, so use whatever case you have on hand. The circuit board is mounted on the bottom of the case using a couple of spacers and screws, and the 9-volt battery is held in place with a piece of double-sided tape. ■

We often take for granted that our identity can be verified by our voice. How many times do we receive phone calls, and just by the sound of the person's voice know who it is without having the person identify themselves. Wouldn't it be fun if we could change our voice from time to time? Well, with the *Voice Disguiser* described in this article, it is possible to electronically change the sound of your voice to the extent it can not be recognized.

Have loads of fun fooling friends and family when they call with this simple frequency-shifting circuit

The microphone picks up your voice (converting it into an electrical signal) and feeds it to the audio amplifier, which boosts the input to a usable level. From there, the signal is output to the first modulator, where it is frequency modulated with the output of the first 4-kHz oscillator. The signal is then fed through the first low-pass fil-

BY VINCENT VOLLONO



VOICE DISGUISER

The Voice Disguiser does not muffle or filter your voice, instead it actually shifts the frequency spectrum of your voice higher or lower. The Voice Disguiser is designed to be used over a telephone or a public address system, however, it can also be used by itself. To couple the altered voice to the phone line, the telephone receiver is placed near the Disguiser's speaker.

You can use the Voice Disguiser to hold confidential conversations without revealing the identity of the participants or to play tricks on your friends. You can also use it to answer your phone when you don't want to reveal your identity.

General Description. Figure 1 shows a block diagram of the Voice Disguiser. The circuit is comprised of a microphone, audio amp, two oscillators (one fixed at 4 kHz and the other variable up to the same frequency), two 5-kHz low-pass filters, two modulators, an output amp, and a speaker.

ter, which passes signal frequencies of 5 kHz or less, stripping the high-frequency components from the modulated signal.

From there the signal is fed to the second modulator, where the modulated, low-pass filtered signal is frequency modulated with the output of the variable 4-kHz oscillator. The output of that modulator is then fed through the second low-pass filter (with the same results as produced by the first) to the audio-output amplifier, where its power is boosted and sent to the speaker.

Getting into Details. A complete schematic diagram of the Voice Disguiser, which is a lot less complicated than it might appear, is shown in Fig. 2. Microphone MIC1 picks up the voice signal and feeds it to an audio amplifier, consisting of Q1 and Q2, and a few support components. The amplifier has a low-pass gain response that limits the voice frequencies to 5 kHz or lower.

The voice signal is then fed to the input of the first balanced modulator, which is comprised of U1-a, U1-b, U2-a,

and U3-a. The output of the first 4-kHz oscillator, built around U3-f and U3-e, is fed to the carrier input of the first modulator. The frequency of the first oscillator is controlled by the setting of potentiometer R13. The modulator output—a double-sideband suppressed-carrier signal centered on 4 kHz—is then filtered by the first 5-kHz low-pass filter, formed by U2-b, which eliminates the upper-sideband signals.

Note that at this point, the voice-frequency spectrum is inverted (e.g., the frequencies that were low now become high, and vice versa), making the voice signal completely unintelligible. That means that it is now necessary to reverse the modulation process to recover the voice signal and make it intelligible again. To do that, the output of the first low-pass filter is fed to a second modulator formed by U1-c, U1-d, and U3-b, where it is frequency modulated with the output of the second carrier oscillator, comprised of U3-c and U3-d; the frequency of the second oscillator is controlled by potentiometer R36.

The output of the second modulator is filtered by the second low-pass filter, which consists of U2-d and few support components, and amplified by Q3. The voice output signal from Q3 is fed to U4 (an LM386 low-voltage,

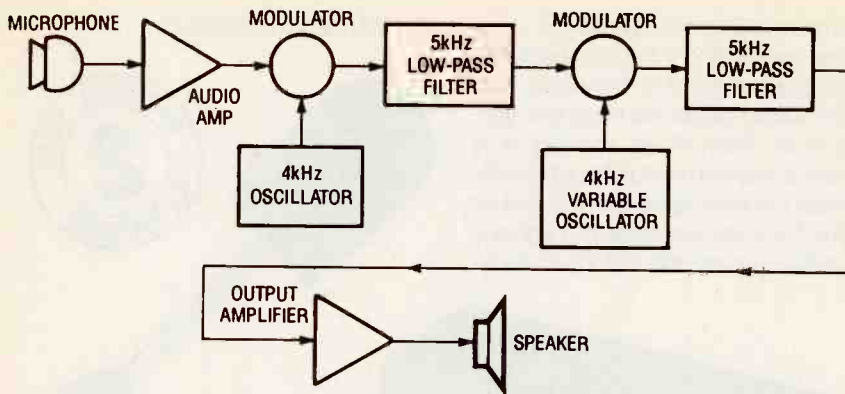


Fig. 1. As shown by this functional block diagram of the Voice Disguiser, the circuit is comprised of a microphone, audio amp, two oscillators (one fixed at 4 kHz and the other variable up to the same frequency), two 5-kHz low-pass filters, two modulators, an output amp, and a speaker.

PARTS LIST FOR THE VOICE DISGUISER

SEMICONDUCTORS

- U1—4016 CMOS quad bilateral switch, integrated circuit
- U2—MC3403 quad op-amp, integrated circuit
- U3—4069 CMOS hex inverter, integrated circuit
- U4—LM386 low-voltage, audio-power amplifier, integrated circuit
- Q1—Q3—PN2222 general-purpose NPN silicon transistor
- LED1—Light-emitting diode

RESISTORS

- (All fixed resistors are 1/4-watt, 5% units.)
- R1, R12, R25—10,000-ohm
 - R2, R7—15,000-ohm
 - R3—68,000-ohm
 - R4, R18, R28—2700-ohm
 - R5—120-ohm
 - R6—56,000-ohm
 - R8, R34—1000-ohm
 - R9—1000-ohm potentiometer
 - R10, R11, R23, R24—100,000-ohm
 - R13—10,000-ohm PC-mount potentiometer
 - R14, R35, R37—5600-ohm
 - R15—220,000-ohm
 - R16, R26—680-ohm
 - R17, R27—9100-ohm
 - R19, R29—150,000-ohm
 - R20, R30—8200-ohm
 - R21, R31—27,000-ohm
 - R22, R32—1500-ohm
 - R33—10-ohm
 - R36—10,000-ohm potentiometer
 - R38—R41—3300-ohm
 - R42—2200-ohm

CAPACITORS

- C1, C3, C7, C12, C15, C21—10- μ F, 16-WVDC, electrolytic

- C2, C5 C22—C25—0.47- μ F, 16-WVDC, electrolytic
- C4, C6, C8, C9, C10, C17—0.005- μ F, ceramic-disc
- C11, C13, C19, C20—0.05- μ F, ceramic-disc
- C14, C16, C18—0.01- μ F, ceramic-disc
- C26—0.001- μ F, 50-WVDC, Mylar
- C27—100- μ F, 50-WVDC, Mylar
- C28—4.7- μ F, 35-WVDC, Mylar

ADDITIONAL PARTS AND MATERIALS

- S1—SPST switch
- B1—9-volt transistor-radio battery
- SPKR1—4-8-ohm speaker
- MIC1—Handheld microphone (see text)
- T1—Audio output transformer
- Perfboard materials, enclosure, AC molded power plug with line cord, battery(s), battery holder and connector, wire, solder, hardware, etc.

Note: The following parts for the Voice Disguiser are available from Xandi Electronics, P.O. Box 25647, Tempe, AZ 85285-5647; Tel. 602-829-8152 (general information and catalogs); 800-336-7389 (orders only). An etched and drilled printed-circuit board (part XV200B) is available for \$15.95; a parts kit (part XV200K) containing all resistors (including potentiometers), capacitors, transistors, integrated circuits, and battery connector for \$40.95. Please add \$4.00 for shipping and handling. COD orders, add \$6.00. Arizona residents please add 6.7% sales tax.

audio-power amplifier) through an impedance-matching transformer, T1. The output of U4 is then used to drive SPKR1 (an 8-ohm speaker). Note: U4 is optional. Although the unit will work without U4, the output will be low but more than sufficient for over-the-telephone use. If the amplifier is left out, capacitor C21 (in the emitter circuit of Q3) can be directly connected to a audio impedance-matching transformer (T1 as shown) and its output used to drive a 4- to 8-ohm speaker.

In operation, if both carrier oscillators are set to the same frequency, the voice signal from the speaker will be an exact duplicate of the input signal from the microphone. However, if the frequency of the second oscillator is varied (via R36), the output voice signal also shifts in frequency. That makes the voice reproduced by the speaker sound higher or lower pitched than normal.

Circuit Construction. The Voice Disguiser was built on a printed-circuit board, measuring about 3 13/16 by 2 7/16 inches. A template of that printed-circuit layout is shown in Fig. 3 for those of you who wish to etch your own board. Or, if you prefer, you can purchase a kit of parts (including a pre-drilled printed-circuit board) or the board alone from the supplier listed in the Parts List. Once you've etched or purchased your printed-circuit board and gathered all the parts listed in the Parts List, assembly can begin.

IC sockets should be provided for U1—U3; besides serving as a circuit-board marker (allowing you to easily locate the proper positions of the support components), they also keep the IC out of harms way (soldering-iron heat) and allow you to make quick and easy replacements should that ever become necessary.

Figure 4 shows the parts-placement diagram. Start by mounting and soldering the IC sockets to the board. Next, install the resistors and capacitors. Be careful that the electrolytic units are properly oriented. After that, carefully install the transistors (Q1—Q3), making sure that they are properly oriented. Once all of the on-board components have been installed, connect short lengths of hook-up wire to the appropriate points on the circuit board for connection to the off-board components.

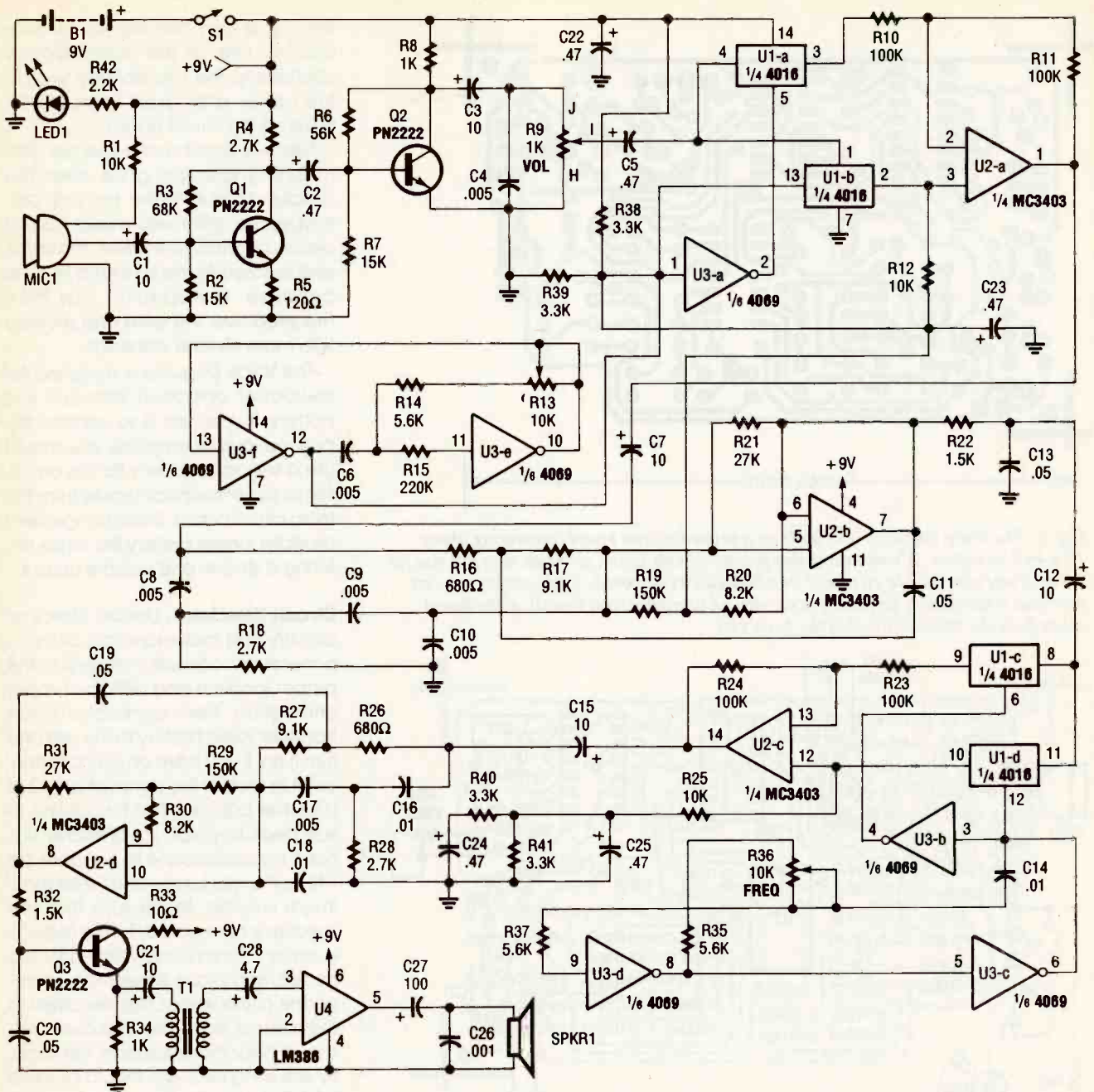


Fig. 2. Although, it might appear otherwise from this schematic diagram, the Voice Disguiser is not very complicated. Note: The LM386 low-voltage, audio-power amplifier (U4) is optional and was added to the main circuit to increase the circuit's output power. It may be left out of your project if desired, however, without it the output volume of the circuit will be greatly reduced.

You will note that the parts-placement diagram shown in Fig. 4 contains no provisions for U4—the LM386 audio-power amplifier, which is optional—or its support components (C26–C28), nor does it have provisions for the audio transformer, T1. If the amplifier is included in your project, it and its associated components can be wired together on a small section of perfboard, along with T1, and

connected to the main circuit board through short lengths of hook-up wire. Although an LM386 amplifier was used to boost the main circuit board's output power, any other type of amplifier can be used to boost the output power of the Voice Disguiser. Be careful when wiring the power amplifier, it's easy to mis-wire those components; in fact, it's wise to double (or even triple) check your work to ensure that the

circuit contains no errors.

In any event, once your project board(s) are completed, prepare the enclosure that will house the circuit board(s). The author's unit was housed in a plastic project box with a metal lid, measuring about $6\frac{1}{4} \times 3\frac{3}{4} \times 2$ inches. It will be necessary to drill holes in the lid of the enclosure for LED1, S1, R9, and R36, and to make a cutout for SPKR1. It will also be neces-

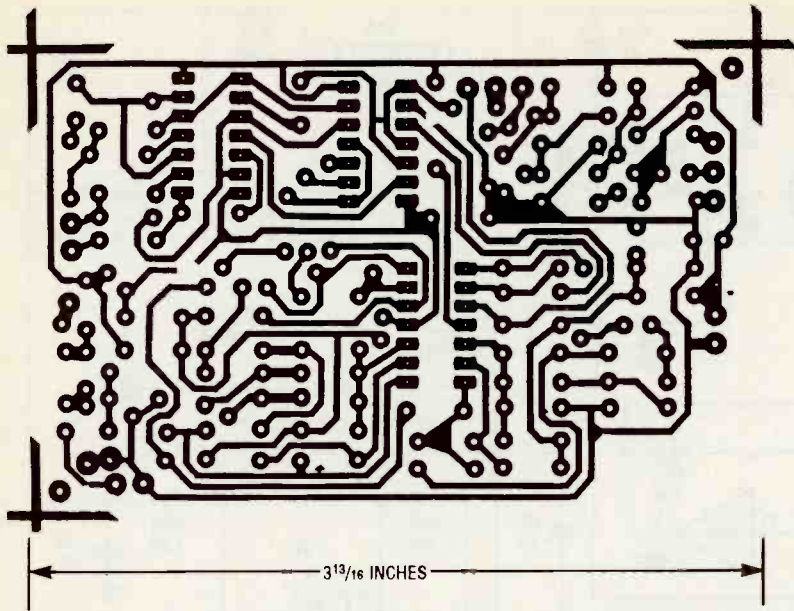


Fig. 3. The Voice Disguiser was built on a printed-circuit board, measuring about $3\frac{13}{16}$ by $2\frac{7}{16}$ inches. A template of that printed-circuit layout is shown here full size for those of you who wish to etch your own printed-circuit board. If you prefer, you can purchase a kit of parts (including a pre-drilled printed-circuit board) or the board alone from the supplier listed in the Parts List.

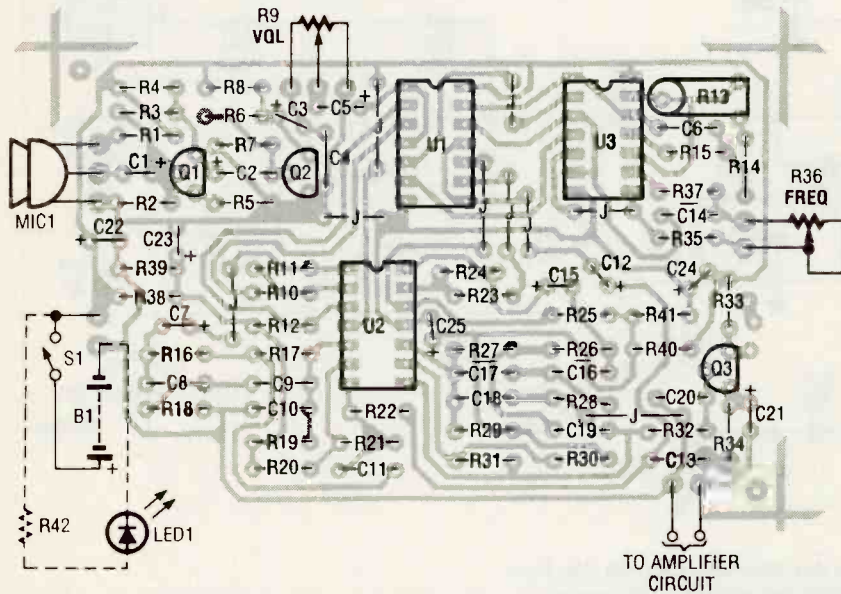


Fig. 4. Here is a parts-placement diagram for the author's printed-circuit layout. You will note that the LM386 amplifier is conspicuously absent from this parts-placement diagram. Also missing are the amplifier's support components (C26-C28), and ditto for the audio transformer (T1).

sary to drill a hole in the side of the enclosure through which to feed the microphone cable. Once all of the holes have been drilled, mount and connect the off-board components and amplifier circuit (if used) to the appropriate points on the printed-circuit board. Note that there is no dedicated connection point on the board for LED1 or R42, the current-limiting resistor for the LED. Those components

were instead connected from battery ground to the "on" side of S1 (the power switch) as shown.

Where the microphone is concerned, the author used one taken from an old video camera. However, you can use just about any microphone that you happen to have on hand. Although the microphone is shown (both in Fig. 2 and Fig. 4) as being a three-terminal (or wire) unit,

the circuit can also be fed by two-terminal unit, as the author did, by connecting the microphone wire to the upper and lower microphone pads on the circuit board.

Next we come to the speaker. First mount a speaker grille over the speaker cutout. In the author's prototype, the grille was made from a piece of window-screen material, and secured to the lid with a silicone adhesive. The speaker was then mounted over the grille and secured with more silicone adhesive.

The Voice Disguiser is designed for low-power operation from a 9 volt battery. If your unit is to contain the optional output amplifier, you should use a separate battery for the amplifier, so as not to siphon power from the main circuit board. That arrangement provides longer battery life, while ensuring a steady and reliable output.

Circuit Checkout. Double check all circuitry and make sure that all components are correctly installed in the proper location and with the proper orientation. Next, connect a 9-volt transistor-radio battery to the unit and turn it on. If you have an oscilloscope, use it to look at the signal at pin 12 of U3, while adjusting R13 for a 4-kHz, 8-volt peak-to-peak, squarewave signal. If no oscilloscope is available, set R13 to the mid range and R9 for maximum volume. Make sure that the speaker is connected. Tune a radio to a station transmitting voice only (no music), and place it near the microphone of the Voice Disguiser. Listen to the sound from the speaker. You should hear the voice from the radio. By adjusting R36, you should be able to shift the pitch of the voice.

Although the maximum audio from the speaker (without the optional audio amplifier) may not be very loud, it provides more than enough volume to drive the transmitter of almost any telephone.

Note that if you are planning to use the Voice Disguiser to transmit over the telephone, it would be best to keep the speaker of the Disguiser right up against the telephone and keep the handheld microphone away from the phone. The reason being is that if the microphone is too close to the telephone, your regular speaking voice will be also picked up by the telephone microphone. ■

Have you ever been frustrated by your digital multimeter when trying to measure resistance below one ohm? If so you're probably not alone because most meters will only measure resistance down to the nearest 0.1 ohm. Well, in this article we'll show you how to build a DMM accessory that will enable you to accurately measure a resistance down to the nearest 0.0001 ohm. The unit injects a precise amp of current into the resistance to be tested. Then you simply use your DMM to measure the voltage drop produced by the injected current. With typical meters, resistances from 1 ohm to 0.0001 ohm can be measured with the aid of the current injector.

You should be able to find many uses for the unit. I have used it to measure shunt resistors, circuit-board-trace re-

If your multimeter is stumped when it comes to reading very low resistance, then this is the multimeter accessory you should build to extend its range.

sistance, relay/switch contact resistance, and motor/transformer winding resistance. You can even use it to determine a wire's gauge by measuring its resistance per unit length or to test diode rectifiers or transistors at 1 amp.

It has some nice features. For example the injector circuit is powered from two "C" cells and features a power-on LED that doubles as a weak-battery indicator. Should the batteries need to be replaced, the LED will fail to turn on during operation.

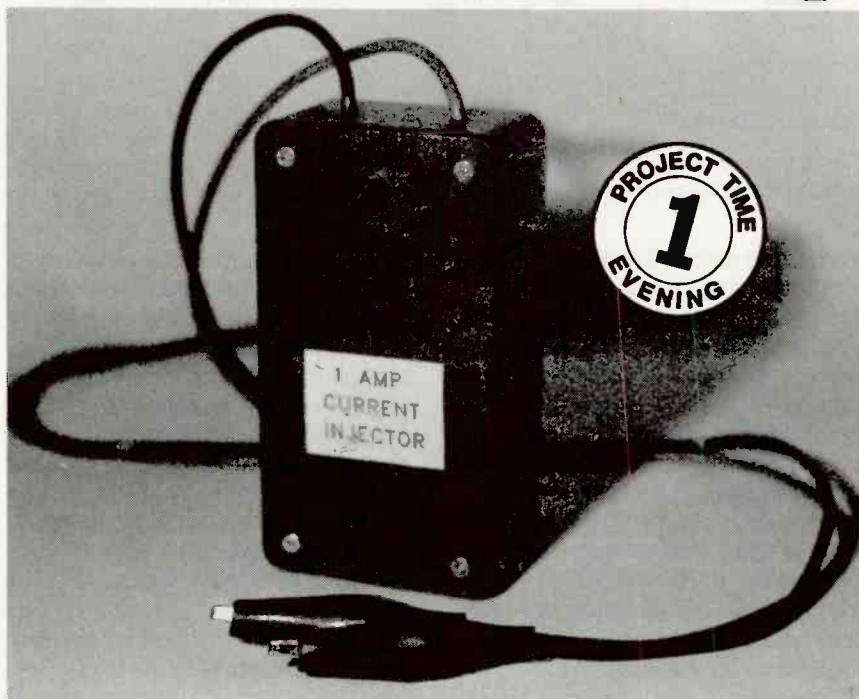
How it Works. Figure 1 contains the schematic diagram for the One-Amp Current Injector circuit. The unit can be divided into three main sections: power supply, current controller, and battery-voltage monitor. Let's examine the power-supply section first.

The circuit is powered by two "C" cells, B1 and B2. A pushbutton switch (S1), which connects the batteries to the circuit, ensures that the system only draws power momentarily. The momentary operation of the switch also discourages prolonged measurement times, increasing the number of measurements that can be taken before the batteries need to be replaced. The large 100- μ F capacitor (C1) helps dampen transients

flows into the inductor (L1) from the 3-volt battery supply. When pin 7 turns off, the energy stored in the inductor emerges as a short voltage pulse, higher in amplitude than the supply voltage. Those voltage pulses are routed to a filter capacitor (C3) through a diode (D1). With the component values chosen, the voltage produced at C3 ranges from about 9 to 12 volts.

