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