The current-control section uses a

Build a One-Amp



Current Injector

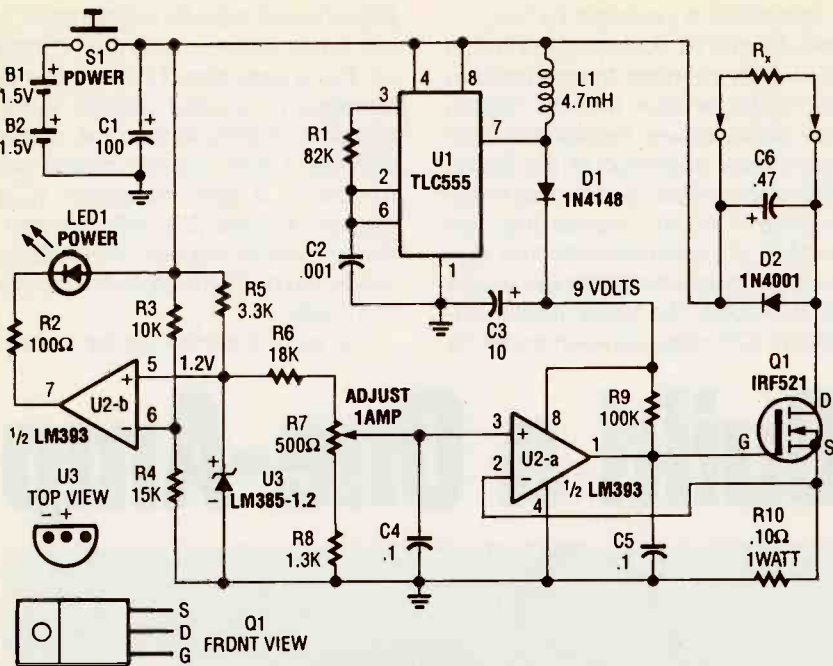
BY DAVID A. JOHNSON

caused by the heavy DC current drawn from the battery during operation.

Because much of the unit's electronic circuits function better at more than 3-volts, the circuit contains a simple flyback voltage converter. It is based on a CMOS version of the classic 555 timer (U1) wired as a non-standard astable oscillator. When pin 7 of the timer (used as an active-low output in this circuit) turns on, current

power MOSFET (Q1) to set the amount of current passed through the unknown resistance (R_x). By controlling the voltage applied to the gate terminal of the FET, it can be made to behave as a variable resistor and can, therefore, vary the current as needed.

For that reason, one comparator in an LM393 IC supplies the FET with a gate-control voltage. That section of the IC has been configured to operate as an operational amplifier with



PARTS LIST FOR THE ONE-AMP CURRENT INJECTOR

SEMICONDUCTORS

- U1—TLC555CP CMOS oscillator timer, integrated circuit
- U2—LM393N dual comparator, integrated circuit
- U3—LM385BZ-1.2 voltage reference, integrated circuit
- Q1—IRF521 or IRFZ12, 50-volt, 0.3-ohm power FET
- D1—1N4148 general-purpose diode
- D2—1N4001 1-amp, 50-PIV rectifying diode
- LED1—Light-emitting diode, red, super-bright T-1¼ style

CAPACITORS

- C1—100-µF, 10-WVDC, aluminum electrolytic
- C2—1000-pF, 50-WVDC, ceramic or Mylar
- C3—10-µF, 25-WVDC, aluminum electrolytic
- C4, C5—0.1-µF, 50-WVDC, ceramic or Mylar
- C6—0.47-µF, 50-WVDC, Mylar

RESISTORS

- (All fixed resistors are ¼-watt 5% units unless otherwise indicated.)
- R1—82,000-ohm
 - R2—100-ohm
 - R3—10,000-ohm
 - R4—15,000-ohm
 - R5—3300-ohm
 - R6—18,000-ohm
 - R7—500-ohm multi-turn trimmer potentiometer (Digi-Key CEG52 or equivalent)
 - R8—1300-ohm
 - R9—100,000-ohm
 - R10—0.1-ohm, 1-watt. (Digi-Key SC1A0.1 or equivalent)

ADDITIONAL PARTS AND MATERIALS

- B1, B2—alkaline "C" cell
- L1—4.7-mH choke coil (Digi-Key TK4320 or equivalent)
- S1—Normally open, SPST, momentary-contact switch
- Printed-circuit or perfboard, LED holder, 2 "C"-cell holder, enclosure, transistor heat sink, red and black hook-up wire, alligator clips (or equivalent), solder, etc.

Fig. 1. The current injector can be broken down into three sections: the power supply (containing a DC-to-DC converter), a current-control circuit, and a battery monitor.

the aid of a resistor (R9) and a capacitor (C5). The two components form a filter network that helps stabilize the voltage fed to the FET. A regulated voltage, developed by a voltage-reference IC (U3) and a resistor (R5), is connected to the noninverting input of U2-a through a voltage-divider network consisting of R6, R7, and R8. The noninverting-input voltage sets the voltage level controlling the FET. Potentiometer R7 allows you to select the value of the noninverting-input voltage so you can precisely adjust the injector's output current to 1-amp.

The injector's output current, which passes through the unknown resistance and the FET (Q1), is also forced through an internal current-monitoring resistor (R10). The voltage developed across R10 is therefore proportional to the injector's output current. The current-monitoring voltage produced by R10 is fed to the inverting side of the control IC (U2-a). So the IC's output supplies the gate of the FET with the correct voltage to maintain the unit's output current at a fixed level.

Diode D3 and capacitor C6 are wired across the output terminals as protection. They absorb any energy that may be sent back to the circuit if you happen to measure a resistor with a large inductance.

The battery-monitor section also

performs an important task. With two fresh "C" cells installed in the unit, a nominal 3-volts is supplied to the current control circuit. However, during operation, the battery voltage will drop. The unit will continue to operate properly as long as the battery voltage remains above 2-volts. The battery monitor's job is to light the power LED (LED1) as long as the battery voltage remains above 2-volts. Should the circuit need new cells, the LED will fail to turn on.

To do its job, the battery monitor uses the second half of the dual-comparator IC (U2-b). It is wired as a classic voltage comparator. The regulated voltage from the voltage reference IC (U3) is compared to a voltage developed by a voltage divider (made of R3 and R4) that is connected to the cells. As long as the voltage from the divider is greater than the reference voltage, the output of the comparator remains low, turning on the power indication LED.

Construction. As illustrated in Fig. 2, the unit's circuitry is housed in a project box (the author's was plastic) that you can purchase from almost any electronic-parts supply store. Using the figure as a guide, first glue a two "C"-cell holder to the inside bottom of the box, with the holder pushed to one end. Drill two ½-inch holes

through the other end of the box to allow the injector's two current-carrying wires to exit. Then drill a ⅜-inch hole for the power switch and a ¼-inch hole for an LED holder through the top cover of the box. With the holes drilled, you can then install the

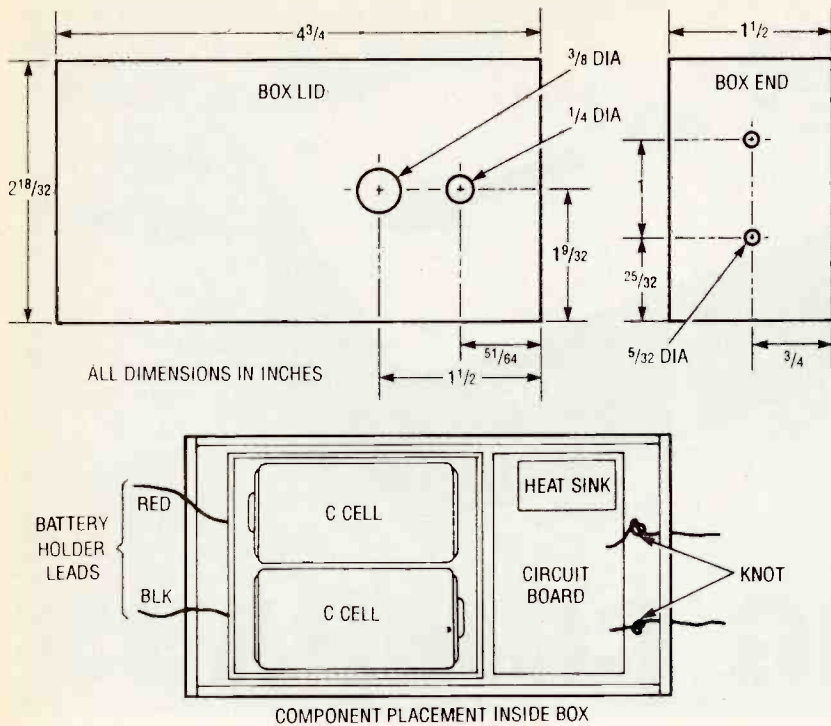


Fig. 2. If you drill your enclosure to these specifications you'll make the task of final assembly a lot easier. Remember to use a holder for the LED.

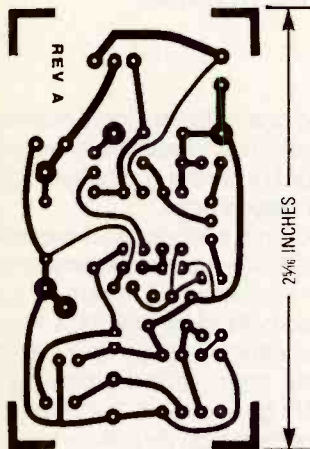


Fig. 3. Using this foil pattern to generate a printed-circuit board will make the assembly of your own current injector a snap.

power switch and the LED (with a holder) in the top of the box.

Next, you'll need to build the rest of the circuit on a suitable platform. The circuit is not complicated and could easily be built breadboard-style. Alternatively, if you wish to, you can etch your own printed-circuit board using the foil pattern shown in Fig. 3. Consult the parts-placement drawing (see Fig. 4) for the correct component placement, being careful to note the orientation and polarity of the components.

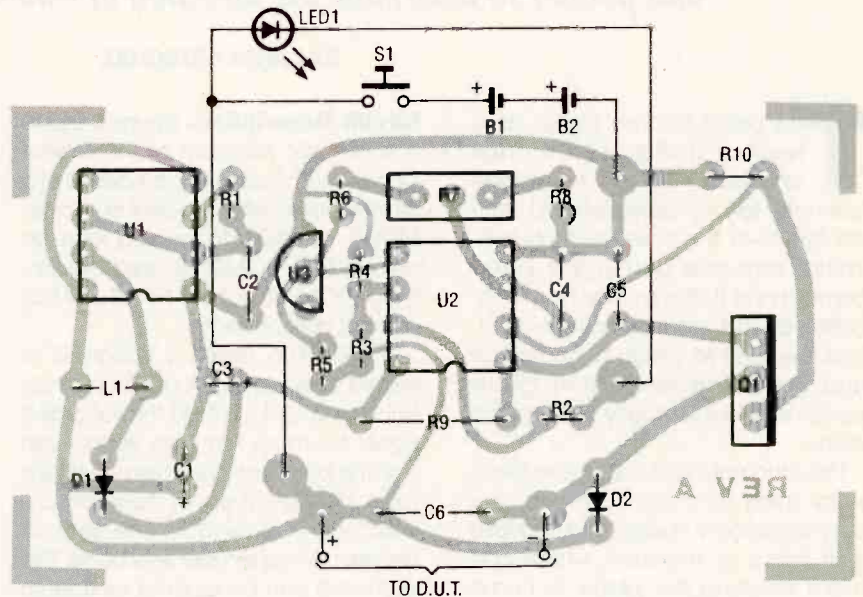


Fig. 4. Follow this diagram to stuff the circuit board. Be sure to orient all the polarity-sensitive parts properly as you proceed.

When you install the FET (Q1), make sure that its body is about 0.15 inches above the board and that it is properly heat-sunk. Once you have soldered all the parts in place, carefully inspect the board for solder splashes, shorts, and misplaced components before moving on.

Next, use pieces of small gauge (No. 28-24) wire to connect the circuit board, battery holder, LED1, and S1

together as shown in Fig. 4. Solder all connections.

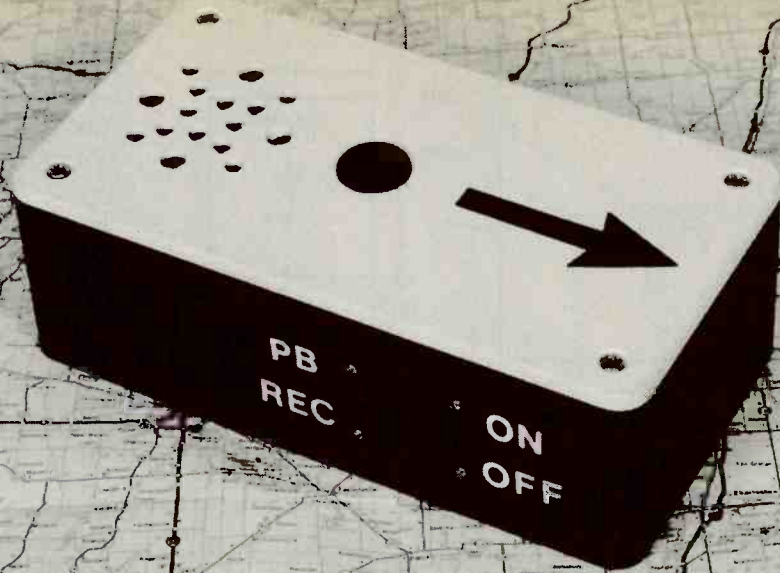
The next step is to prepare two test leads. Use standard No. 20-18 gauge red and black wires about 36 inches long. First solder alligator clips or other suitable probe tips to the end of the test lead wires. Next, feed the two wires through the holes in the end of the box. Once through the hole, tie a tight knot about 1 inch from the end of each wire to act as a strain relief. Finally, solder the leads to the indicated points on the circuit board, paying attention to the polarity—red for positive and black for negative.

With everything installed, inspect the connections to make sure you followed the schematic and parts-placement diagram exactly. If you are satisfied everything is in order, you can install the two "C" cells. The unit still must be calibrated, so do not install the lid at this time.

Unit Calibration. You will need a good digital multimeter to accurately

calibrate the unit. Before connecting the injector's output to the digital multimeter's leads, make sure the meter is set to measure DC amps (usually on a 2-amp scale), and not DC milliamps. **If you mistakenly set the multimeter to the millamp or microamp scale, the 1 amp of current from the injector could blow the meter's protection fuse.**

(Continued on page 102)



TALKING COMPASS

With this project, you need not be able to see a dial pointer to determine the direction in which you are headed.

BY LARRY MITSCHKE

This project came about as a result of a search for a quick and easy method to provide telemetry for a remotely piloted vehicle (RPV)—in this case, a radio-controlled airplane carrying a video camera and TV transmitter. From a location on the ground, that set-up allows the pilot to watch a TV monitor and guide the plane through its paces without actually seeing the plane.

Unfortunately, with the plane flying so far away from the "home 40," it is easy to become disoriented and lose your sense of direction, which can make returning the plane to home base very difficult if not impossible. That's when I decided that an on-board compass would be necessary to avoid losing the plane. And since the pilot (myself) would not be in the cockpit where the compass heading might be checked, it was decided that an audible compass (whose output could be relayed by an audio input on the TV transmitter) was the easiest way to transfer that vital information to the pilot. That led me to develop the *Talking Compass* that is described in this article.

Circuit Description. Figure 1 shows a schematic diagram of the Talking Compass. The circuit is comprised of a directional sensor (or digital compass, MOD1), an ISD1016 analog storage device (U2), a 74S188 preprogrammed PROM (U3), and a handful of additional components.

The ISD1016, which is designed to record and playback analog signals (such as voice) will hold the recorded signal for more than ten years even with the power off. The chip provides a total storage time of 16-seconds, which can be used in one shot, or broken up into smaller segments. The segments can be as short as a tenth of a second. Because each tenth of a second of the total storage time is fully addressable by way of the chip's 8-bit binary address (pins 1 through 7, and 9 and 10), messages can be recorded on those small segments and individually selected for playback by accessing the proper address bus.

In our application, the total time is divided into eight 2-second segments. The starting point addresses for the eight 2-second segments are located at the binary equivalent of 1, 20, 40, 60, 80, 100, 120, and 140. By

placing one of those binary numbers on the chip's address bus, a two second word or phrase can be recorded and/or played back.

Directional information is provided by MOD1, which uses a subminiature jewel-suspended magnet surrounded by four Hall-effect IC's. In use, the Hall-effect device that is directly opposite north turns on, causing its output to go to ground. The other outputs are held high by pull-up resistors R13 through R16.

As the sensor is rotated (say between north and east) two of the Hall-effect devices will be directly opposite north, so they both will turn on, thereby giving the intermediate direction (in the above example, north-east). The digital compass (MOD1) outputs directional information as a 4-bit binary code. That 4-bit information is transformed into 8-bit binary data by integrated circuit U3—a 256-bit bipolar PROM. Table 1 is the truth table for the 74S188 PROM.

The 8-bit data is used to select specific starting point addresses on the ISD1016 (U2), which can then be recorded to; or, if a message has been recorded at the specified address, it

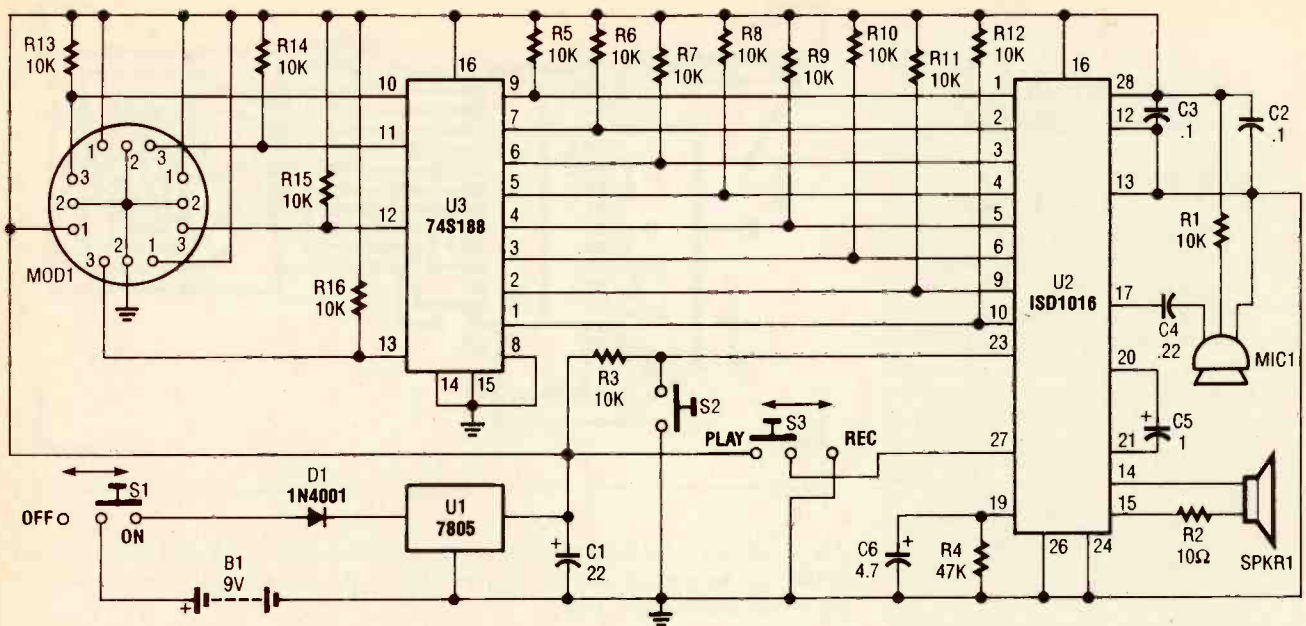


Fig. 1. The Talking Compass is comprised of a digital compass (MOD1), an ISD1016 analog storage device (U2), a 74S188 preprogrammed PROM (U3), and a handful of additional components.

TABLE 1—74S188 TRUTH TABLE

Directory	Input					Output							Decimal Equivalent	
	A4	A3	A2	A1	A0	B0	B1	B2	B3	B4	B5	B6	B7	
North	L	H	L	H	H	0	0	0	0	0	0	0	1	1
N.W.	L	L	L	H	H	0	0	0	1	0	1	0	0	20
West	L	L	H	H	H	0	0	1	0	1	0	0	0	40
S.W.	L	L	H	H	L	0	0	1	1	1	1	0	0	60
South	L	H	H	H	L	0	1	0	1	0	0	0	0	80
S.E.	L	H	H	L	L	0	1	1	0	0	1	0	0	100
East	L	H	H	L	H	0	1	1	1	1	0	0	0	120
N.E.	L	H	L	L	H	1	0	0	0	1	1	0	0	140

can be played back. Switch S3 is used to select the mode of operation; record or playback. Switch S2 enables the recording or playback process chosen by S3. Diode D1 at the input to U1 (a 7805 5-volt voltage regulator) protects the circuit in case the battery is connected with its polarity reversed, which would ruin the compass sensor. The speaker connects directly to U2, which has its own output amplifier.

Construction. Begin by making a printed-circuit board; a full-size printed-circuit pattern is provided in Fig. 2. After etching and drilling the board, clean the traces with steel wool and check for shorts.

Begin assembling the board by installing IC sockets for U2 and U3, guided by the parts-placement diagram shown in Fig. 3. Follow that with the resistors and the capacitors; then diode D1, the digital compass

(MOD1), and the voltage regulator (U1). Solder wires to the appropriate pads on the board for connection to the off-board components (battery connector, speaker, switches, and microphone).

Once the circuit has been checked for faults, put the assembly aside for a while, and prepare the enclosure that will house your project. The circuit must be housed in a non-magnetic enclosure (such as Radio Shack's #270-223 plastic project box). Whatever housing you select, make sure that it allows the speaker to be separated from the digital compass by at least 4 inches (center to center) so that the speaker magnet will not affect the operation of the compass.

It will be necessary to drill mounting holes in the side of the enclosure for the switches. A hole for the microphone along with speaker grille holes should also be drilled in the lid of the

enclosure. Once the holes have been drilled, mount the off-board components to the enclosure. The speaker can be mounted using silicon sealer or some other suitable adhesive. The microphone element can be secured to the lid of the enclosure by placing a rubber grommet in the microphone hole and just pressing MIC1 into place.

Once the off-board components have been mounted to the enclosure, install the circuit board and connect the off-board components to the circuit board using hookup wire. Be sure that when the lid is attached to the enclosure, the compass is located at the end opposite the speaker. Label the playback/record (S3) and on/off (S1) switches.

Install a battery using double-sided foam tape to hold it in position and check for correct voltage at U2's and U3's power terminals. Also check for continuity to common at the ground terminals of those IC's. Next install the two DIP IC's (U2 and U3). Remember that the ISD1016 is a CMOS device, and is thus sensitive to electrostatic discharge.

Now comes the moment of truth.

Operation. To record a message, place S3 in the REC (record) position and apply power to the circuit. Rotate the box to the direction (east, west,

PARTS LIST FOR THE TALKING COMPASS

SEMICONDUCTORS

- U1—7805 1-amp, 5-volt, voltage regulator, integrated circuit
 U2—ISD1016 analog storage device, integrated circuit
 U3—74S188 256-bit PROM (preprogrammed), integrated circuit
 MOD1—Dinsmore digital compass
 D1—1N4001 1-amp, 50-PIV, rectifier diode

RESISTORS

- (All resistors are 1/4-watt, 5% units.)
 R1, R3, R5–R16—10,000-ohm
 R2—10-ohm
 R4—470,000-ohm

CAPACITORS

- C1—22- μ F, 16-WVDC, tantalum
 C2, C3—0.1- μ F, ceramic-disc
 C4—0.22- μ F, ceramic-disc
 C5—1- μ F, 16-WVDC, axial-lead electrolytic
 C6—4.7- μ F, 16-WVDC, axial-lead electrolytic

ADDITIONAL PARTS AND MATERIALS

- S1, S3—DPDT slide switch
 S2—SPST momentary pushbutton switch
 SPKR1—8-ohm, 0.2-watt, 2-inch speaker
 MIC1—Electret microphone element
 B1—9-volt transistor-radio battery
 Printed-circuit materials, enclosure, 9-volt battery holder and connector, grommet, adhesive, wire, solder, hardware, etc.

Note: The Digital Compass (MOD1), part #1490, is available from Dinsmore Instrument Co., 1814 Remell St., Flint, MI 48503, for \$12.00 each, plus \$0.52 postage. Michigan residents must add appropriate sales tax.

The ISD1016 analog storage chip (U2) is available from Information Storage Devices, Inc., 2841 Junction Avenue, Suite 204, San Jose, CA, 95134, for \$27.99 each postpaid. California residents must add appropriate sales tax.

The 74S188 256-bit preprogrammed PROM (U3) is available from Funtech, P.O. Box 772747, Houston, TX 77215-2747, for \$5.99 each postpaid. Texas residents must add appropriate sales tax.

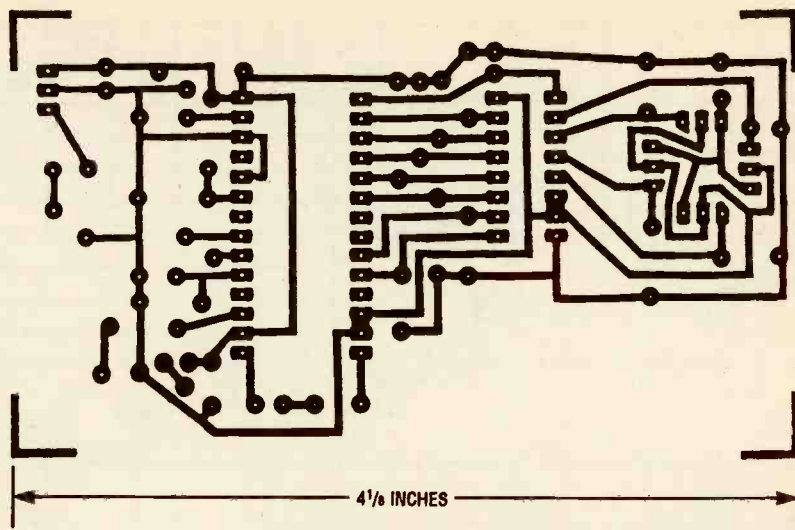


Fig. 2. Here is a full-sized template of the printed-circuit artwork used to produce the author's prototype unit. After etching and drilling the board, clean the traces with steel wool and check for shorts.

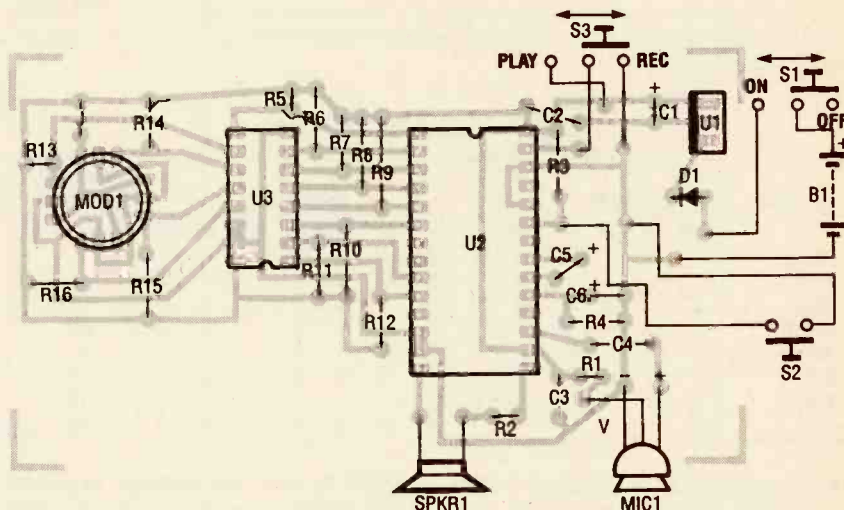


Fig. 3. Assemble the board guided by this parts-placement diagram, beginning with the IC sockets for U2 and U3, followed by the resistors and the capacitors; then diode D1, the digital compass (MOD1), and the voltage regulator (U1).

north, or south) that you want to record and make sure that the project is level. Press S2 and speak into MIC1. When through speaking, release S2 to stop recording. You have two seconds to record your phrase or word. You could say "north" or a quick "you're facing north." I have found it better to face off to one side while speaking so that your breath does not hit the microphone and produce wind noises when recording "s" and "th" sounds.

Check the recording by placing S3 in the PLAY (playback) position, and with the box pointed in the same direction momentarily press S2. The compass should play back what you've recorded. It is not necessary to

hold S2 down; just a quick press and release is all it takes.

Go through the recording process with all 8 direction points, positioning the compass to point in each direction. Remember that the sensor is internally damped and it takes a couple of seconds for it to stabilize in the correct direction when setting up for recording or playback. If you attempt to record messages that are longer than two seconds, the recording will run over into another section and erase whatever might have been stored there. But it is a simple matter to re-record both.

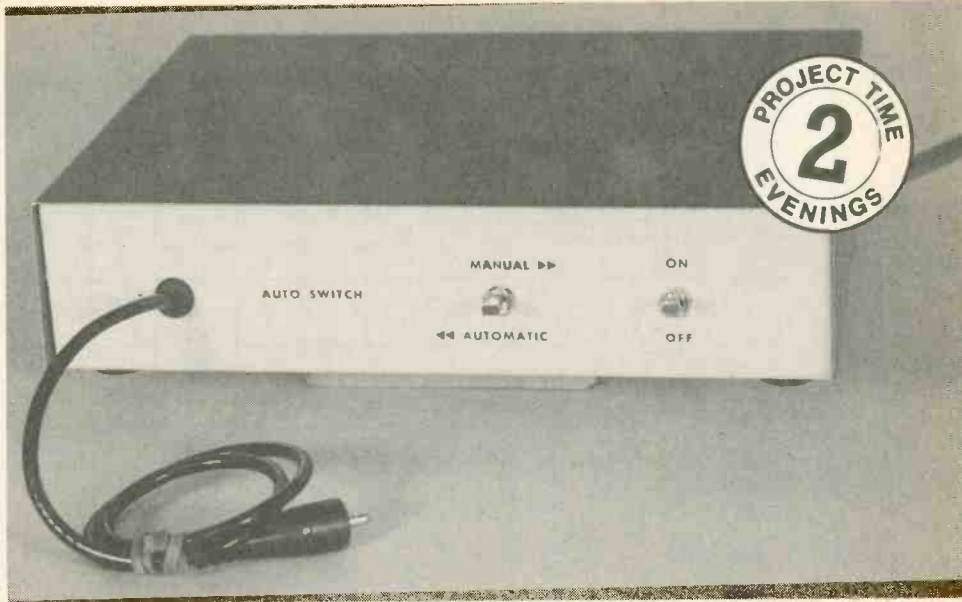
It is possible to playback everything
(Continued on page 102)

Using a cable-ready VCR as a tuner can, in many cases, save the cost of renting a cable box. Unfortunately, doing so means always having to turn two units (both the TV and VCR) on or off due to the lack of switchable accessory outlets. Admittedly, that's a minor annoyance, but it is a constant one. Tiring of that inconvenience, I came up with the *VCR/TV Auto-Switch* described in this article.

What the VCR/TV Auto-Switch does is monitor the baseband-video output of your VCR. When a video signal is detected, the VCR/TV Auto-Switch automatically turns on your TV set or video monitor. Note, however, that this approach will not work with a television that stores channel or volume information in a volatile memory.

How It Works. A schematic diagram of the VCR/TV Auto-Switch is shown in Fig. 1. The circuit is comprised of a 24-volt center-tapped transformer (T1), a 1-amp, 100-PIV fullwave bridge rectifier (BR1), and two 12-volt regulators (U1 and U2), which form a dual-polarity, regulated, power supply; a dual BiFET op-amp (U3) and a general-purpose NPN silicon transistor (Q1), which form the basis of a signal detector/trigger circuit; a 12-volt relay (K1); two AC sockets (SO1 and SO2); and a few additional components.

A voltage divider formed by R5 and R6 provides a very small positive offset to the inverting inputs of both U3-a and U1-b to help prevent false triggering. The circuit takes its input from the baseband-video output of your VCR via PL2 (an RCA plug that mates with the video-output jack of the VCR). When switches S1 and S2 are in the positions shown and the VCR is turned off, no signal is applied to the circuit (through PL2), so the input to op-amp U1-a is at zero volts, forcing its output low. That low is applied to the non-inverting input of U3-b, forcing its output low. The low output of U3-b holds Q1 at cutoff, keeping relay K1 from energizing, and the TV connected to SO2 from turning on. Note that when there is no signal present, the output of U3-b swings close to the negative supply rail, producing a negative voltage that exceeds the emitter-base breakdown voltage of Q1. Diode D2's



Automatic Power Switch for your TV

Add an accessory outlet to your video system that turns on your TV whenever your VCR is turned on

function is to block the negative going output of U3-b, thereby preventing damage to Q1.

On the other hand, when the VCR is turned on, a baseband-video signal is applied to the circuit at PL2. That signal is routed to the non-inverting input of U3-a, causing the output of that op-amp to swing positive. The output of U3-a is fed through diode D1 (which passes only the positive portion of the signal), causing C11 to charge. Diode D1 also prevents the charge on C11 from being discharged through U3-a during U3-a's negative-going output transition. The charge on C11 is bled off via R7 during the negative-going output transition and power is removed from the circuit. The C11/R7 combination also forms a glitch filter, which provides a short time-delay that prevents a momentary signal loss from cycling the television or monitor off and on.

The output of U3-a is applied to the

non-inverting input of U3-b, causing its output to go high. That high is applied to the base of Q1 through D2 and R8, causing Q1 to turn on.

When Q1 conducts, it, in turn, completes the ground path for the relay, causing it to energize. With the relay energized, AC line voltage is applied to SO2, automatically turning on the TV. Diode D3 is used to protect Q1 from the inductive kickback (spikes) caused by the relay's collapsing field. Without that protection, an inductive spike could cause Q1 to short, turning it into a three-legged Zener diode. That would result in the TV being on continually.

Switch S1 allows you to choose between auto and manual operation. When S1 is placed in the MANUAL position and S2 is set to the ON position, a positive voltage from the power supply is applied to the non-inverting input to U3-a, causing the TV to turn on as if the circuit were in the auto mode

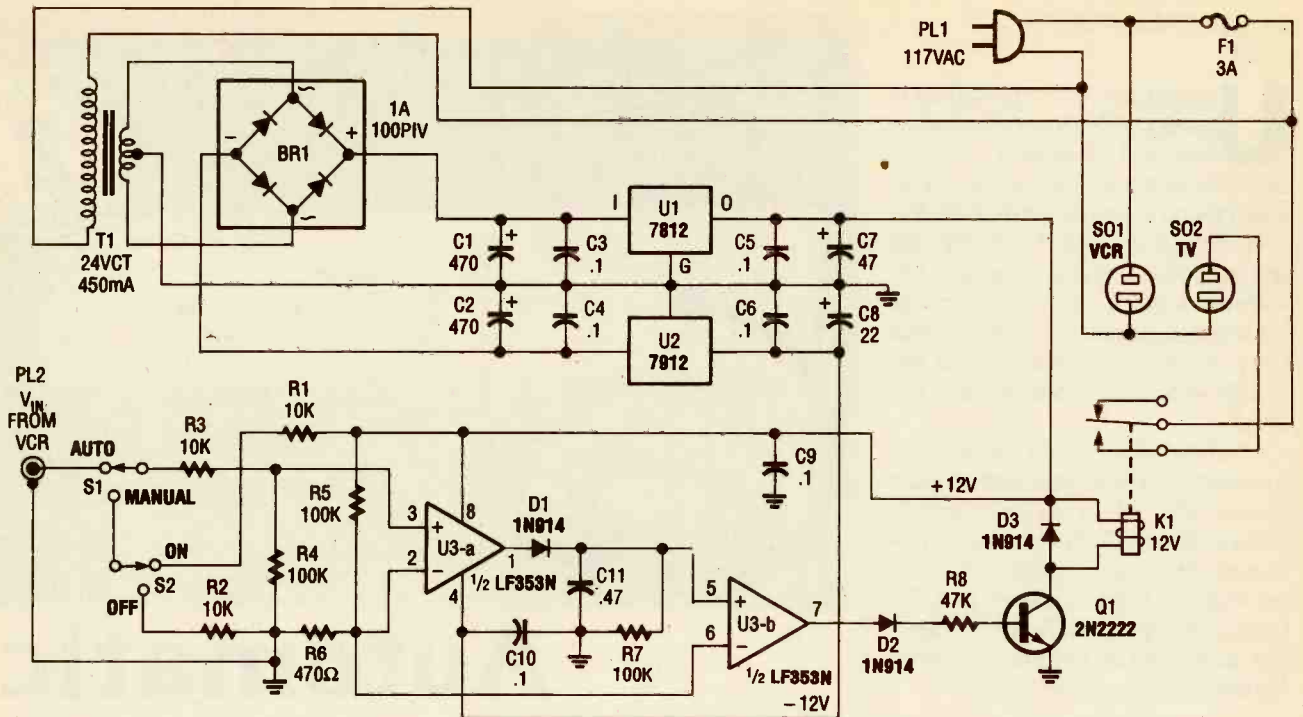


Fig. 1. The VCR/TV Auto-Switch is comprised of a 24-volt center-tapped transformer (T1), a 1-amp, 100-PIV, fullwave bridge rectifier, and two 12-volt regulators (U1 and U2), which form dual-polarity, regulated, power supply; a dual BiFET op-amp (U3) and a general-purpose NPN silicon transistor (Q1), which form the basis of a signal detector/trigger circuit; a 12-volt relay (K1); two AC sockets (SO1 and SO2); and a few additional components.

and a video signal from the VCR were present.

Construction. As shown in the photo, the author's prototype of the VCR/TV Auto-Switch was assembled on a section of copper-clad experimenter's board and point-to-point wiring was used to make the component interconnections. When assembling the circuit, all of the standard project-building precautions apply: Keep all leads as short as possible, and all power-supply bypass capacitors (C3-C6, C9, and C10) should be mounted as close to their respective IC's as possible. It is also recommended that an IC socket be provided for U3 (the op-amp).

Because 117-volts AC is applied to the circuit board via the relay, the board must be securely mounted on standoffs. In addition, wire connections to the relay should be made with wire of sufficient size to handle the AC-line voltage. Instead of enlarging the pre-drilled holes in the experimenter's board to accommodate 18-gauge (line-cord size) or heavier wire, the author used dual strands of 20-gauge hook-up wire for the relay, which is more than equal to a single 18-gauge

wire. Mount the relay to the board and connect short lengths of wire to the relay contacts. Do not connect the relay-contact wires to SO2 and the AC line at this point; you will be instructed when to do so later on, during the checkout procedure.

Note that the circuit contains two AC sockets (SO1 and SO2): The two sockets are actually a single, standard duplex AC wall-outlet. The socket

should be of the type that has break-away tabs between the two outlets. As shown in the schematic diagram, the cold (or neutral, large-spade side) remains as normal; however, the two hot tabs have been separated, with the hot side of SO1 going directly to the AC line, and the hot side of SO2 going to the relay's wiper.

For safety reasons, it is also important that the duplex socket (which is

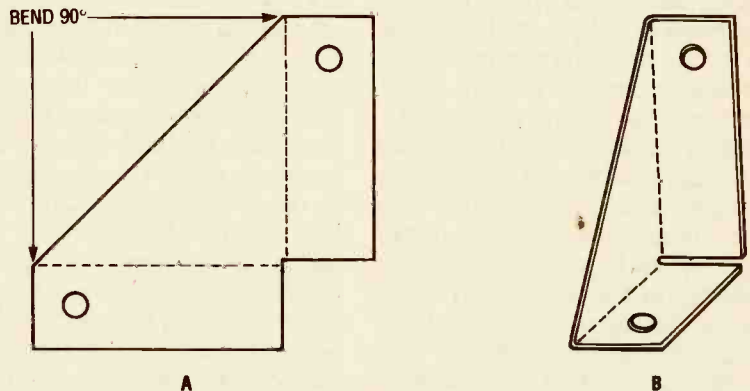
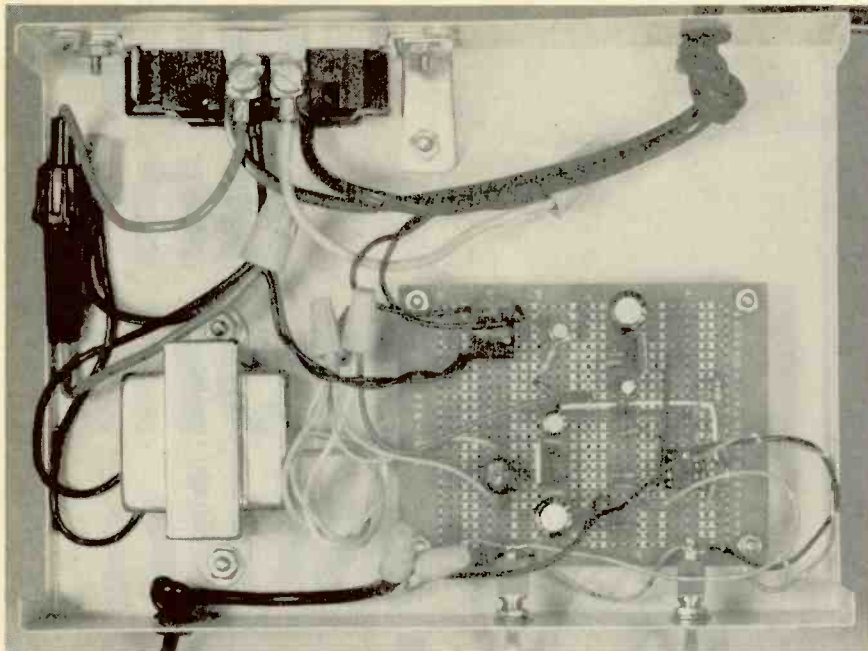


Fig. 2. For safety reasons, it's also important that the duplex socket mounted to the rear panel of the enclosure be able to withstand power-cord insertion force without the case flexing and possibly forcing the AC wiring to contact the case or other components. To that end, reinforcing brackets fabricated from scraps of sheet aluminum were placed at one end (either end) of the outlet, although placing brackets at both ends makes for a much sturdier project.



Here is an inside view of the VCR/TV Auto-Switch. In the prototype, fuse F1 is not the board-mounted type; instead the author chose to use an in-line fuse. The enclosure for the project has enough space for the circuit board, as well as all of the off-board components.



Once the project enclosure has been drilled, labels can be affixed to the front and rear panels to indicate switch functions, and outlet designations.

mounted to the rear panel of the enclosure in the prototype) be able to withstand the power-cord insertion force without the case flexing and possibly forcing the AC wiring to contact the case or other components. To that end, reinforcing brackets fabricated from scraps of sheet aluminum were placed at one end (either end) of the outlet, although placing brackets at both ends makes for a much sturdier project. Figure 2 gives details on how to fabricate the bracket(s).

Since the project is intended to be in constant use, it does not have a power switch; however, adding one certainly wouldn't hurt anything. It is essential that a polarized AC power cord be used to connect the circuit to

the AC source. That's because the relay can interrupt only one line and that really should be the hot (small spade) side of the AC line cord. Modern electronics gear (particularly VCR's and TV's) may (and often do) also require the correct polarity. A three-wire plug and cord (with the ground wire connected to the case) is even better for PL1.

When it comes to PL2, you have a couple of options: You could use a jack instead of a plug for PL2, and use an RCA patch cord to connect the circuit to your VCR; or you can do as the author did, cut the connector from one end of a patch cord and connect the wires directly to the circuit board. With the latter arrangement, you could simply plug the unit

PARTS LIST FOR THE VCR/TV AUTO-SWITCH

SEMICONDUCTORS

- U1—7812 12-volt, 1-amp, positive voltage regulator, integrated circuit
- U2—7912 12-volt, 1-amp, negative voltage regulator, integrated circuit
- U3—LF353N or TL082 dual BiFET op-amp, integrated circuit
- Q1—2N2222A general-purpose NPN silicon transistor
- D1—D3—1N914 general-purpose, small-signal diode
- BR1—1-amp, 100-PIV, fullwave bridge rectifier

RESISTORS

- (All resistors are 1/4-watt, 5% units.)
- R1—R3—10,000-ohm
 - R4, R5, R7—100,000-ohm
 - R6—470-ohm
 - R8—47,000-ohm

CAPACITORS

- C1, C2—470- μ F, 35-WVDC, electrolytic
- C3—C6, C9, C10—0.1- μ F, 50-WVDC, monolithic-ceramic or ceramic-disc
- C7—47- μ F, 35-WVDC, electrolytic
- C8—22- μ F, 35-WVDC, electrolytic
- C11—0.47- μ F, 35-WVDC, tantalum

ADDITIONAL PARTS AND

MATERIALS

- T1—24.6-volt, center-tapped, 450-mA transformer
 - F1—3-amp, fast-acting fuse
 - K1—SPDT 12-volt relay (Omron G2E-184P, All Electronics catalog #RLY 787)
 - S1, S2—SPDT toggle switch
 - PL1—Polarized AC power plug with line cord
 - PL2—Video dubbing (patch) cord, see text
 - SO1, SO2—117-volt duplex AC outlet
- Experimenter's board, enclosure, fuse holder, 8-pin socket, standoffs, strain-reliefs or grommets, wire, solder, hardware, etc.

into the VCR's baseband-video output.

If you opt for the latter arrangement, cut off one of the RCA plugs and carefully remove one inch of the thin outer insulation, exposing the braided sheath. Bend the cable at the end of the insulation and spread the braid away from the bend. Pull the inner cable through the opening in the braid. Strip about 1/2 inch of insulation from the inner cable. Connect

(Continued on page 102)

Does your present lure fail to attract the fish to your line? If so, perhaps an illuminated lure will change your luck, and enable you to catch the big one that always seems to get away.

It rained all weekend again. I had planned to go fishing but it just wasn't in the cards. So, I thought I would tinker around with my electronic stuff and wait for the rain to stop. Obviously, my heart wasn't in it, because what grew out of that weekend was a strange, but effective, fishing lure. Perhaps, it is stretching the definition of "electronics" to call it an electronic device, but it does use electricity and in some mysterious way it communicates with fish.

The lure is the essence of simplicity (see Fig. 1). Using a paper clip, a calculator battery, and a light-emitting diode (LED) or micro lamp, you can make an effective multi-purpose fish-catching device and amaze your friends at the same time. If you're like me, your friends have come to expect strange ideas from you and this device will certainly strengthen that image. I think it may even be legal, but you better check the local laws governing your favorite fishing hole to be sure.

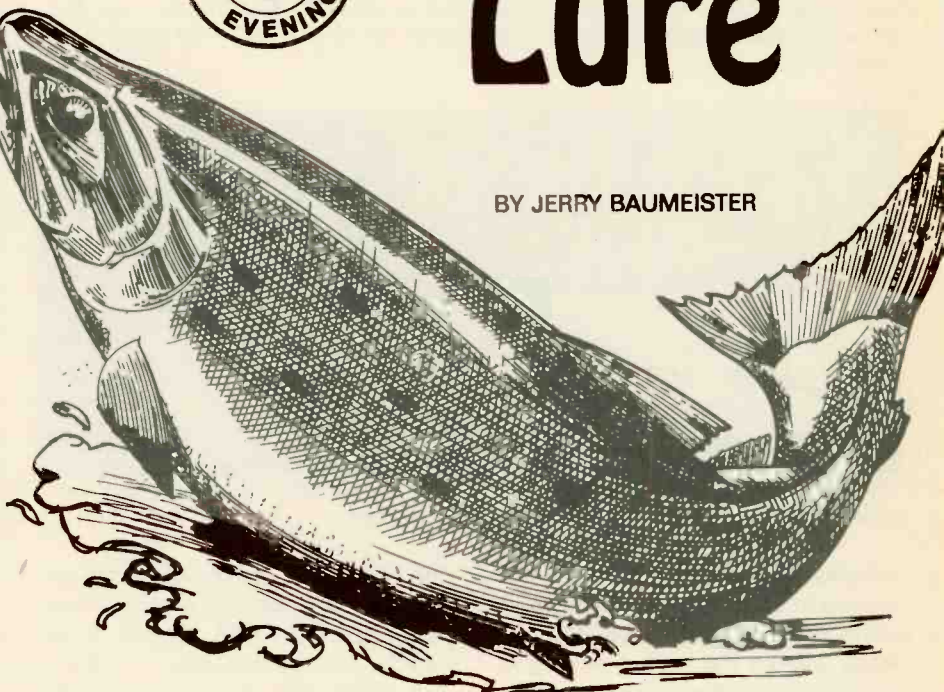
The lure consists of a large paper clip, a flat, wafer-type battery (1.5 or 3 volt), an LED or micro lamp, a treble hook, and a pair of needle-nose pliers. The author's version uses a 3.0-volt lithium battery (CR-2430), but the lure can be modified to use any size wafer battery. There is one problem though; if you are going to use an LED as the light source, you'll need to use a 3-volt battery. It takes 1.6 volts of junction potential to "light" an LED and the 1.5 volt batteries just don't have enough voltage.

How it Works. The circuit behind the fish lure (see Fig. 2) is so simple—a battery, resistor, and a lamp—that it is almost not worth showing. A resistor can be added (as shown) to limit current through the light-producing element and to regulate the brightness of the light, but it is not usually needed because the internal resistance of the battery will keep the current at about 33 mA.

Build an Electronic Fishing Lure



BY JERRY BAUMEISTER



The prototype unit used a 1.5-volt lamp powered from a 3-volt battery. That's a bit over the lamp's designed voltage, and tends to shorten both battery and lamp life a bit. However, the extra brightness is attractive to the fish and since catching fish is what this is all about, operating the lamp a little "hotter" than the lamp designers had intended seems a worthwhile tradeoff.

You can use either an LED or micro lamp. You can even use one of those flashing LED's, but make sure it can operate from a 2.5-volt source. I have found that in the waters around my

home, diffused yellow LED's work best for black bass. (I don't know why. I guess it's just part of the mystery that makes fishing so interesting.)

Water proofing was not necessary for the ponds where I fish. The resistance of local pond water around here is about 10,000 ohms per cm. Since the resistance through the lamp circuit is about 11 ohms, most of the current flows through the lamp circuit and not the water (current follows through the path of least resistance). The resistance of the circuit using an LED instead of a micro lamp is a bit higher, but it is still low

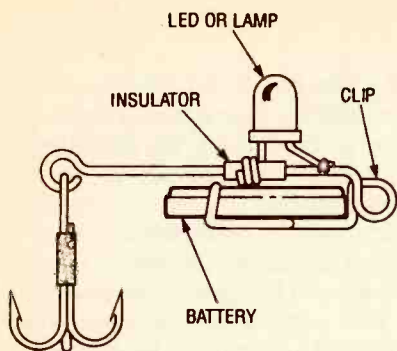


Fig. 1. The Electronic Fish Lure was created from an ordinary paper clip twisted so as to hold the leads of an LED in contact with both poles of a battery.

PARTS LIST FOR THE ELECTRONIC LURE

LED1—Light-emitting diode or micro lamp
 R1—Optional, see text
 B1—1.5-3-volt, flat wafer-type, calculator battery, see text
 Paper clip, cellophane tape, thin-plastic or film insulating material (see text), treble hook, fingernail polish (see text), etc.



Fig. 2. Here is the simple circuit that comprises the electrical portion of the Electronic Fish Lure. Note: The resistor (R1) may or may not be needed; that will have to be determined by experimentation.

enough to feed the lion's share of the current through the lamp.

In chlorinated water, water that has a high ionic concentration, or in salt water, water proofing is necessary. A little fingernail polish works just fine. Just paint the entire lure, battery and all. You can even use different colors to jazz it up a little. I favor yellow lures with red dots, but use whatever color scheme or pattern that works for you.

The lure can be turned on and off by removing the battery or by sliding a small piece of plastic or film between the battery and the point where it touches the lamp lead. Push the film in to turn the lamp off, remove it to turn the lamp on.

Construction. The wire clip is everything. Take your time and get it right. Start, as shown in Fig. 3, by straightening a large paper clip. Figure 3A shows the

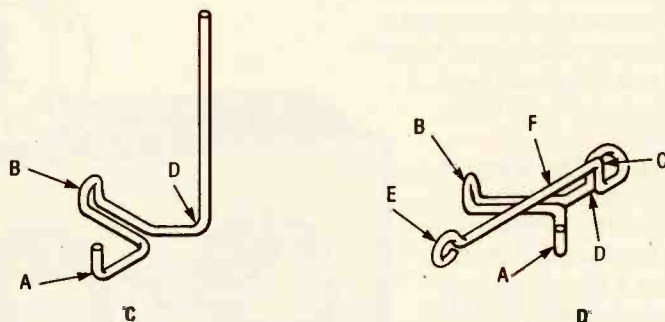
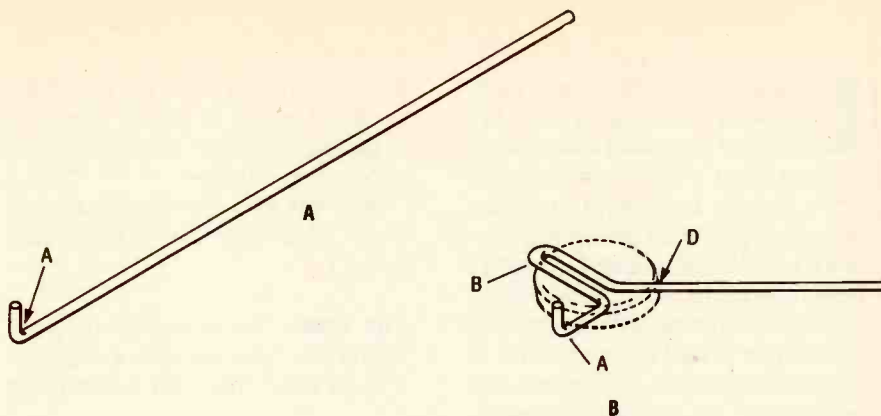
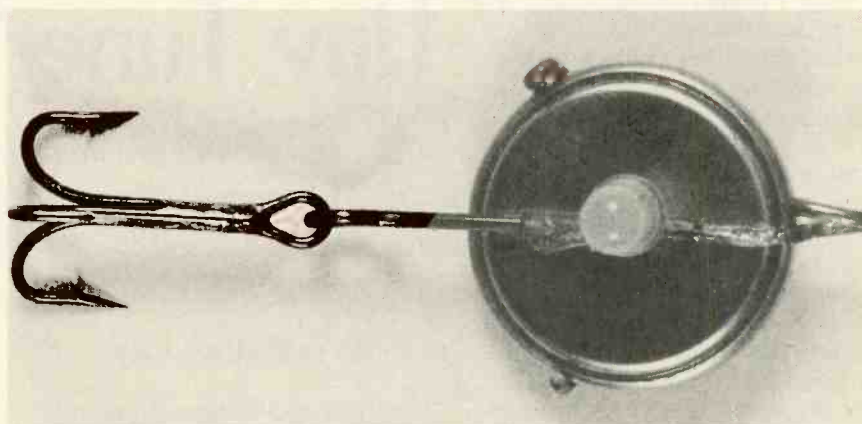


Fig. 3. Follow this clip-bending diagram to form the battery holder for the Electronic Fish Lure. Starting with a straightened large paper clip, make a bend at point A (A), follow by the bend at point B (B), and then the bend at point D (C). Then form a loop at point C and another at point E (D).



Here is the finished lure. Under some circumstances, depending on the conductivity of the waters you fish, it may be necessary to insulate the electrical portion of the unit. Should insulating be necessary, a coat or two of fingernail polish works well.

first bend, a 0.2-inch, 90-degree bend. With the bend pointing toward the ceiling, bend the wire to conform to the diagram in Fig. 3B. Next bend the last 0.2-inch of the double wire at point B in the same direction as point A (toward the ceiling).

Lay a battery, with cellophane tape covering the negative side, on the wire form. The cellophane tape is to keep the battery from shorting during construction. You will need to remove the tape before using the battery in the finished lure. The positive (+) side of the battery should be resting on the wire

and firmly against the bends at points A and B.

Next bend the wire at point D toward the ceiling forming a 90-degree bend tight against the battery (as shown in Fig. 3C). Bend the wire at point C and form a loop as shown in Fig. 3D. At the point where the loop reaches point D, bend the wire 90 degrees to the vertical and then again 90 degrees at a point 0.2-inch away to extend over the negative side of the battery. Finally, bend a loop in the wire at point E as shown.

(Continued on page 99)

Low-power amateur-radio operation is challenging and fun. The thrill of making international contact using a rig of less than five watts is really something to experience. Low-power (or QRP) equipment tends to be small and light, making it perfect to carry along on vacations. Unfortunately, some of the peripherals needed for a QRP station can be as large or larger than a complete QRP transceiver. For example, commercially available antenna tuners are often designed to handle upwards of 200 watts, which means large inductors and capacitors. Because of that, the tuners are much larger than needed.

But that needn't be because of the *Tiny Tuner* described in this article. The *Tiny Tuner* is small enough to fit in the palm of your hand, and it is flexible enough to match almost any piece of wire that you might use for an antenna. That's accomplished through an L-type filter network.

L-Type Filters. In its basic form, the L-type filter—so named for its resemblance to the letter L—is built around two components; either an inductor and capacitor (LC-type) or resistor and capacitor (RC-type). Such circuits can be used for impedance matching, selecting a band of frequencies from among many, etc.

Two L-type LC filters are shown in Fig. 1. Figure 1A shows an L-network configuration that can be used to match a low-impedance output to a 50-ohm load (the antenna). Figure 1B shows an L-network configuration that can be used to match a high-impedance output to a 50-ohm load.

Those filter circuits, in addition to their impedance matching properties, also provide low-pass filtering, which in our application, is well suited to the suppression of harmonics in the transmitted signal. A low-pass filter will pass all frequencies that are at or below its design parameters, while attenuating all others.

Although the two circuits shown in Fig. 1 are configured for low-pass operation, they can easily be converted to high-pass operation by reversing the positions of the inductor and ca-

pacitor. The high-pass type filter would, of course, pass only signals at or above the design frequency, while attenuating all others.

Now let's take a look at our tuner circuit, which uses both of the circuits in Fig. 1.

The Tuner. The schematic diagram for the *Tiny Tuner* is shown in Fig. 2. As can be seen, the tuner is little more



"Tiny Tuner"

If you've been having problems with your QRP equipment this tuner may be just what you need to optimize your rig for the frequency of interest

BY PHIL SALAS, AD5X

than a tapped inductor (L1), variable-capacitor (C1), L-type LC filter. The capacitor is connected to the inductor through a center-off DPDT switch (S1), which allows the capacitor to be connected to either the input or output of the circuit. The switch enables the *Tiny Tuner* to provide *either* a step-up or a step-down impedance transformation (depending on which extreme the switch is set to).

When S1 is set to "I" (input), the capacitor is connected to the input (transmitter) side of the antenna tuner. That configuration matches the low-impedance to a 50-ohm circuit in Fig. 1A, and therefore permits you to tune short antennas. When the switch is flipped to the "O" (output) position, the variable capacitor is connected

to the load side of the antenna tuner (matching the high-impedance to a 50-ohm circuit of Fig. 1B), permitting you to tune long antennas.

Tuning is handled through the inductor/switch combination. The inductor's 12 taps are connected to the contacts of a 12-position rotary switch, S2. That switch is used to select the number of turns that will be included in the circuit. The number of turns included in the circuit determines the electrical length of the antenna; i.e., the S1/L1 combo is used to electrically lengthen or shorten the antenna. In that way, the antenna can be made resonant at the frequency of interest.

When S1 is in the off position (which takes the capacitor out of the circuit) and the inductor is set to zero inductance, a direct path to the output is provided through switch S2, thereby bypassing the antenna tuner.

Construction. Because the *Tiny Tuner* is comprised of so few parts, there is nothing difficult about building the circuit. In fact, the most difficult aspect of the circuit's assembly lies in winding the inductor, L1—and even that is really quite simple. Inductor L1 was made from #24 enamel-coated wire hand-wound on an Amidon Associates (12033 Otsego Street, North Hollywood, CA 91607) T130-6 (yellow core) torroid coil form. When winding the coil, leave an extra length of wire at

the beginning of the coil; that will serve as the zero (0) tap. Then wind 21 turns of the wire on the coil form. As you wind, make loops (which will form the taps) at turns 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19. As the loops are made, give them a twist close to the toroid body (see Fig. 3) to hold the turns in place. The taps should be equally spaced around the coil form. That helps to place the taps in good position to be soldered to the contacts of the rotary switch. At turn 21, again leave an extra length of wire, which will also serve as a tap.

Once all 21 turns have been wound, snip off the ends of each loop, scrape the enamel from the leads, individually twist the pair of wires from each loop, and then tin them. After tinning

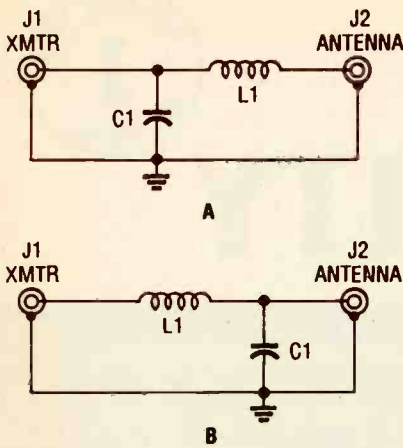


Fig. 1. Here are two L-type, LC filters; the one in A can be used to match a low impedance to a 50-ohm load, while the one in B can be used to match a high impedance to a 50-ohm load. Those filter circuits, in addition to their impedance matching properties, also act as a low-pass filter.

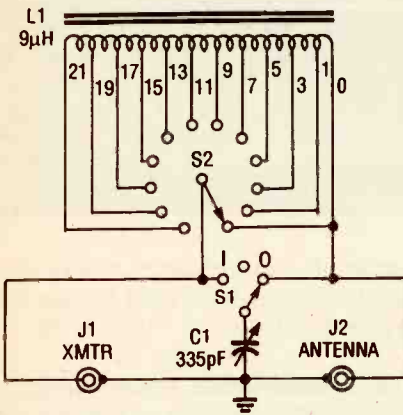


Fig. 2. The Tiny Tuner is comprised of a tapped inductor (L1) and a variable capacitor (C1), which is connected to the inductor through a center-off SPDT switch (S1). That switch arrangement permits the capacitor to be connected to either the input or output of the circuit, thus allowing the circuit to emulate both of the circuits in Fig. 1.

all the taps, solder the inductor to a 12-position rotary switch. Assuming a clockwise rotation of S2, the turn-21 tap should be connected to the first switch contact (making the first switch contact the position of maximum inductance); The turn, 0 tap should be connected to contact 12. Connect lengths of insulated hook-up wire to contact 12 and the wiper terminal of S2. They will be used to connect the switch/inductor assembly to switch S1. Place the switch/inductor assembly to the side, and begin preparing the en-

closure to accept the tuner.

The author housed the prototype unit in a $3\frac{1}{16} \times 2\frac{1}{16} \times 1\frac{1}{8}$ -inch plas-

PARTS LIST FOR THE TINY TUNER

- C1—335-pF tuning capacitor
- L1—See text
- S1—DPDT center-off toggle switch
- S2—SP12T rotary switch
- J1, J2—BNC chassis-mount jacks

ADDITIONAL PARTS AND MATERIALS

Amidon Associates T130-6 yellow-core toroid coil form, $3\frac{1}{16} \times 2\frac{1}{16} \times 1\frac{1}{8}$ -inch plastic enclosure, knobs, #24 enameled wire, miniature microphone cable or RG-174 coax, hook-up wire, solder, hardware, etc.

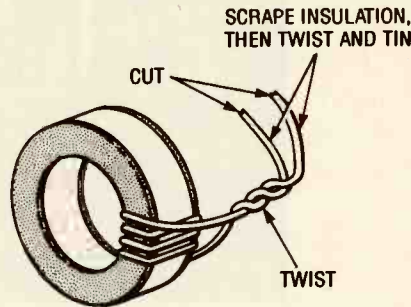


Fig. 3. Inductor L1 is comprised of 21-turns of #24 enamel-coated wire handwound on a T130-6 (yellow core) toroid coil form. When winding inductor L1, taps are made at turns 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19, with turns 0 and 21 serving as the first and twelfth taps.

tic project box. The metal lid of the box was used as the front panel of the unit. Prepare the lid by first drilling holes for the unit's controls. A full-scale template of the Tiny Tuner's front panel is

shown in Fig. 4. The template can be copied or cut from the page, and used as a combination drilling guide and panel label.

If the template is to serve as a label, it should first be covered with clear plastic laminating film (the type used to protect wallet ID's) and glued to the lid; if not, all that is needed are a couple of strips of tape to hold the drill guide in place. In any case, drill holes at the three crosshairs. The center and left holes (for the DPDT center-off switch and variable capacitor, respectively) should be $\frac{1}{4}$ -inch in diameter; the right hole should be $\frac{3}{8}$ -inch in diameter (for the 12-position switch).

Once the front panel has been prepared, mount S1, S2 (with inductor), and C1. The center position is reserved for S1; the capacitor and inductor (S2) positions are indicated on the front panel by "C" and "L," respectively. Unfortunately, C1 (the 335-pF variable capacitor) is not easily mounted. That unit is one of those flush-mounted jobs that have flat tuning knobs—that's the type used in portable radios. Thus, it was necessary to mount that unit, and outfit it with a conventional knob, in an unconventional manner. To mount the variable capacitor, first place the unit flush against the back side of the lid at the proper location. While holding it firmly in place, apply a bead of hot-melt glue around the unit; allow the glue to cool before releasing it.

Once cooled, mount the flat knob to the capacitor's tuning shaft. The flat knob will be used as a base for mounting a more conventional knob. Turn the capacitor fully counter-clockwise

(Continued on page 103)

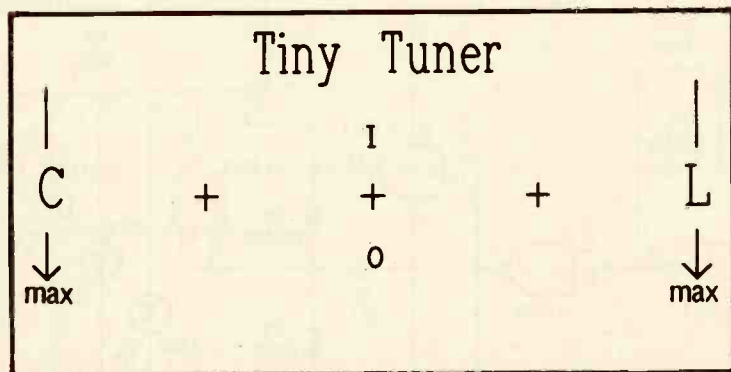


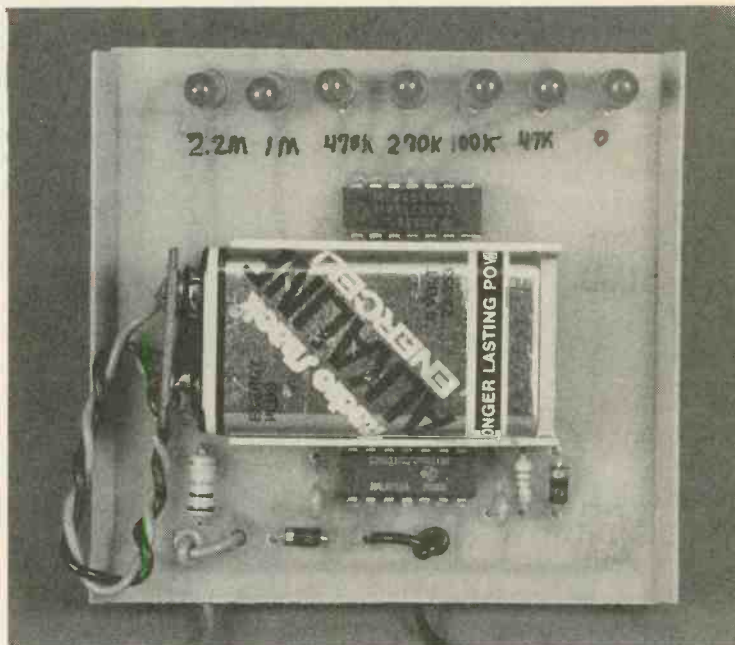
Fig. 4. The author's prototype unit was housed in a $3\frac{1}{16} \times 2\frac{1}{16} \times 1\frac{1}{8}$ -inch plastic project box with a metal lid. If the same size enclosure is used to house your unit, this full-scale template can be used as a combination drilling guide and panel label.

3x3 VISUAL CONTINUITY TESTER



This handy little tester does more than indicate a continuous circuit path; it also gives a relative resistance reading.

BY RICHARD HAMPTON



Whether you're an electronic hobbyist or professional, or maybe just an occasional tinkerer, one thing you simply can't do without is some sort of test equipment. One of the more basic test instruments is the continuity tester.

There are all kinds of continuity testers, ranging from a simple light bulb and battery to sophisticated, commer-

cial-grade units. One drawback with the majority of testers is that they indicate complete circuit paths only, with no indication as to the resistance in the path. However, the *3 x 3 Visual Continuity Tester* described in this article can tell you more than just continuity: By

judging the rate at which a particular LED flashes, you'll be able to estimate the resistance.

Circuit Description. Figure 1 is a schematic diagram of the *3 x 3 Visual Continuity Tester*. The circuit consists of two IC's (a 4011 CMOS quad 2-input NAND gate, U1, and a 4024 binary counter, U2), seven LED's, and a handful of additional components. All of the gates in U1 are wired as inverters.

Two of the inverters (U1-a and U1-b) comprise an astable-multivibrator (free-running oscillator) circuit, whose operating frequency depends on the amount of resistance detected between the test probes. Feedback from the output of the oscillator (at pin 4 of U1-b) back to the input of the circuit (at U1-a, pins 1 and 2) is provided via C1. Resistor R1, along with the unknown resistance between the test probes, completes the RC timing circuit. The frequency of the oscillator decreases as the resistance between the test probes increases.

The output of the oscillator is fed to pins 12 and 13 of U1-c, the output of

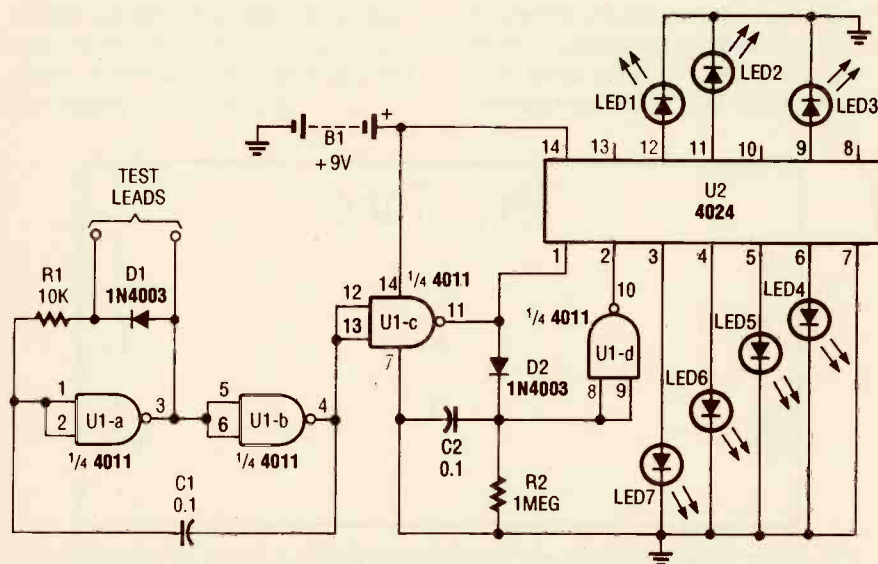


Fig. 1. The *3 x 3 Visual Continuity Tester* consists of two IC's, seven LED's, and a handful of additional components.

which then divides along two paths. In the first path, U1-c's output is applied to the clock input of U2 (a 4024 binary counter) at pin 1; in the other path, the signal is fed through D2 and across capacitor C2, causing it to begin charging. The charge on C2 is applied to U1-d at pins 8 and 9. The output of that inverter (U1-d) is fed to the reset terminal (pin 2) of U2. If there is continuity or a measurable resistance between the test probes, U2's reset terminal is pulled low, triggering the counter and allowing it to process the input pulses (count).

The rate of the count is proportional to the resistance between the test probes. If the resistance between the test probes is low, the counter advances rapidly. If a large resistance is detected between the test probes, the counter advances slowly. The counter provides a 7-bit binary output that is wired to seven LED's.

When the test probes are placed across a short circuit, LED7 flashes. If the tester is placed across a resistance of, say 2 megohms, LED1 will flash. In either case, the LED whose assigned value most closely corresponds to the resistance connected between the two probes will flash continually at a steady pace, while the other LED's will seem to flash intermittently.

PARTS LIST FOR THE 3 × 3 VISUAL CONTINUITY TESTER

SEMICONDUCTORS

U1—CD4011 quad 2-input NAND gate, integrated circuit

U2—CD4024B binary counter, integrated circuit

D1, D2—1N4003 1-amp, 200-PIV, rectifier diode

LED1-LED7—Light-emitting diode

ADDITIONAL PARTS AND MATERIALS

R1—10,000-ohm, ¼-watt, 5% resistor

R2—1-megohm, ¼-watt, 5% resistor

C1, C2—0.1-µF, ceramic-disc capacitor

Perfboard materials, enclosure, 9-volt transistor-radio battery, battery holder and connector, test-lead wire, test probes, hook-up wire, solder, hardware, etc.

Note: An etched and drilled printed-circuit board is available for \$5.00 from Richard Hampton, 17005 E. 4th Street South, Independence, MO 64056; order part VC-3. Missouri residents add \$0.29 state sales tax.

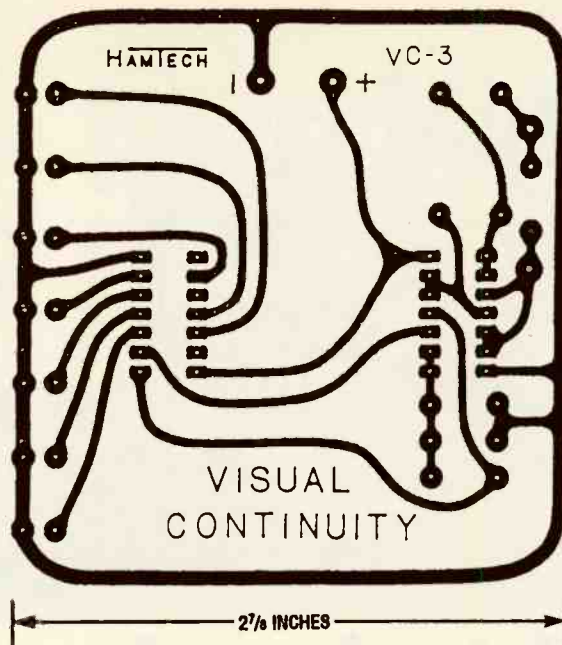


Fig. 2. The continuity tester was built on a printed-circuit board, measuring 3 × 3 inches; here is the template for that printed-circuit board.

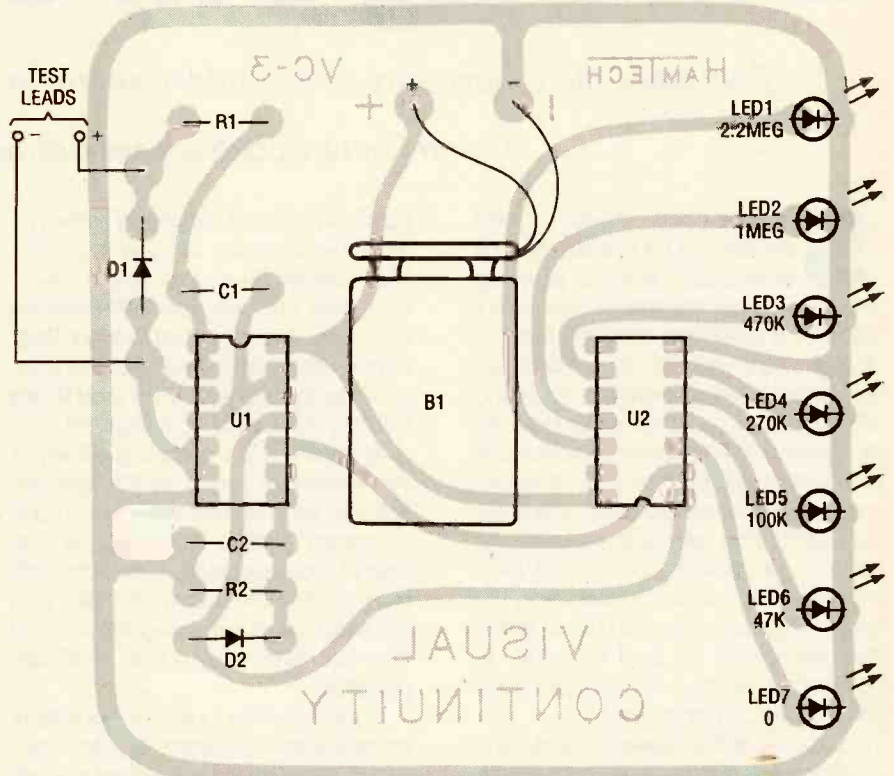


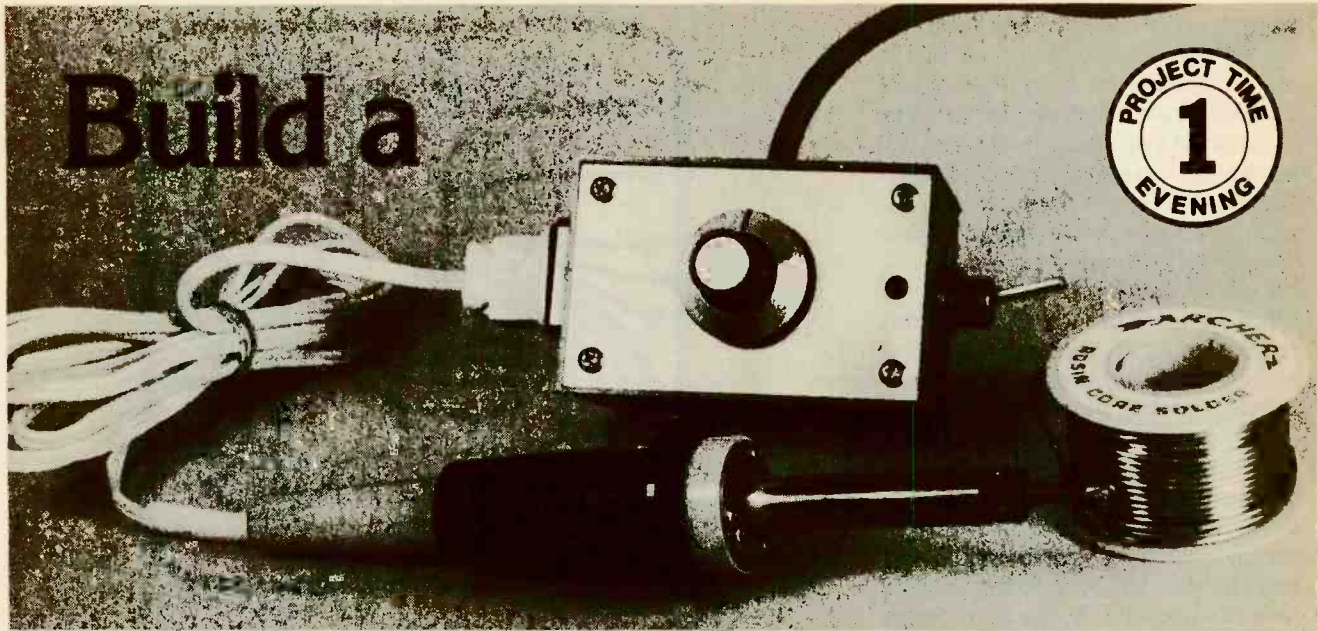
Fig. 3. Assemble the printed-circuit board using this parts-placement diagram as a guide. When assembling the project, be sure to pay attention to the orientation of the semiconductors and battery polarity.

The circuit is powered from a 9-volt battery (B1). Since the circuit is off in the presence of an open circuit, you can expect a long battery life.

Circuit Construction. The continuity tester was built on a printed-circuit

board, measuring (what else?) 3 × 3 inches. A template for that printed-circuit board is shown in Fig. 2. A parts-placement diagram corresponding to the Fig. 2 template is shown in Fig. 3.

When assembling the project, be sure
(Continued on page 108)



Build a Soldering-Iron Controller

Tone down the temperature of any soldering iron with precession controller

BY JOHN J. YACONO AND MARC SPIWAK

Soldering has always been something that requires a bit of experience to do properly. However, even for the experienced, too-hot a soldering iron can lead to trouble. Sure you can go out and buy an adjustable-temperature soldering station, but at great expense. Now this is where the *Iron Leash* described in this article comes into play; it will let you adjust the temperature of any old soldering iron, although it's best with an iron of 25 watts or less—at least with the parts we've chosen. And the best thing about the Iron Leash is that the circuit can be built for under 10 dollars, depending on what parts you may have on hand already.

Not only is the device handy and inexpensive, but it also uses some ordinary parts in an extraordinary manner. So let's take a look at the circuit and see what makes it tick.

Current Regulation and More. Many of the circuits that appear in these pages contain voltage regulators, and that's as it should be. All circuits require power, and most circuits require it in the form of well behaved (read that "constant") DC, and

no IC is better at supplying tame DC than the common voltage regulator. They provide excellent ripple rejection. They are also very safe devices and most shut off if overheated. Regulators often have a short-circuit shutdown feature as well; if the load shorts out, the device's output shuts off.

As you may be aware, a subset of this important family of IC's are adjustable. By using two resistors, you can "program" such a unit to supply voltage at a desired level. . . . at least that's their typical use. Many of them can be used as current regulators and they can even play a role in AC applications.

In the normal course of operation, an adjustable regulator tries to maintain a specific voltage called the reference voltage (typically between 1.2 and 1.5 volts, depending on the regulator type) across an external resistor. The resistor in question is shown as R1 in Fig. 1. It does that by producing current flow between its output and adjust terminals. However, it limits the current flow through the adjust pin to a bare minimum (typically from 40 to 100 μ A depending on the temperature and the particular regulator.) The

remainder of the current is forced through R2. The combined resulting voltage drop across R1 and R2 is the desired output voltage.

By Ohm's law, since the regulator tries to maintain the voltage across R1 at a specific value, the current through that resistor (which is essentially equal to the current through R2) depends on R1's value. If we know the regulator's reference voltage (V_{ref}) we can set the value of R1 to deliver a precise amount of current to R2 as follows:

$$I = V_{ref}/R1$$

If R2 is actually the load for the circuit, then the regulator and R1 form a current regulator for the load.

That technique should only be tried with "floating" adjustable regulators. Floating regulators do not need to be referenced to ground, so the load can be light or even shut off without causing harm to the regulator. Many common adjustable regulators are floating, so that is not a difficult requirement to fill.

To see how such a regulator might be used in an AC application, look at Fig. 2. That is the circuit for the Iron

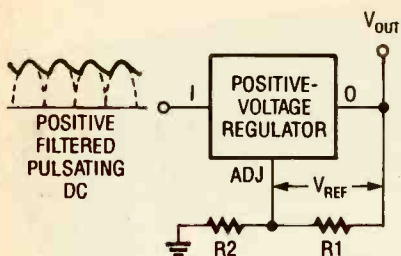


Fig. 1. Floating adjustable regulators can be used as current limiters. Resistor R1 programs the current flowing through R2.

Leash. Integrated circuit U1 (a high-voltage regulator) is configured as a current regulator just as we've described. Resistor R1 limits the current flow to an absolute maximum value and R2 (a variable 5-watt wire-wound resistor) allows the user to set the value of current below that maximum.

The current regulator is placed between the DC terminals of a bridge rectifier composed of D1-D4. That means the regulator is only exposed to DC. However, the AC socket (SO1) and AC plug (PL1) are both outside the bridge (i.e., in the AC portion of the circuit). That allows the current regulator to be in series with the AC legs of the circuit, and even control the current through them, without direct exposure to AC.

That is how the Iron Leash does it's

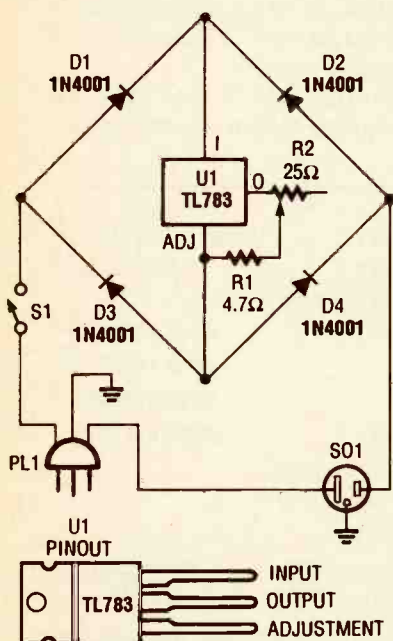


Fig. 2. This is the Iron Leash in the buff. The application is unusual, but functional. With the component values specified, the circuit should be used with a soldering iron of 25 watts or less (see text).

job. As you may know, the heat given off by a resistive element, such as a soldering iron tip, is equal to its resistance times the square of the rms current. Since the regulator circuit limits the maximum current through the soldering iron, it limits the rms current and therefore the heat dissipated by the iron tip.

There are some interesting advantages to this scheme: The circuit emits less RFI than a Triac power-control circuit. To control power output, a Triac circuit would turn on 120 times a second and generate harmonics that can interfere with delicate test instruments or ham-radio equipment. On the other hand, the Iron Leash just curtails current flow to a set maximum, it doesn't turn anything on or off so you can leave your iron hot while testing RF sensitive circuits.

PARTS LIST FOR THE IRON LEASH

SEMICONDUCTORS

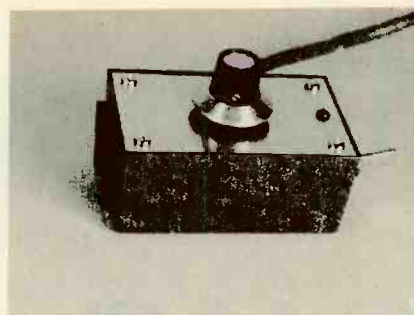
- U1—TL783 high-voltage regulator, integrated circuit
- D1-D4—1N4001 1-amp rectifying diode

ADDITIONAL PARTS AND MATERIALS

- R1—4.7-ohm, 1/2-watt, 5% resistor
- R2—25-ohm, 2-watt, wirewound potentiometer
- PL1—3-terminal AC power plug with line cord
- S1—SPST power switch
- SO1—3-terminal AC socket
- Project case, high-efficiency heat sink (or case with a metal lid, see text), heat-sink compound, regulator-mounting hardware (including mica insulator), rubber grommet, potentiometer knob, solder, wire, etc.

Construction. The circuit for the Iron Leash is so simple that it would be silly to go through the trouble of making a PC board for it, so we decided to go with point-to-point wiring. We didn't even use any perfboard; connections were twisted together and insulated with heat-shrink tubing. The line cord enters the case through a rubber grommet, and the AC outlet, control potentiometer, and on/off switch are mounted in holes drilled in the case.

Choosing a case to house the circuit should be carefully thought out.



Everything fits inside this small project case; the metal lid is being used as a heat sink. Mounting an AC socket to the side of the enclosure allows the Iron Leash to be used for more than a soldering-iron temperature control.

We built the unit as a stand-alone device—in other words, it's basically a variable-current outlet. Therefore, the device can also be used for things like dimming a low-wattage light bulb—again, it's best if it's 25 watts or less. However, if you feel that you will use it only for a soldering iron (as will be the case with most people), you may want to incorporate a soldering-iron stand and sponge into the case. You can even hard wire the iron directly to the circuit to avoid purchasing an AC socket. Before we get down to "choosing" a case, let's talk about why it's best to power a load of 25 watts or less with the parts we've chosen.

Most voltage regulators, unless called upon for extremely light-duty work, do require heat sinking (you know, the little metal tab with the screw hole in it must be secured to some kind of heat-dissipating material). And regulator heat sinking is a must for the Iron Leash; it would simply overheat and either shut down or destroy itself after a short time in use.

Knowing that our Iron Leash would require heat sinking, we found a small plastic project case that all of the parts could be crammed into—but it has a metal lid that we used as a heat sink. If it were not for the metal lid, a separate heat sink would not have fit into the case. We'll get into how you use the lid as a heat sink in a moment, but as for why a 25-watt load is a maximum, this is the reason: The metal lid gets too hot for comfort with anything over 25 watts.

So, if you can find a similar case that all of the parts you choose will fit into, then use it. However, keep in mind that the metal tab on the regulator is elec-

(Continued on page 103)



Eight-Channel Audio Switcher

Give your present A/V system something that the audio-component manufacturers seem to have overlooked—more audio inputs

The home-entertainment revolution of the past few years has meant a big improvement in the selection of what we can listen to and watch in the comfort of our own homes. Hi-fi videotapes, stereo television, surround sound, laser discs, CD's, cassette decks, radio tuners, and record players or turntables (yes, some people still have and use them) have added up to a number of audio choices that were never even dreamed of 20 years ago.

In fact, until just recently, most manufacturers of receivers and amplifiers didn't seem to notice the changes. They kept designing and manufacturing audio equipment with just one or two inputs for auxiliary equipment, and we consumers kept buying them. But now, as we play "catch up with the Joneses," adding another piece of equipment here and there, we're finding that our amplifiers and receivers just can't handle all the choices.

Although you could rush right out and get new equipment to handle the problem, that often isn't the most practical solution, especially when there's nothing else wrong with the old stuff. That's where the *Eight-Channel Audio Switcher* described in this article comes in. The switcher allows you to choose between eight-different, stereo-audio sources, and feed the selected signal to one pair of stereo inputs on your current receiver or amplifier, freeing up any additional inputs that might be present on the unit.

The Heart of the Matter. At the heart of the audio switcher is an LM1037, a dual low-noise, four-channel analog switch. That chip is designed to switch between 4 different stereo audio sources (A, B, C, and D). Figure 1 shows a pinout diagram of the LM1037, which, as you can see, has eight input pins (for four stereo sources) and two pins for the stereo output.

Four pins on the LM1037 (16, 18, 1, and 3) control which stereo input is transferred to the output. The desired input is selected by placing a high (+V) on the appropriate control pin. For example, to listen to source A, 12 volts would be placed on pin 16, the A-channel input selector. Any audio source connected to pins 2 and 4 (the A-channel input terminals) would be transferred to the chip's stereo output at pins 9 and 10. All other input control pins are kept low (at ground) until they are selected.

If no inputs are selected and pin 7 (mute) is held low, the output is disabled. That feature allows the outputs of several LM1037's to be connected in parallel to increase the number of available inputs. In this project, two LM1037's are used to provide 8 stereo inputs. Alternately, if pin 7 is left disconnected and no inputs are selected, a monophonic audio input at pin 12 (the optional common input/bias) will be switched to both output pins. That last option could prove useful for a paging system, but is not used in this project.

About the Circuit. Figure 2 shows a complete schematic diagram of the Eight-Channel Audio Switch. Source selection is accomplished by pressing momentary-contact pushbutton switch S1. Switch S1 is connected to the trigger of a 555 oscillator/timer (U1) that's configured as a monostable multivibrator, which generates one short output pulse for each press of S1. That pulse turns on LED1 to give a visible indication that the 555 is working correctly. That pulse is also used to clock U2 (a 4017 CMOS divide-by-10 counter/divider).

Both LED1 and its associated current-limiting resistor R3 are optional.

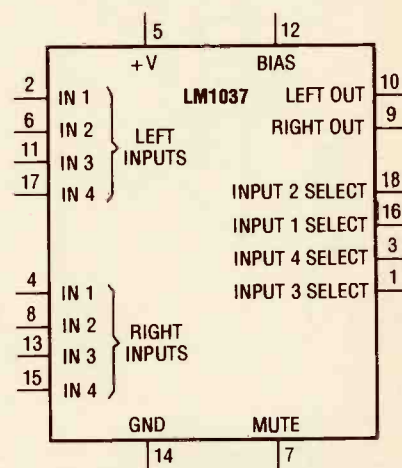


Fig. 1. This block pinout diagram shows that the LM1037 has eight input pins (for four stereo sources) and two pins for the stereo output. Four pins on that chip (16, 18, 1, and 3) are used to select which stereo input is transferred to the output.

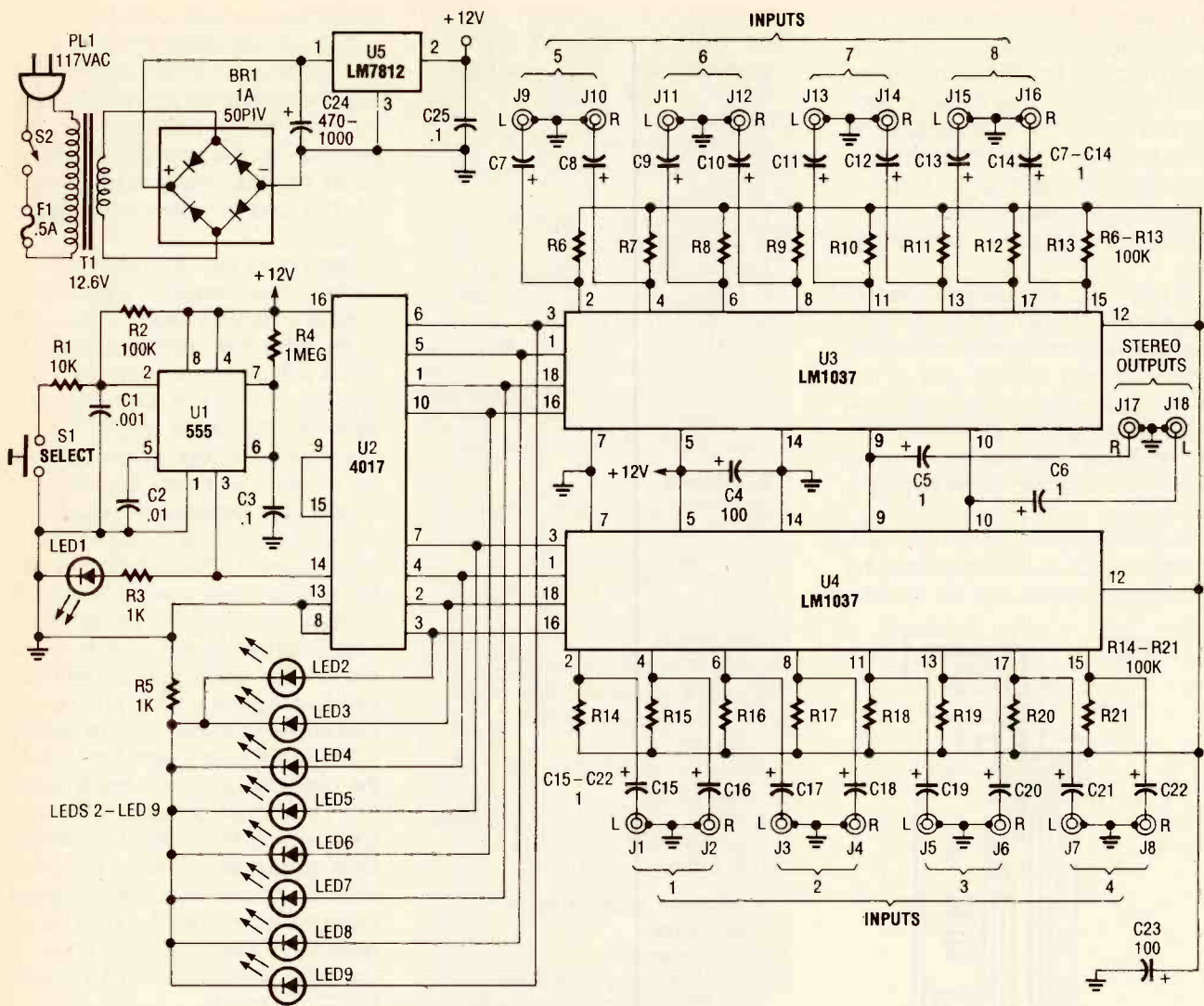


Fig. 2. Input-source selection is accomplished by pressing S1; a single output pulse is produced by U1 for each press of S1. That pulse is used by U2 to activate one of its ten sequential outputs. Those outputs, in turn, inform U3 and U4 which input source is to be transferred to the output.

and may be left out of the finished project without any affect on circuit operation. The 4017 advances by one clock pulse each time S1 is pressed, turning on its corresponding output. Pin 9 (corresponding to output 8) of U2 is directly connected to its own reset terminal at pin 15. That allows the counter to count from zero to seven, and then reset to zero on the eighth count.

Pin 13, the enable input of U2, is tied to ground to allow the counter to operate. Outputs zero through seven are connected to eight indicator LED's and the control pins of the two LM1037's (U3 and U4). When an output is selected, its LED lights and the corresponding control input on the LM1037

is brought high. To illustrate what is happening, assume that pin 3 of U2 is high. LED2 lights and pin 16 of U4 (the channel 1 enable) is brought high. Integrated circuit U4 then switches the audio signals applied to pin 2 and pin 4 to the IC's outputs at pins 9 and 10.

Since none of U3's control pins are high and pin 7 is grounded, U3's outputs are disabled, and only the selected audio signal from U4 appears at the left and right outputs (J17 and J18). Pin 12 (bias) of both LM1037's are tied together and connected to ground via C3, a 100- μ F capacitor, to prevent switching thumps when going from the output of one LM1037 to another.

The LM1037 has extremely high-im-

pedance inputs and low-impedance outputs, so interconnection between various types and brands of equipment should not be a problem. That, together with a wide-frequency response and low distortion, makes it ideal for use with good-quality, home-entertainment systems. The prototype of the audio switcher has a usable frequency response of from just a few hertz to over 100 kHz.

Power for the switcher is provided by a rather simple circuit (see Fig. 2). Since the switcher only draws between 20 and 30 milliamps, a simple circuit using the popular 7812 or 78L12 (a low power version) voltage regulator works quite well.

Construction. A printed-circuit pat-

tern for the Eight-Channel Audio Switcher is shown in Fig. 3. The circuit board is a little larger than necessary for the simple circuitry of the project, but that allows plenty of maneuvering room for soldering and drilling mounting holes. Unfortunately, due to space limitations, that also means that the pattern must be shown here at half size.

Figure 4 shows a parts-placement diagram for the Eight-Channel Audio Switcher. Note that the printed-circuit board doesn't contain any of the power-supply circuitry. Instead, it was hard-wired together within the switcher's enclosure, and connected to the printed-circuit board at the appropriate points.

Begin assembly by installing sockets for the four IC's, but do not install the IC's in their sockets until the circuit is

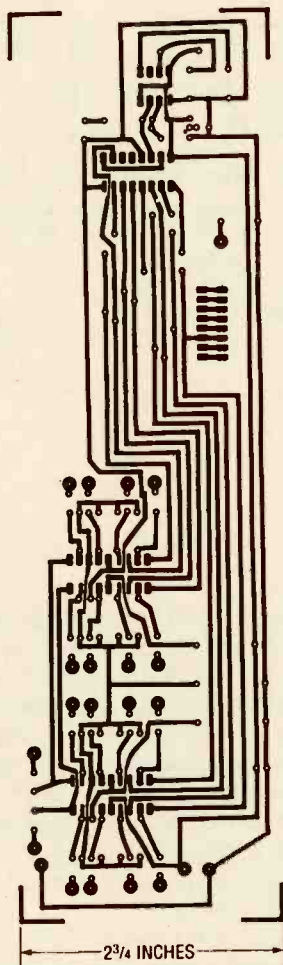


Fig. 3. Here is a half-size printed-circuit pattern for the switcher. The circuit board is a little larger than necessary for the simple circuitry of the project, but that allows plenty of maneuvering room for soldering and drilling mounting holes.

PARTS LIST FOR THE EIGHT-CHANNEL AUDIO SWITCHER

SEMICONDUCTORS

- U1—555 oscillator/timer, integrated circuit
- U2—4017 decade counter/divider, integrated circuit
- U3, U4—LM1037N four-channel analog-switch, integrated circuit
- U5—7812 (1-amp) or 78L12 (100-mA) 12-volt, voltage regulator, integrated circuit
- BR1—1-amp, 50-PIV, fullwave-bridge rectifier
- LED1—LED9—Light-emitting diode

RESISTORS

- (All resistors are 1/4-watt, 5% units.)
- R1—10,000-ohm
 - R2, R6—R21—100,000-ohm
 - R3, R5—1000-ohm
 - R4—1-megohm

CAPACITORS

- C1—0.001- μ F, ceramic-disc
- C2—0.01- μ F, ceramic-disc
- C3, C25—0.1- μ F, ceramic, disc
- C4, C23—100- μ F, 35-WVDC, electrolytic
- C5—C22—1- μ F, 35-WVDC, tantalum or metal-film
- C24—1000- μ F, electrolytic

ADDITIONAL PARTS AND MATERIALS

- F1—0.5-amp fuse
- T1—12.6-volt stepdown transformer
- S1—SPST momentary pushbutton switch
- S2—SPST toggle switch
- PL1—Molded 117-volt AC power plug with line cord
- J1—J18—RCA jack
- Printed-circuit materials, enclosure, IC sockets, fuse holder, wire, solder, hardware, etc.

completely assembled and checked for errors. Although the use of sockets makes the project a little more expensive, they can also save hours of grief later when trying to remove and replace defective chips. Jumpers and resistors can be installed next, followed by the capacitors, taking note of the polarization of the electrolytic and tantalum units.

Once all of the on-board components have been installed, place the circuit board to the side and prepare the enclosure that will house the circuit board and off-board components. Remember that the enclosure

should have ample room for the circuit board, off-board power supply, and the other off-board components. Drill nine holes in the front panel of the enclosure for the LED's and 2 for the switches. On the rear panel, drill 18 holes for the input/output jacks (J1—J18), and another for the power cord.

Install all of the off-board components in their respective mounting holes and secure in place. In the case of the LED's, they can be secured in place with silicon cement. Begin wiring the off-board components (switches, LED's, jacks, etc.) to the circuit board. Although single-conductor hookup wire can be used for connections between the input and output jacks if a metal project box is used, shielded cable will provide better isolation (less crosstalk between sources) between the audio channels. When wiring this portion of the project, it is recommended that you carefully mark or color-code the cables and then solder them in place.

The final step is to wire the LED's to the circuit board. There are 8 separate anode lines for those LED's, corresponding to the 8 input channels. One output serves as a common cathode for all 8 LED's in your finished project; simply label the LED's as required. For example, LED2 (input 1) could be tuner. LED3 (input 2) could be CD player, etc.

Once all of the parts have been installed and the off-board components are wired to the circuit board, check your work for the usual construction errors. When you are satisfied that the circuit contains no construction errors, it's time for the smoke test.

Set-Up and Use. Very little has to be done to set-up the switcher, since there is nothing to adjust. As long as everything has been soldered in the right place, it should work as soon as it is connected in your AV system.

One possible problem that might crop up can be traced to the action of the 4017. The 4017 has a tendency to allow more than one of its outputs to be on at power-up. If that happens, 2 or more LED's will light. To correct that situation, simply press S1 several times to select whichever source you would like to listen to. To avoid the problem, just leave the power to the switcher on.

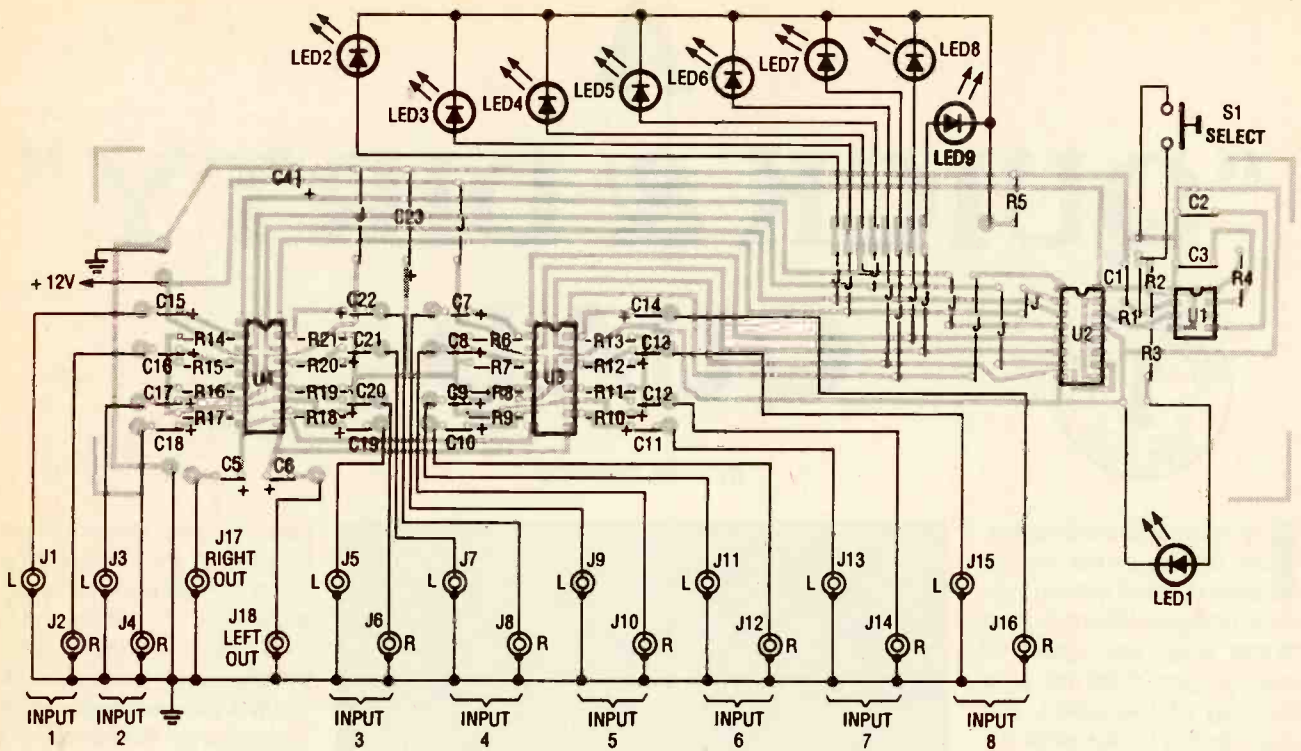
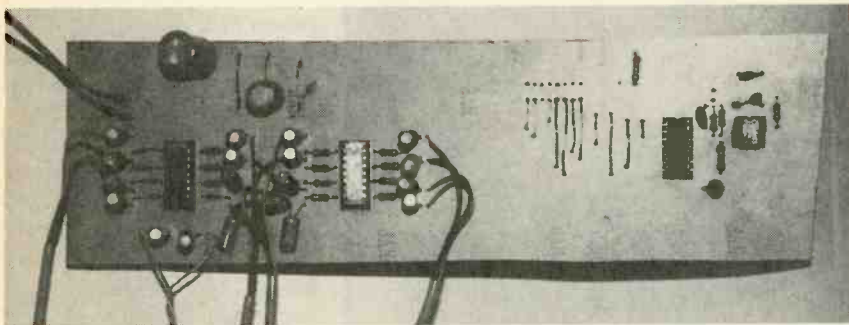


Fig. 4. Note that this parts-placement diagram for the Eight-Channel Audio Switcher doesn't show any of the power-supply circuitry. The power supply was, instead, hard-wired together within the switcher's enclosure, and connected to the printed-circuit board at the appropriate points.



Here's the author's populated circuit board. It is a little larger than necessary to make assembly easier.



The author's prototype incorporated two audio-switcher circuit boards and a switching network.

To connect the switcher to your equipment, simply plug the outputs from your audio sources (CD player, tuner, etc.) into the switcher's eight stereo inputs. Then connect the stereo outputs from the switcher to one input pair on your amplifier/receiver. Anytime you select that amplifier/receiver input, you'll be able to hear whatever has been plugged into and selected on the audio switcher... without having to change one cable!

Something Different. The author chose to incorporate two audio-switcher circuit boards into his final product. The output of one of them feeds his main amplifier. The output of the other goes to the input of a cassette recorder. That allows him to listen to one source, while recording another. In addition, a switching network was added to decide which output, if any, was set for equalization. You might have some other arrangement in mind.

However you decide to modify the circuit, it should give you many years and countless hours of listening pleasure.

A "QUICK & DIRTY" QUAD



BY MIKE DEUPREE

If you're a student of antenna design, or the kind of person who insists on precision and good technique no matter what, well, good for you, but you'd better stop reading at this point. You aren't going to like what follows.

On the other hand, if you're a CB operator or a ham who wants to take advantage of the current hotspots on the 10- or 12-meter bands, and all you care about is getting a good signal on the air quickly and cheaply, the QuAD Special may be just the ticket.

We call it a QuAD not just because it's a full-wave loop antenna, but because its "Quick And Dirty," too. As the name might suggest, this antenna won't win any beauty or efficiency contests, but it should cost less than \$15 even with all new parts, and you can have it on the air in a couple of hours with the most basic tools. Plus, it can be erected just about anywhere you could install a vertical, but it requires no ground plane, puts out twice the signal, and is directional.

Gathering Parts. Sound like it's worth a try? Then start by surveying your garage to see how many "antenna components" you have on hand. For the frame you'll need two 1-inch radiator-hose clamps, four U-bolts, a scrap piece of plywood about nine-inches



If you want to get an antenna up quickly, then our design is what you're looking for.

square, and three 10-foot lengths of PVC water pipe, each a different diameter. I suggest 1-inch, $\frac{3}{4}$ -inch and $\frac{1}{2}$ -inch sizes, but it depends on the pipe stock you buy. The important thing is that the smallest pipe must slide snugly into the next-largest; check for a good fit before you buy. As for the 1-inch section, which will be the vertical member, the thin-wall type isn't as strong, but it slips neatly over the tapered end of a standard Radio Shack antenna mast, which can be important for mounting purposes.

For the antenna itself you'll need about 40 feet of wire. I used No. 14 stranded electrical wire with polyvinyl insulation because it's cheap, strong, and easily available. The exact length of the wire depends upon the frequency design of the antenna. The formula for the wire length is 1005 divided by the frequency in megahertz.

You will also need a short length of 75-ohm coax to match the antenna to a 52-ohm feedline. The matching-section length should be 246 divided by the frequency in megahertz, multiplied by the velocity factor of the coax you use. If the antenna is for a CB base station and you are using standard Radio Shack RG59U coax, you'll need 37 feet, 2 inches of antenna wire and 6 feet, 10 inches of coax.

The Assembly. With a hacksaw, cut two slots in a cross configuration (as viewed from the end) at each end of the 3/4-inch pipe, which will allow it to be "squeezed" a bit. Cut the 1/2-inch pipe into two 5-foot lengths. Insert one length about halfway into each end of the 3/4-inch pipe, slip a hose clamp over each junction and tighten them enough to keep the inner pipes from slipping.

You have just completed the horizontal frame member. You will be joining it to the vertical frame member by using the plywood as a hub, so drill four pairs of holes in the plywood, configured as shown in Fig. 1, each large enough to permit a leg of a U-bolt to pass through. Using two U-bolts, attach the plywood to the center of the horizontal member. Tighten the U-bolts until they're good and snug but aren't deforming the pipe.

Attach the vertical member (the largest pipe), to the plywood in a similar manner, but on the other side of the board at a 90-degree angle to the 3/4-inch pipe. Fasten it a couple of feet from one end of the pipe, instead of at the center as you did with the horizontal member, and leave these U-bolts loose enough to allow the pipe to slide easily through them.

Feed the antenna wire through the length of the horizontal member. Drill holes through opposite walls of the vertical member about a quarter-inch from the top end. Strip a couple of inches of insulation (if there is any)

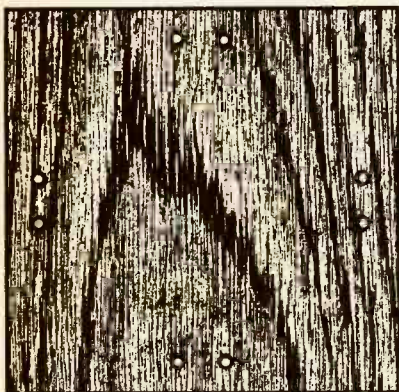


Fig. 1. The 10-Meter version of the Quick And Dirty Quad should be mounted on a TV-antenna rotator and tripod. Four pairs of holes should be drilled in the plywood in this configuration. The spacing and diameter of each pair of holes depends upon the U-bolt chosen to pass through them.

off one end of the antenna wire, run it through one hole and twist it around itself. Do the same with the other end of the wire in the opposing hole. Strip one end of the 75-ohm coax and fasten the center conductor to one end of the antenna wire and the braid to the other.

You must now secure the connections. That can be done with with automotive-type crimp connectors. If you choose to solder them instead, **be extremely careful not to transfer too much heat to the PVC pipe. The material burns readily, and the fumes are toxic.**

Attach an RF connector to the other end of the coax, and fasten the coax to the vertical member. Use with electrical tape, spaced every foot or 18 inches, for that.

Mounting. Your antenna is finished and needs to be mounted. Ideally you might have an old TV-antenna tripod and rotator left up on the roof from the "Dark Ages" before cable TV. If you aren't that lucky, secure the base of the vertical member to the best anchor you can find, the higher the better. If you aren't using a rotator, orient the antenna so it presents its largest area in the direction favored for reception. Attach the feedline to the matching coax.

Now slide the plywood and horizontal member down the vertical member as far as you can without running into your mounting apparatus, and tighten the U-bolts to keep it there. Slide the inner sections of the horizontal member out by the same distance on each side until the antenna wire is taut.

As you do that, the bottom member will bend upward like a bow, which is not only okay, but is one of the reasons (there were others) we used PVC pipe. The flexibility of the bottom member, and the ability to change its length by telescoping the end sections, allows you to adjust the tension and, to a certain degree, the shape of the antenna to fit your particular circumstance. You want sufficient tension to retain the shape and keep the wire from tangling or going slack, but not so much that it puts a serious strain on any of the components.

When you get it the way you want it, tighten the hose clamps and that's it, you're done.

There isn't much troubleshooting advice we can give because if you did it right, your rig should be looking at an acceptable SWR reading. If that isn't the case, recheck the lengths of antenna wire and coax, as well as the connections.

Incidentally, by its nature few mechanical aspects of the "QuAD" are inviolable. You could feed it from the bottom or from a corner, turn it upside down, or even feed it to an antenna tuner with open-wire line instead of using coax.

One final note to fans of portable or field-day operations: Once built, this antenna quickly breaks down into a small, light, easily transportable bundle. When you get where you're going, tie a length of line (I favor nylon seine cord) to the top, throw the line over something high, and pull'er up. Attach other lines to each end of the horizontal member to anchor or "steer" it. ■

ELECTRONIC FISHING LURE

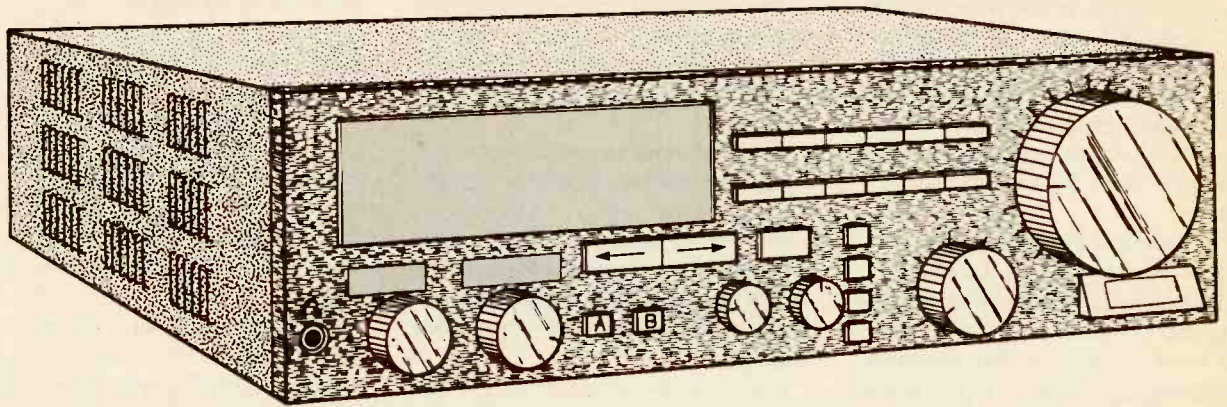
(Continued from page 87)

The battery should be held in place by the clip. If not, remove the battery and adjust the bends at points A and B so that when the battery is slipped into place, it "clicks." Once you have the battery clip working correctly test the assembly. To test it, simply tie it to a string and spin it around. Make sure there are no breakables or anyone else in the room. If the battery doesn't fly out, you've made a good clip.

Take a 1/2-inch piece of 1/4-inch wide cellophane tape and wrap around the wire as shown in Fig. 1 at the point labeled "insulator." Make the wrap several layers thick. Next wrap the negative leg of the LED or the micro lamp around the cellophane-tape insulator. Flow some solder on the windings on the side that contacts the battery. Solder the other wire to the clip just beyond the cellophane-tape insulator.

The lamp or LED can be mounted to face in a variety of directions—for example, pointing directly out away from the battery or, perhaps, pointing toward the hook end of the lure. The switch is the essence of simplicity—a thin piece of plastic or film slid between the battery and battery-contact lead of the LED. Cut the plastic or film into a strip about 1/8-inch wide and an inch or two long. ■

BASS AND TREBLE



BOOSTER CONTROLS

BY A. SINGMIN



Add some pizzazz to your low budget audio projects with a true tone control that'll make them sound better.

Pick up any electronics magazine and before long you're sure to come across an easy to build, low parts-count audio amplifier, suitable for use with your turntable, tape deck, or whatever. Typically, once you've connected the project to the often suggested junk-box speaker and managed to generate some sound out of it, you hear some dismally disappointing tinny audio—nothing at all like the bone-shaking bass and glass-breaking treble from your high cost hi-fi system in the living room. The simple circuits often published rarely have more than a volume control. When they do have a tone control, it is usually no more than a treble-cut control that merely converts the original tinny audio into an

equally disgusting muddy sound.

Of course, using a decent speaker would improve the sound quality, but what you also need is a circuit that provides individual bass boost and treble boost just as you would find on a hi-fi set. The original Baxandall type of bass/treble control and its derivatives are found everywhere. They generally take the form of a 4-terminal network (*i.e.*, there's a terminal for the input, one for the output, one for a common ground, and a terminal for the feedback loop). For the more basic enthusiast, a simpler, easy-to-use circuit that has only three terminals (*i.e.*, an input, output, and ground) will be described.

The Bass Section. The best way to

describe how the three-terminal circuit works is to split it into its bass- and treble-boosting portions and handle them separately.

To help illustrate the bass-section's operation, take a look at the basic DC voltage divider in Fig. 1. You can imagine that R1 and R2 are discrete resistors, or consider them as two halves of a volume-control potentiometer with the wiper positioned between them. As shown, the input voltage (V_{in}) is applied across R1 and R2. Let's say that V_{in} is derived from some piece of audio gear. The divided output signal is derived from the junction of R1 and R2 (or the potentiometer wiper) and is proportional to the ratio of $R2/(R1 + R2)$. Thus, as the value of R2 is increased (which is accompanied by a decrease in R1 for the case of a potentiometer), the output-signal voltage and volume rises.

Taking things a step further, consider the simple capacitor. Unlike the resistor, its reactance (or "AC resistance") is a function of the frequency and is found from:

$$X_C = 1/(2\pi fC)$$

where: X_C is the capacitive reactance in ohms, f is the frequency of the applied signal in hertz, and C is the value

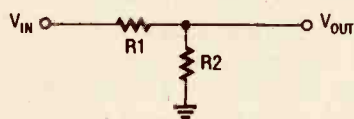


Fig. 1. This basic voltage divider forms the foundation of the bass- and treble-boost circuits. It simply lacks frequency selectivity.

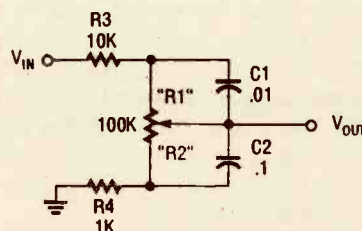


Fig. 2. The frequency dependence of the capacitor's impedance permits this circuit to boost the bass if desired.

of the capacitor in farads. So we can see that as the frequency increases, the reactance drops. We can take advantage of that to make a frequency-dependent voltage divider that we can use as a tone control.

Let's now look at a bass-boost circuit (see Fig. 2). Consider an AC signal fed to resistor R3 and ground, with the output taken across the potentiometer wiper tap. For clarity, the 100k potentiometer can be considered to be a series combination of 2 resistors (R1 and R2), as shown. Capacitors C1 and C2 shunt R1 and R2 respectively.

Note the differing values for R3 and R4, and C1 and C2 (we will explain the difference shortly). The output signal magnitude is given by:

$$V_{out} = V_{in} \div (1 + ((R1/X_{C1}) + R3)/((R2/X_{C2}) + R4))$$

This seemingly cumbersome statement is no more than the basic voltage-divider equation reworked to include the capacitors.

Fortunately, you won't have to use this formula to determine the output

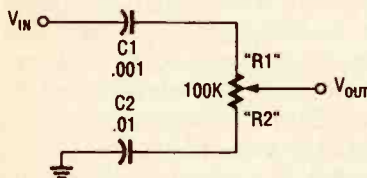


Fig. 3. The treble control is similar in principle to the bass control, but the capacitors are placed in series with the potentiometer.

as a function of frequency and various ratios of R1 and R2 as that information is already summarized in Table 1. For example; with R1 = 0 and R2 = 100k (representing the potentiometer fully advanced to one end), the output voltage is a maximum (86% of the input) at the low frequency end (10Hz) and drops to only 9% at the high frequency end (100kHz). What that means is that the bass frequencies are enhanced with the potentiometer in this position. As the potentiometer is rotated so R1 starts to get larger and R2 starts to decrease, the amount of bass is reduced. Finally at the other end of the scale, with R1 = 90k and R2 = 10k, the output is essentially flat with respect to frequency.

The Treble Control. The treble control (shown in Fig. 3) works in a similar way. The input is applied to C1 and the output is taken from a potentiometer wiper. Resistors R1 and R2 make up the two halves of the potentiometer.

The output signal is given by:

$$V_{out} = V_{in} \times (R2 + X_{C2}) / (R2 + X_{C2} + R1 + X_{C1})$$

The response of the circuit as a function of frequency is summarized in Table 2. With R1 = 0 and R2 = 100k, the high frequency signals are now enhanced, while the low frequencies remain nearly the same.

With a few additional components, the two circuits (bass and treble) can be combined as shown in Fig. 4. It is assumed that the signal sent into the

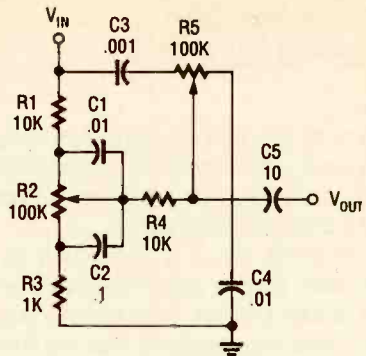


Fig. 4. The bass and treble circuits can be combined to form a two-control tone-adjust circuit, as shown here. Note the additional AC-coupling capacitor.

network has been AC coupled and contains no DC component.

If your application requires, you can use just the treble portion (shown with the capacitors in series with the potentiometer) by itself. However, if you want to use just the bass-boost circuit (on the left side of the circuit), be sure to AC-couple both the input and output terminals. ■

TABLE 1—BASS BOOST

R1	R2	Percentage Output Across R2				
		10Hz	100Hz	1kHz	10kHz	100kHz
0	100K	86%	60%	20%	10%	9%
10K	90K	75%	43%	14%	9%	9%
30K	70K	56%	28%	11%	9%	9%
50K	50K	40%	21%	10%	9%	9%
70K	30K	25%	16%	10%	9%	9%
90K	10K	10%	10%	10%	9%	9%

TABLE 2—TREBLE BOOST

R1	R2	Percentage Output Across R2				
		10Hz	100Hz	1kHz	10kHz	100kHz
0	100K	9%	14%	42%	86%	98%
10K	90K	9%	14%	39%	78%	89%
30K	70K	9%	12%	31%	61%	69%
50K	50K	9%	11%	24%	44%	49%
70K	30K	9%	10%	17%	27%	30%
90K	10K	9%	9%	9%	10%	10%

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TV/VCR SWITCH

(Continued from page 85)

the outer sheath to circuit ground and the inner wire to switch S1. Strain reliefs should be provided for the power cord and the signal cable.

Once the circuit is completely assembled, visually check for wiring errors, solder bridges, cold solder joints, etc. Clear any problems that you find. Once everything appears okay, you are ready for the smoke test.

Smoke Test. At this point, all of the components except for U3 should be mounted on or connected to the circuit board in a manner that conforms to the schematic diagram in Fig. 1. **Do not** connect the wiring from the relay to the AC line yet. Check for continuity between both of the relay's AC contacts and the circuit board's ground. There must be no continuity. If there is, find and correct the problem.

Once all is okay, plug the unit in and check for the proper voltages at pin 8 (+12 volts) and pin 4 (-12 volts) of U3's socket. If the voltages on those pins are correct, unplug the unit and install U3. Reapply power and check for proper operation of the relay with S1 in the MANUAL position and S2 in the ON position. If that checks out, unplug the unit, and assuming everything is okay so far, complete the relay's AC wiring. Close up the case and apply power again. With switch S1 in the MANUAL position and S2 in the ON position, check for 117 volts AC at SO2 (the TV outlet).

When the unit has passed all tests, it's ready for use. Plug the VCR and TV into their respective outlets. Connect the signal cable to the VCR's baseband video output (video-dubbing jack). Place the VCR in the VCR mode by operating the TV/VCR switch. Many VCR's provide no baseband output unless they are placed in the VCR mode. The TV should be set to Channel 3 or 4, since the video source selected for viewing will be delivered to the TV (which functions as a monitor) through the RF or antenna input. Now check and verify the operation of the circuit.

Once the circuit has been verified as operational, you are ready to enjoy your new video accessory, and the convenience that it provides. ■

ONE AMP CURRENT INJECTOR

(Continued from page 79)

With everything ready, push and hold the current injector's power switch. Now adjust the trimmer potentiometer (R7) until you read 1.000 amp of current on the multimeter. That's it. You're done. Once you have calibrated the unit, you can attach the box lid using four screws.

Some multimeters cannot directly measure current or don't have a 2-amp scale. If this happens to be the case, you will need to measure the current indirectly with the use of an accurate resistor of known value. A 0.1 to 1-ohm, 1% precision resistor that can handle 1 amp would be ideal. Attach the current injector clips across the calibration resistor. Then, connect the digital multimeter leads across the resistor. Set the meter to measure volts. With everything connected, press and hold the power pushbutton on the top of the unit's box. Note the voltage reading and adjust the current-control potentiometer (R7) on the circuit board for a voltage reading equal to the resistor value. If all goes well, the unit is now ready for use.

Unit Operation. With fresh batteries installed, the FET (Q1) will dissipate a maximum of 2.5 watts. The transistor dissipation will be maximum when the unit is measuring resistances below 0.1 ohms. Although you installed a small heat sink onto the transistor, it could still get very hot if the unit is operated for longer than a few minutes. I recommend that you use the system only in a momentary manner. Connect it up to the resistor to be measured, attach your digital multimeter, then take a quick measurement.

With fresh alkaline batteries, you should be able to make hundreds of measurements before the batteries have to be replaced. Also, under weak-battery conditions the power LED may turn on when the unit is not connected to a resistor but will fail to turn on when a resistor is connected. This is caused by a drop in the battery voltage under a loaded condition. The best way to make sure the unit's battery is still good is by activating the unit while the two test clips are shorted together. If the light fails to turn on, replace the batteries. ■

TALKING COMPASS

(Continued from page 82)

on the chip at once by pointing the compass north and holding the push-button down all the time. It will playback all recorded compass directions, in order. Then it will be in an overflow condition and cannot be pulsed to playback again. If that happens, just turn the power off and then back on again to reset the circuit. Likewise, should the Talking Compass ever quit playing back, it is probably in an overflow condition; as described previously, just turn the power off and then on and the unit should resume working normally once again.

If the battery runs down, the chip will not record; at that point, it will playback only, and the recorded message will eventually sound drawn out. That's a built-in low-battery warning feature.

Other Uses. Since the Talking Compass is capable of recording a full 16 seconds of voice communications, it can also be used as a message center. To use the unit as a message center, simply place S3 in the record mode, and with the unit facing north, press S2 and begin speaking. The unit will stop recording when S2 is released, or it will automatically shut down after 16 seconds has elapsed and its memory is full.

After recording your message, reset the unit by simply turning it off and on again. Then place S3 in the playback mode, and with the unit facing north, press S2. Note that in order to recover the message, the unit must be facing the direction in which the message was recorded. Of course, the unit can not be used as a compass that way, but it is a simple matter to re-record the compass points later.

You could also record two 8 second messages; one with the compass facing north and one with the compass facing south. Each message is played again by pointing the compass in the direction that the message was recorded and pressing S2.

As you can see, there are several ways to use the Talking Compass. You may want to "can" a few special phrases for use at an appropriate time. Don't let it get you in trouble, though! ■

TINY TUNER

(Continued from page 89)

(maximum capacitance), then apply a few drops of quick-setting epoxy to the flat knob, and mount a conventional knob, centering it over the flat one. The right knob will fit perfectly over the capacitor's flat knob. Make sure that the conventional knob is positioned so that its pointer is oriented where you want the maximum capacitance position to be. Next, mount S1 and the switch/inductor assembly to the front panel, and place a matching knob on the shaft of S2 (the inductor/switch combo), making sure that the zero-inductance position is where you want it.

After that, mount J1 and J2 (two BNC jacks). Those connectors can be mounted at any location on the plastic portion of the enclosure. In the author's prototype, the jacks were mounted opposite to the front panel, one on top of the other. Once all of the components have been mounted, it is time to interconnect them. The physical wiring is shown in Fig. 5. Miniature shielded microphone cable should be used to connect the circuit's input and output to J1 and J2. Make sure the shields of the two coax cables are connected together (in

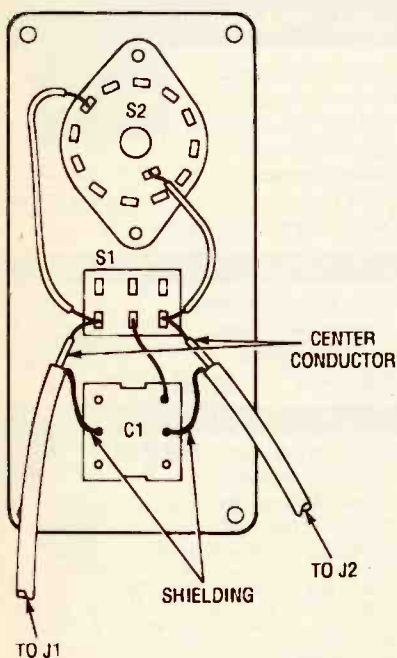
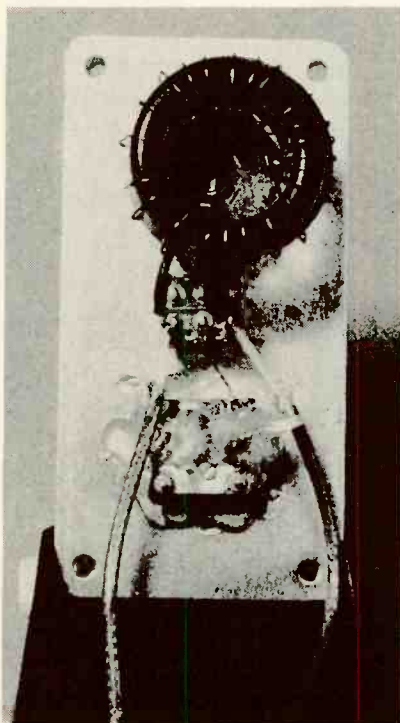


Fig. 5. Once all of the components have been mounted to the enclosure, use this diagram as an aid in the final wiring of the circuit.

the author's unit, that was handled through the capacitor's ground terminals) and to the shell of the BNC connectors.

While the circuit is very simple and nothing should go wrong, it's a good idea to check your work for wiring errors anyway. If all appears okay, your tuner is complete and you can close up the enclosure.



Here is the fully wired Tiny Tuner prior to the sealing of its enclosure. Note that L1 obscures the rotary switch to which it is mounted.

Conclusion. Now you have an antenna tuner for QRP operation that is small enough to literally fit in your pocket. The Tiny Tuner can be left permanently in the line since it is bypassed when the inductance switch is set to minimum, and the center-off toggle switch is in the center position. With the inductance set to zero, you can tune out inductive reactances with the variable capacitor. With the switch set to off, you can tune out capacitive reactances with the tapped inductor. You electrically reverse the tuner by flipping the capacitor switch from "I" to "O," thereby, permitting you to match high or low impedances. And while the power-handling capability is not very high, it is certainly high enough for almost any QRP rig that you might wish to use. ■

SOLDERING-IRON

(Continued from page 93)

trically part of the circuit, so it must be isolated from the metal lid with a mica insulator. Drill a hole in the lid in a convenient location, put heat-sink compound on both sides of the mica insulator, and secure both the regulator and insulator to the lid with either a nylon screw or a metal one with a plastic insulator.

If you choose to use a separate heat sink, then you'll have to go with a bigger project case. But, it's a good idea to use a mica insulator even if you use a separate heat sink.

One last thing to keep in mind: The unit's output *increases* as the resistance of R2 *decreases*. So wire R2 accordingly for an increasing output with a clockwise rotation. Also, because most of the usable range of the unit is in the lower adjustment range of R2, try to use a potentiometer of 25 ohms or less. Using a higher-value potentiometer will result in a very small adjustment range at the very end of the potentiometer's rotation. ■



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WIRE ANTENNAS

(Continued from page 69)

The D.E. Zepp will work on a lot of different bands. For hams, a 15-meter band D.E. Zepp will work as a Zepp on that band, a dipole below that band, and a four-lobed or "cloverleaf" antenna above the band.

Collinear Franklin Array Antenna.

Perhaps the cheapest approach to real gain is the Collinear Franklin array shown in Fig. 4. That antenna extends the dipole and D.E. Zepp concepts even further. It consists of a half-wavelength dipole fed in the center with a 4:1 balun and 75-ohm coaxial cable. At each end of the dipole is a quarter-wavelength phase-reversal stub that endfeeds another half-wavelength element. Each element is a half-wavelength long (L_1), and their length can be calculated from the equation given back in Fig. 1A. The phase reversal stubs are a quarter-wavelength long (L_2), or one-half the length calculated for L_1 .

The version of the Collinear shown in Fig. 4 has a gain of about 3 dB. There is no theoretical reason why you can't extend the design indefinitely, but there is a practical limit set by how much wire can be held by your supports, and how much real estate you own. A 4.5-dB version can be built by adding another half-wavelength section at each end, with an intervening quarter-wavelength phase-reversal stub in between. Once you get longer than five half-wavelengths, which provides the 4.5-dB gain, the size becomes a bother.

Lazy-H Antenna. The Lazy-H antenna (shown in Fig. 5) is called a "stacked" antenna because it consists of two antennas, one on top of another. That antenna provides gains as high as 5.5 to 6 dB just because of its configuration. In addition, the angle of radiation is lower, so it can put the "first hop" of a shortwave transmission a lot further out than a simple dipole antenna.

The phase-reversal harness between the elements should be made from either 450-ohm parallel transmission line, or 450-ohm twin-lead. Note that it is twisted over on itself in order to make the phase reversal

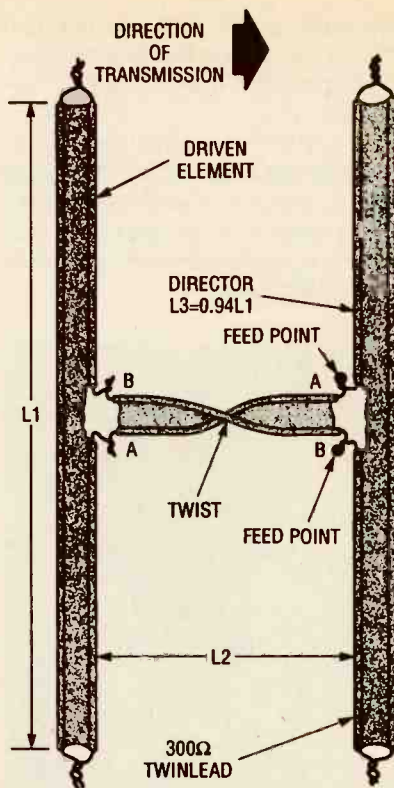


Fig. 6. The ZL-special antenna is sort of a folded dipole version of the lazy-H antenna shown back in Fig. 5. However, it does not have a discreet matching section.

FOR FURTHER READING

ARRL Antenna Handbook (multiple editions), American Radio Relay League.

Wire Antennas For Radio Amateurs, William I. Orr, W6SAI Radio Publications, Inc.

Radio Handbook—23rd Edition, William I. Orr, W6SAI, editor. Howard W. Sams & Co., Inc. (Carmel, IN). Cat. No. 22424.

Practical Antenna Handbook, Joseph J. Carr, TAB Books, Inc., (Blue Ridge Summit, PA, 17294-0850; 1-800-233-1128), Cat. No. 3270. \$21.95 paperback, 439 pages.

happen (lack of this phase reversal is one reason why this antenna may seem to "fail" when built). The matching section (with length L_3) should also be made of 450-ohm line.

The 75-ohm coaxial-cable transmission line should be connected to points "A" and "B" through a 1:1 balun transformer. These points are found experimentally by moving the balun connection points up and down along the stub until a 1:1 SWR is achieved. The formulas for the lengths of the elements (L_1), their spacing (L_2), and the matching section (L_3) are shown in the figure.

ZL-Special Antenna. Figure 6 shows a ZL-Special antenna. It is a half-wavelength horizontal antenna (seen from above in Fig. 6). It consists of two folded-dipole elements built of 300-ohm television twin-lead wire coupled with a 135-degree phase-reversal harness (also made of 300-ohm twin-lead). The length of the driven element is found from the equation back in Fig. 1, while the director element length (L_3) is about 6% less than L_1 . The equation for the length of the phasing harness (L_2), which is also the spacing between elements, is the same as that for the double-extended Zepp antenna (look back at Fig. 3). The feedpoint impedance is about 100 ohms, so it is a reasonable (but not exact) match for 75-ohm coaxial cable. Alternatively, either a 2:1 broadband impedance transformer, or a quarter-wavelength matching section similar to the Lazy-H antenna can be added.

The selection of antennas here should give you plenty of ideas to experiment with. If you build them safely and wisely, they should perform very well.

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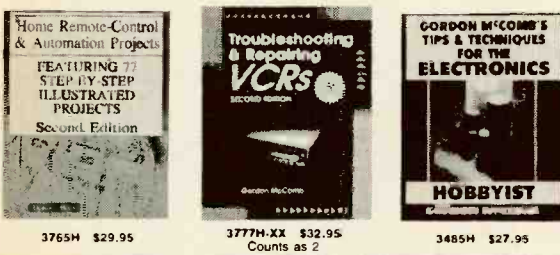


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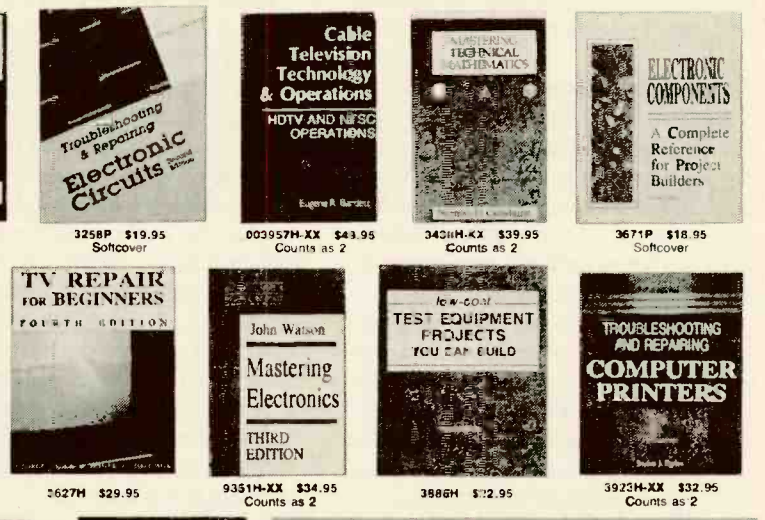
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PORCH-LIGHT CONTROL

(Continued from page 65)

Since the Triac is one of the tallest components in the circuit you will have to alter it to reduce its profile. To do so, file-down the upper "fat" part of each of its terminals. That will allow the terminals to slide all the way through the PC-board holes so the bottom of the part will rest on the circuit board. The filing must be done with care so that the legs are not made so thin that they break. Increasing the size of the holes instead of filing the terminals is not recommended as it increases the likelihood of forming a solder bridge between terminals, (which is especially dangerous for pins 1 and 2, which carry AC power).

It is strongly recommended that IC sockets be used for both IC's. That means you'll have to turn an 8-pin IC socket into a 6-pin socket to accommodate the optocoupler. To do that, carefully cut-down an 8-pin socket.

Stuffing the Board. Using Fig. 3 as a guide you can begin filling the board. The order in which you place the parts on the board is not important, however you should not install the switch or the IC's yet. In fact, keep the 4020 IC in its package until you are ready to install it to avoid static damage.

Furthermore, do not solder the polarized components to the board until you double-check their orientation. In this circuit none of them will be forgiving if power is improperly applied; it is not a question of whether there will be damage, but rather how much!

Having double-checked their orientation, solder all the components in place leaving the switch for last. Taking care not to over-handle the 4020, place it and the optocoupler in their sockets. Double check their orientation as well.

If, for some reason, you later need to take the switch out of its bracket after it is soldered in place, it can be done without unsoldering by very carefully unscrewing the last section of the base of the switch, being ultra-careful not to lose the two small springs and contact plate from inside the body of the switch as you do so.

The last step is to install the 8-32 screws back into the nuts soldered to

the board. The screws should be inserted from the foil side of the board and secured loosely.

Testing the Unit. For the rest of this procedure keep in mind that much of the circuit is hot. **Touching any exposed contact must be avoided.**

Turn the porch light on by using its wall switch. Then remove power from the porch-light circuit using the appropriate breaker or fuse in the electrical entry box.

Now remove the wall switch's front panel by taking out the two screws on the panel's face. Unscrew the two additional screws that hold the switch and its bracket to the wall box. Carefully pull the switch bracket with its two attached wires out of the wall box and use some kind of test equipment (a multimeter, a neon-bulb, etc.) to check that neither screw terminal on the switch is hot. If everything appears dead, untighten the screw terminals to release the two wires.

Hook each wire from the wall box around one of the 8-32 screws, placing the hooks in the wire in a clockwise direction and tighten the screws. Now start gently pushing the circuit into the wall box checking to see that there is no possibility of the sides or back of the control unit touching any metal part of the wall box. Some wall boxes are made of plastic and present fewer dangers. Even so, if there is any possibility of metal touching metal use layers of electrical tape to insulate them from one another. With the circuit in place, screw the switch bracket to the switch box. Restore power to the porch light circuit via the fuse or circuit breaker in the entry box.

The bulb may very well light immediately and if it does, it should extinguish after about 2¼ minutes (or whatever time delay you have selected). If it does not immediately light (or after it has first gone out), press the push button and the bulb should light and stay lit for the delay period selected. Any failure of the circuit board will either leave the light on permanently, (similar to the spring of the switch having broken with the switch closed); or permanently off.

Fit the new front panel in place (removing the button if necessary) and screw it to the bracket. Press the button onto the switch shaft, and you're all done. ■

49-MHZ FM TRANSMITTER

(Continued from page 54)

whip antennas are chrome plated and therefore do not readily accept solder. The mounting hardware makes it a lot easier to attach a lead wire to the antenna. Once all of the components have been installed or connected to the circuit board, check your work for accuracy. If all appears okay, move on to the test and adjustment phase of the construction.

Test and Adjustment. Before using the 49-MHz FM Transmitter, you must adjust R10, L1, T1, and T2. The tuning-core setting for L2 as supplied by the

SPECIAL COMPONENT SOURCES

Toko Inductors

Digi-Key Corporation
701 Brooks Ave. South
Thief River Falls, MN 56701-0677
Tel. 800-344-5439

Varactor Tuning Diode (Motorola)

Circuit Specialists
P.O. Box 3047
Scottsdale, AZ 85271-3047
Tel. 800-528-1417

49.890 MHz Crystal (may be used at 16.630 MHz)

Jameco Electronics
1355 Shoreway Rd.
Belmont, CA 94002
Tel. 800-831-4242

2SC1687 NPN RF Transistor

MCM Electronics
858 E. Congress Park Dr.
Centerville, OH 45459-4072
Tel. 800-543-4330

CRYSTAL SOURCES

International Crystal Manufacturing Co. Inc.

P.O. Box 26330
729 W. Sheridan
Oklahoma City, OK 73126-0330
Tel: 800-426-9825
Fax: 800-322-9426

Jan Crystals

2341 Crystal Dr.
P.O. Box 06017
Fort Myers, FL 33906-6017
Tel: 800-526-9825
Fax: 813-936-3750

Crystek Crystals Corp.

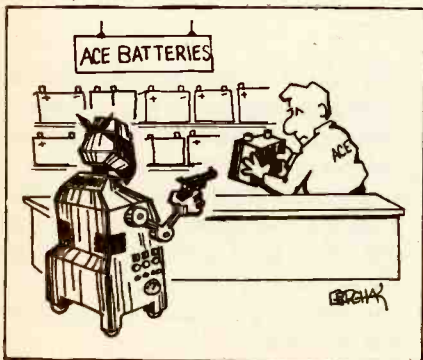
1000 Crystal Dr.
FT. Myers, FL 33907
Tel: 813-936-2109
Fax: 813-939-4226

factory is satisfactory and should not require adjustment. When adjusting any of the Toko coils (L1, T1, and T2), use a $\frac{3}{64}$ -inch blade, non-metallic alignment tool or, as a last resort, a jeweler's screwdriver. The cores are very brittle and fit snugly. Because of that, it is wise to avoid any unnecessary adjustments.

Initially, set R10 to about the 2-o'clock position. Fully extend the telescoping antenna, connect a 9-volt battery to the circuit, and press S1. Then, using a DC voltmeter, check for 3 volts at the R12/R13 junction; if the voltage is otherwise, the oscillator may not tune to the crystal's frequency. The core of inductor L1 may be adjusted to fine tune the oscillator's frequency. Generally, however, that is not required.

The cores of RF transformers T1 and T2 should be adjusted for maximum RF-output power. That is indicated by a dip in the DC emitter voltage, or a peak in reception range. As an alternative, you can lightly couple the probe of a 50- or 100-MHz oscilloscope to the antenna, and then tune T1 and T2 for maximum signal strength. Once the adjustments are completed, your transmitter is ready for operation.

Conclusion. The 49-MHz FM Transmitter offers many advantages over other 49-MHz transmitters and wireless microphones. Its highly stable VCXO keeps its signal locked on frequency. It's easy construction and low cost allow you to build as many transmitters you need to operate on the frequencies that are of interest to you. And the 9-volt power requirement allows you to use a battery or a 9-volt wall adapter. In addition, the 49-MHz FM Transmitter is just plain fun to build and use, offering insight into the world of RF circuits. ■



FREQUENCY COUNTER

(Continued from page 50)

pins 29, 34, and 35 of U8 to be sure they are tied to ground.

When the display properly indicates all zeros with no input to the counter, apply a signal to the input and note the display response on all ranges. Use an audio or RF oscillator, or function generator if available. Any wave shape is fine; the amplitude of the signal should be at least 0.5-volt rms, but not more than 5 volts.

Set the oscillator to about 1.9 MHz and check the frequency on the highest range of the counter; it should read close to 1900.0 kHz. Set the frequency to 190 kHz and switch the unit to the 200-kHz range. The display should read about 190.00 kHz. Finally, set the oscillator to 19 kHz and counter's range switch to 20 kHz. The counter should read about 19000 Hz.

If the counter does not give the proper indication, use an oscilloscope to locate the fault. First check pin 11 of U3-d for 3.2768 MHz at 5-volts peak-to-peak. If the signal is absent, check the wiring and components associated with U3-c and U3-d. Try a new IC if possible. Check U1 pin 3 for the presence of the trigger pulse on the two highest ranges of the counter. There should be a 7-millisecond wide, negative-going pulse, repeating about once every half second. When the range switch of the counter is set to the 20-kHz position, the pulsewidth triples, and repeats every 2 seconds. The absence of a trigger pulse indicates a problem with U1 and its associated components. Check R3, R4, R6, R7, C3, C4, and Q1 for proper values and orientation.

Check pin 4 of U3-b for a periodic 10-, 100-, and 1000-millisecond, positive-going gate signal for each of the positions of the range switch. The absence of that pulse could be caused by a failure of the flip-flop (U3-a and U3-b), U6, U4, or U5. The decade dividers can easily be checked by observing the wave shapes at pins 6 and 14 of U6—a rectangular wave shape at a frequency of 327.68 and 32.768 kHz, respectively is normal.

The binary divider can be checked by observing any of the 12 output terminals of U4, and pins 9, 7, and 6 of U5. Each succeeding output terminal

should produce a squarewave of half the frequency of the previous stage. If the binary dividers are not operating, and there is a clock signal present at pin 10 of U4, the fault may be with the latch circuit. In order for the binary dividers to count, the logic level at pin 11 of U4 and U5 must be zero for a period of 10, 100, or 1000 milliseconds after each trigger pulse from U1.

The operation of U8 should be checked by examining the input signals at pins 31, 32, and 33 of U8. At pin 32, the amplified signal-generator signal should appear as a 5-volt peak-to-peak waveform. Pin 31 should exhibit the positive-going gate signal generated by U3-b at pin 4. Pin 33 should have a narrow, negative-going (5 microseconds), differentiated pulse.

The absence of a waveform at pin 32 of U8 indicates that the analog amplifier is defective. Check the orientation of Q2 and Q3 carefully, and be sure that they are not interchanged. Check all the parts associated with those transistors to be sure they are of the correct values. Also check the orientation of C8.

Using the Counter. The operation of the frequency counter is simple. The only operating control is the frequency-range switch, which allows full-scale readings of 19,999 Hz, 199.9 kHz, and 1999.9 kHz. Note that the resolution of the counter for the ranges is 1, 10, and 100 Hz, respectively.

The circuit is not sensitive to the level of input voltage or wave shape, but it should be within the range of about 0.5- to 5-volts rms. The circuit is usable at frequencies of 10 Hz to 2 MHz, but the counter will respond to frequencies somewhat outside that range.

The counter's 1-Hz resolution on the 20-kHz range can be exploited on higher frequencies by taking advantage of the overflow characteristic of the counter. That feature permits the 1-second gate time of the 20-kHz range to be used to indicate the last 4 digits of the frequency even though the first digit, 1, is not a valid digit on overflow.

The circuit draws about 7 milliamperes, which allows in excess of 20 hours use from a fresh alkaline battery. At the end of battery life, the display will become dim and/or the frequency count will become erratic. ■

CONTINUITY TESTER

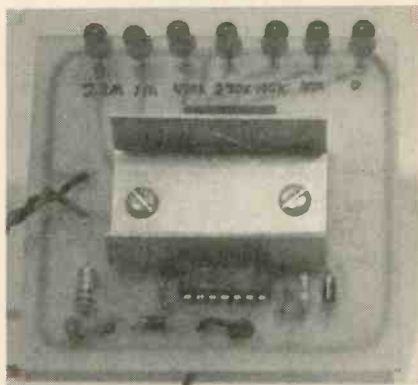
(Continued from page 91)

to pay attention to the orientation of the semiconductors; and pay particular attention to battery polarity when connecting the power source. Connecting the battery with reversed polarity can destroy the semiconductors.

A small battery holder fashioned from a 1 $\frac{3}{4}$ - x 2-inch strip of scrap sheet metal (bent to conform to the battery's body) was used to hold the battery to the board between the two IC's. A commercially available battery holder will also fit that area. A homebrew holder was used because the sheet metal was available, and to help keep costs down.

Although the author chose not to do so, the circuit can be housed in any suitably sized enclosure. The enclosure will require at least eight holes; seven in the top for the LED's and one in the side, through which to feed the test leads. Note: If the circuit is to be placed in an

enclosure, it will be necessary to either move the battery or the LED's off-board to allow the LED's to protrude through the case. (I'd opt for moving the battery, since doing so involves adding no wire leads to the board).



If you decide to mount a battery holder on the board, care should be taken so as not to sever or short the circuit-board traces. In the case of the latter, it may be necessary to use insulating washers on the foil side of the board.

The test leads can be terminated in the test terminal of your choice; probe

tips, alligator clips, hook clips (which the author used for his prototype), etc.

Test and Operation. To check the continuity tester, insert a 9-volt battery in the battery clip. Touch the two test probes together. The LED's should flash very rapidly. When the test points are opened, the LED's should extinguish. As was noted earlier, the rate at which the LED's flash is proportional to the resistance between the two test points.

As mentioned, the continuity tester also gives a relative indication of the resistance between its probes. For example, if a resistance of 330k is connected between the test probes, LED3 will flash at a 2 Hz rate, while all others flash at a rate that's either faster or slower than 2 Hz. With a little practice it is easy to judge the 2-Hz flash rate.

The tester can be used to test semiconductor junctions and other components. A forward-biased silicon junction will cause LED5 to flash at 2 Hz. No LED's will flash when the test points are connected to a reverse biased junction (effectively an open circuit). ■

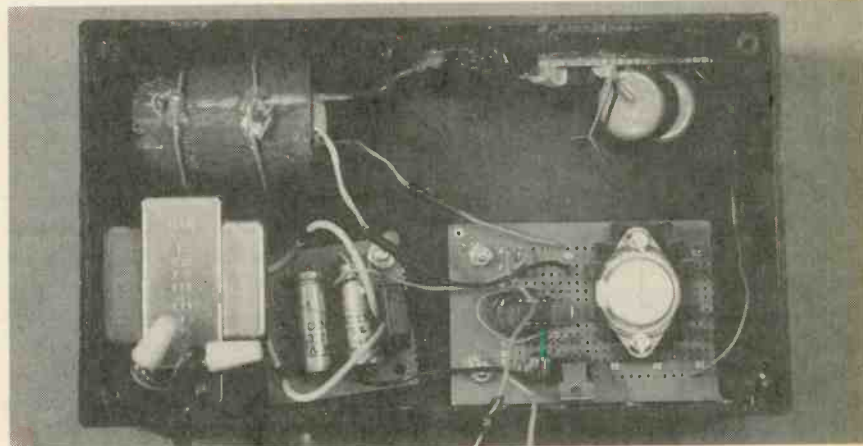
NEGATIVE ION GENERATOR

(Continued from page 14)

In passing, if you chose not to buy D1 from the supplier mentioned in the Parts List an exact replacement may be difficult to locate. However, even though it has a lower current rating, an ECG-518 should work fine, although this substitution has not been tried.

The discharge point should be "pointy" to enhance the ionization of the air. You can use a sewing needle, for example. An alternate discharge point can be fashioned from a small piece of No. 22 stranded wire. Strip off about $\frac{1}{2}$ inch from one end of the wire and separate the fine copper strands so that they are more or less evenly dispersed. When the wire is connected to the high negative voltage, the end of each strand will behave as a discharge point.

You can use any enclosure large enough to hold all the components. I'd recommend using a plastic enclosure if one is available. You should place a few air holes in the side or bottom of your enclosure for the fan to draw air in. The fan should be situated in the enclosure to pull air in past the discharge point(s)



As you can see, there is some space left between components. Note that in the prototype two capacitors have been used to emulate C1.

and out through an opening hole at the top of the enclosure.

Any screen or covering on the fan-outlet hole should be non-metallic or plastic in nature. Using a metal screen would severely cut the efficiency of the generator because the negative ions that come into contact with the metal screen would be neutralized.

When testing the circuit, if you see

any arcing or discharge from the high voltage transformer or high voltage capacitors, cut the power immediately. Let the project sit for awhile to let the capacitors discharge, and, without touching the project if possible, coat the faulty area with a little "No Arc" spray (available from Radio Shack). Allow the material to dry before testing the unit again. ■

TRACKING TRANSMITTER

(Continued from page 24)

spread. Spreading the windings will alter the inductance of the coil, thus changing the frequency range of the transmitter. That could make it impossible to tune in the designed FM range.

Once all of the on-board components have been mounted, connect the antenna. The antenna is nothing more than a 12-inch length of #22 stranded insulated hook-up wire. At this point, connect a 9-volt battery snap to the circuit. If you wish, you can add an on/off switch to the circuit by connecting the switch in series with one of the battery leads.

Although the Tracking Transmitter is designed to be used without a chassis box, you can house the unit in a small plastic or metal box (recommended if you will be including an on/off switch in the circuit). A metal box is the preferred enclosure; it will make the transmitted frequency much more stable and easier to set.

Checkout. Check over your work for proper assembly and short circuits. Make sure that each transistor is correctly oriented and in its proper place. Check each resistor and make sure the resistor values are in the proper location as well. Connect a 9-volt battery to the circuit.

Use an oscilloscope to look at the signal at the collector of Q2. You should see a pulse train with a peak-to-peak amplitude of approximately 8 volts. The positive-going pulses should be approximately 300-millisecond wide and should be separated by approximately 1500-millisecond spaces. If you don't have an oscilloscope, connect the ground lead of an analog (non-digital) voltmeter to the negative terminal of the battery. Set the voltmeter for 10 volts or higher. Connect the positive lead of the voltmeter to the collector of Q2. The meter reading should repeatedly pulse from about 1 to about 9 volts.

Next, turn on an FM receiver and set it to a clear (unused) frequency between 88 and 108 MHz. Using a non-conductive alignment tool adjust C7 and C6 until you hear the transmitter on the receiver. You may have to squeeze or spread L2 to insure that the Tracking Transmitter tunes from the low end to the high end of the band. ■

RING LAUNCHER

(Continued from page 34)

ground the AC line voltage to a metal chassis. In addition, an isolation transformer should be used when testing or troubleshooting the circuit to avoid a very serious shock hazard.

Apply power to the circuit; DISP1 should display a 9. Press S1 and monitor the display. The display should show a descending count. If the counter does not function (the display fails to count after pressing S1), check for a clock pulse on pin 3 of U5. If U5 is receiving the proper clock signal, check the BCD output wiring that feeds U4 (the latch/decoder/display driver) for a BCD output at pins 3, 2, 6, and 7 of U3. Confirm that those terminals are wired to pins 7, 1, 2, and 6, respectively, of U4. Also check U4 pins 5 and 16 for the proper supply voltage.

The monostable timer (U2) should trigger as soon as the counter reaches zero. A TTL logic probe or an oscilloscope can be used to check that Q1 pulls pin 2 of U2 low when the count of zero is reached. About one second later, the output of U2 at pin 3 should go low, resetting the flip-flop (U1-a/U1-b). Check for a low on pin 11 of U3; that disables the counter/display at a count of zero.

If the ring is not repulsed when the count reaches zero, check to make sure that pin 12 of U3 goes high, triggering U6, on the zero count. If that's okay, check that the gate of TR1 receives a trigger voltage from the optoisolator/coupler on the zero count. If all seems to be okay up to that point, check the interconnections to and from the Triac. If the Triac is wired correctly, but the ring is still not repulsed, try replacing the Triac. Continue checking the individual sub-circuits until the problem is located and corrected.

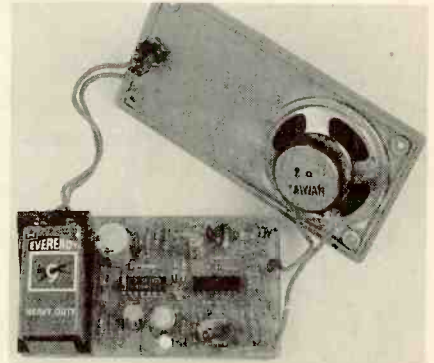
One final note on safety before we conclude: While the prototype does not propel the aluminum ring with any great force, you should, nonetheless, not point the unit at any person or against any object that may be harmed by contact with the ring. It would be a shame to ruin the fun this project could provide through a careless act. ■

HOT CANARIES

(Continued from page 31)

their sockets, but do not mount the board in its enclosure yet; it must still be tested.

Testing. To test the circuit, place a 9-volt transistor-radio battery in the holder, attach the snap-on connector to the battery, and turn S1 to the on position. You should hear chirping sounds not long after the circuit is powered up. Using a voltmeter, check the +V input of each chip at pin 4 for +9 volts. Once you established that the IC's are receiving power, potentiometers R5 and R6 must be adjusted.



Once the printed-circuit board has been attached to the lid-mounted speaker and switch, it must be tested and adjusted to ensure proper operation, prior to being sealed in its enclosure.

Adjustments to R5 and R6 are best done by temporarily desoldering R1 and R2 in turn. Remove R1 first and adjust R6, so that chirping starts at a slow pace then increases to a faster rate, and then stops before starting again. If the trimmer is too far counterclockwise, the canary will hardly chirp at all, but if it's too far clockwise, it will not stop chirping. Once that adjustment is complete, reinstall R1, remove R2, and adjust R5 in the same manner. The chirping from the second half of the circuit should sound slightly different from the first.

Once the second half of the circuit has been adjusted, the printed-circuit board can be mounted in the enclosure, and the enclosure can then be sealed. As a final touch, you can attach a pair of artificial canaries to the lid of the enclosure to partially conceal the speaker holes and the switch lever in the lid. ■

VOLTAGE ADAPTER

(Continued from page 22)

Put an "S"-shaped kink in the wires to the switch to allow them to fold over once they are put in the lighter plug. Now insert the assembly, switch-first, into the lighter plug. As you do so, fold back the wire that goes to the center contact of the lighter plug. Make sure that the switch's body is perpendicular to the hole for the coax. That allows the switch to slide over the coax without pinching it. Once the switch is all

across the lighter plug's contacts. It should read about 6000 ohms. If you get zero or an off-scale reading, check for an open or short in the circuit, respectively. If all is well, plug the unit into your car's cigarette-lighter socket and measure its output with a voltmeter. Unless you've redesigned the unit for different outputs, with the switch in the center position, the device should yield 9 volts. The other positions should give 6 and 3 volts.

If you get nothing out, check the ground and V_{out} connections. If you get three incorrect voltages, check

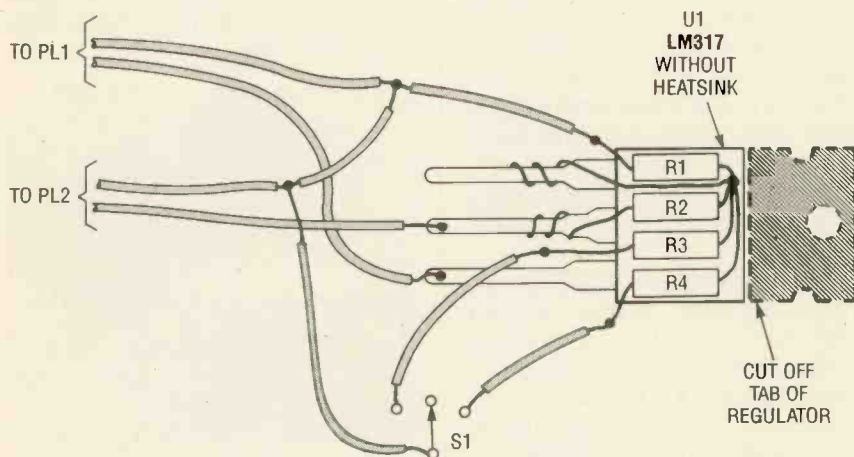
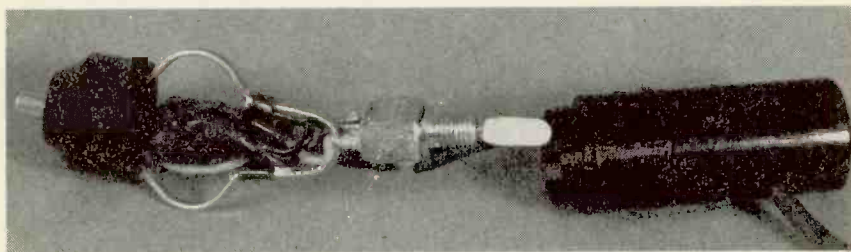


Fig. 3. Here is the best way to lay out the parts to form a neat, compact package. You should use heat-shrink tubing to insulate all the connections.



The inside of the Car-Power Adapter is laid out like this. As you can tell, the compact design requires precise lead lengths to fit properly in the plug.

the way in, turn it to align it with the coax. Push the clip the rest of the way in and screw on the cap containing the center contact.

The plug you connect at the far end of the power cord (PL2) and its polarity is up to you. I chose to use an RCA phono plug because I have a few adapters that can convert it for use with the devices I have. Once you have connected PL2 you're all done.

Testing. Before plugging the unit into your car, take a resistance reading

the connections to R1 and R2. If the maximum voltage (9 volts for the authors model) is correct, but one or both of the other voltages are wrong, check R3 and/or R4 as necessary.

Once ready, your Car-Power Adapter should bring you many hours of listening pleasure. As you'll probably discover, it can be used for more than just audio and is perfect for working on a laptop by the shore, or to give yourself a quick shave before an important appointment. You're bound to come up with more uses on your own. ■

TUNE PIANOS

(Continued from page 20)

the piano is less than a semitone below standard pitch, then bring it up by 20 cents. Never bring a piano down in pitch, always up.

You may have noticed the slight discrepancy between the value that we calculated for middle C and the value listed in Table 1. As indicated in the table, C40 is "stretched" downward by 2 cents. The reason for that is that because of their stiffness, steel strings generate overtones that are slightly higher than true harmonics. That makes an octave sound flat, unless it is stretched to compensate. The pitches shown in Table 1 are stretched for the average piano tuned to standard pitch, which will produce excellent results for any piano.

To include the -2¢ stretch in our previous calculation of C40, the exponent of 2 would have been $902/1200$. For any pitch other than standard, you'll have to calculate and tabulate a new table of pitches. That's an involved and tedious task. Fortunately, there is an easier approach: A computer program for the PC, available from the vendor named in the Parts List, will do the work for you and print the results. It calculates the pitches for all 88 keys for any value of A49, and can optimize the stretch for the type of piano, whether spinet, upright, or grand. It can also generate tables of unstretched values.

When tuning the strings in sequence, it's best to start with key 1 and work your way up the keyboard to key 88. The top-octave strings do not sustain well, and may present some difficulty in reading their waveforms on the scope. The stereo headphones can be used here to give an audible indication of relative pitch. They are also useful when tuning in a noisy environment, which can disrupt the waveform display. It is possible, with practice, to tune the entire piano without the microphone and oscilloscope; that is done by listening to the tone in the headphones while carefully adjusting each string of the instrument for zero-beat.

If you use the Precision Audio-Frequency Generator to tune an organ or other non-stringed instrument, no stretch should be used. The pitches can be calculated from the formula given in this article. ■

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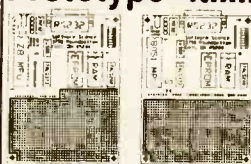
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TELEPHONE RING CONVERTER

(Continued from page 56)

Testing and Operation. Start by re-checking your wiring to make sure you haven't made any errors. When you are confident that everything is okay, you can check out the ring converter by using the 60-Hz signal present on your home's powerlines. To do that you will have to take a line cord and add a fuse to it to form a test jig as shown in Fig. 5. **Be sure to use a ¼-amp fast-acting fuse as shown, and insulate all connections to prevent a shock hazard. Be cautious when working with house current—remember: safety first!** Once you've modified the line cord, attach it securely to the appropriate points on the circuit board.

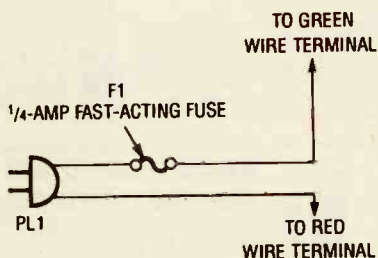


Fig. 5. A quick test jig can be made from a linecord and a fast-acting fuse, as shown here. Be very careful to insulate all the connections of this assembly.

Turn both the volume and tone controls to mid-position, and plug the assembly into a wall outlet. Adjust the volume and tone controls through their ranges; you should hear the warble of the ring converter. If nothing is heard, unplug the assembly and check to make sure the fuse hasn't blown. If it has, check for a wiring error before replacing the fuse.

Make sure the ring converter passes this test before connecting it to the phone line. When you are satisfied with its performance, disconnect the line-cord/ fuse assembly. Finish the project by using decals or a label maker to provide legends for the controls, and fit the circuit into an appropriate case.

Disable the bell in the telephone by switching the bell off (look for a slide switch on the side of the telephone near the bottom), or move the bell loudness lever to low. Another way to

PARTS LIST FOR THE TELEPHONE RING CONVERTER

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(All fixed resistors are ¼-watt, 5% units.)

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- R2—1-megohm, linear-taper potentiometer
- R3—1-megohm
- R4—100,000-ohm, linear-taper potentiometer

CAPACITORS

- C1—C5—0.1 μ F, 400-WVDC, Mylar
- C6—10- μ F 100-WVDC non-polarized electrolytic

ADDITIONAL PARTS AND MATERIALS

- U1—TCM1506 Texas Instruments ring-detector/driver, integrated circuit
- BZ1—25,000-pF piezo transducer element
- Modular telephone extension cord (see text for type), project box, potentiometer knobs, circuit-board materials, wire, solder, etc.

mute a mechanical bell is by wrapping the bell rim(s) with electrical tape. The tape will dampen the bell ring to a whisper.

To use the Ring Converter simply plug the Jack into a modular wall socket as shown in either Fig 4A or Fig. 4B. Call up a friend and ask them to call you back and let the phone ring. Adjust the tone and volume to a pleasant level and you are done. You will find the Ring Converter indispensable if you work in an office area full of ringing telephones. ■



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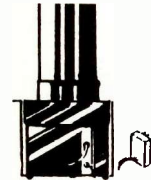
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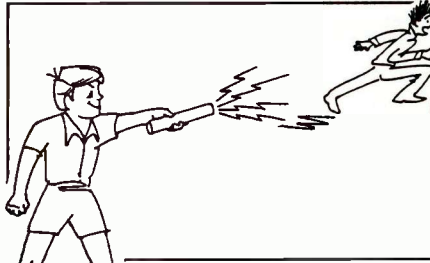
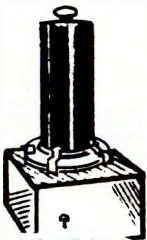


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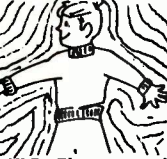
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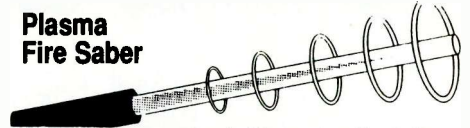
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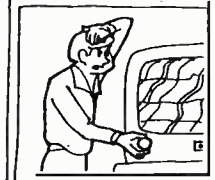
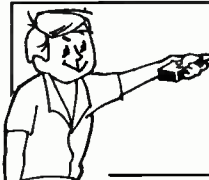
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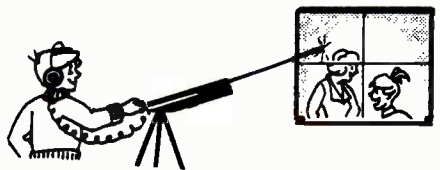
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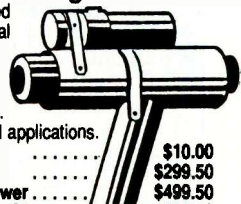
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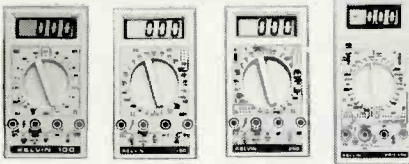
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LCR - Hz - dBm - True RMS - Logic Probe
The only meter with 0.1% Accuracy on DC Voltages, built-in True RMS, Freq Counter to 20MHz Res: 10 Hz, LCR-Inductance Tester Res: 10 uH, DC/AC Voltages Res: 0.1mV, Ohm Meter Res: 0.1 ohms

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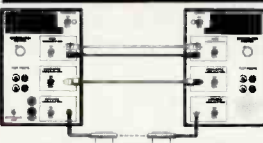
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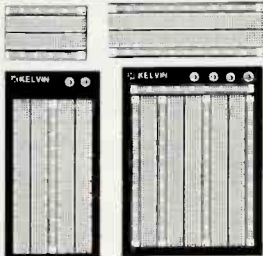
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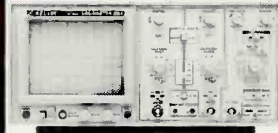
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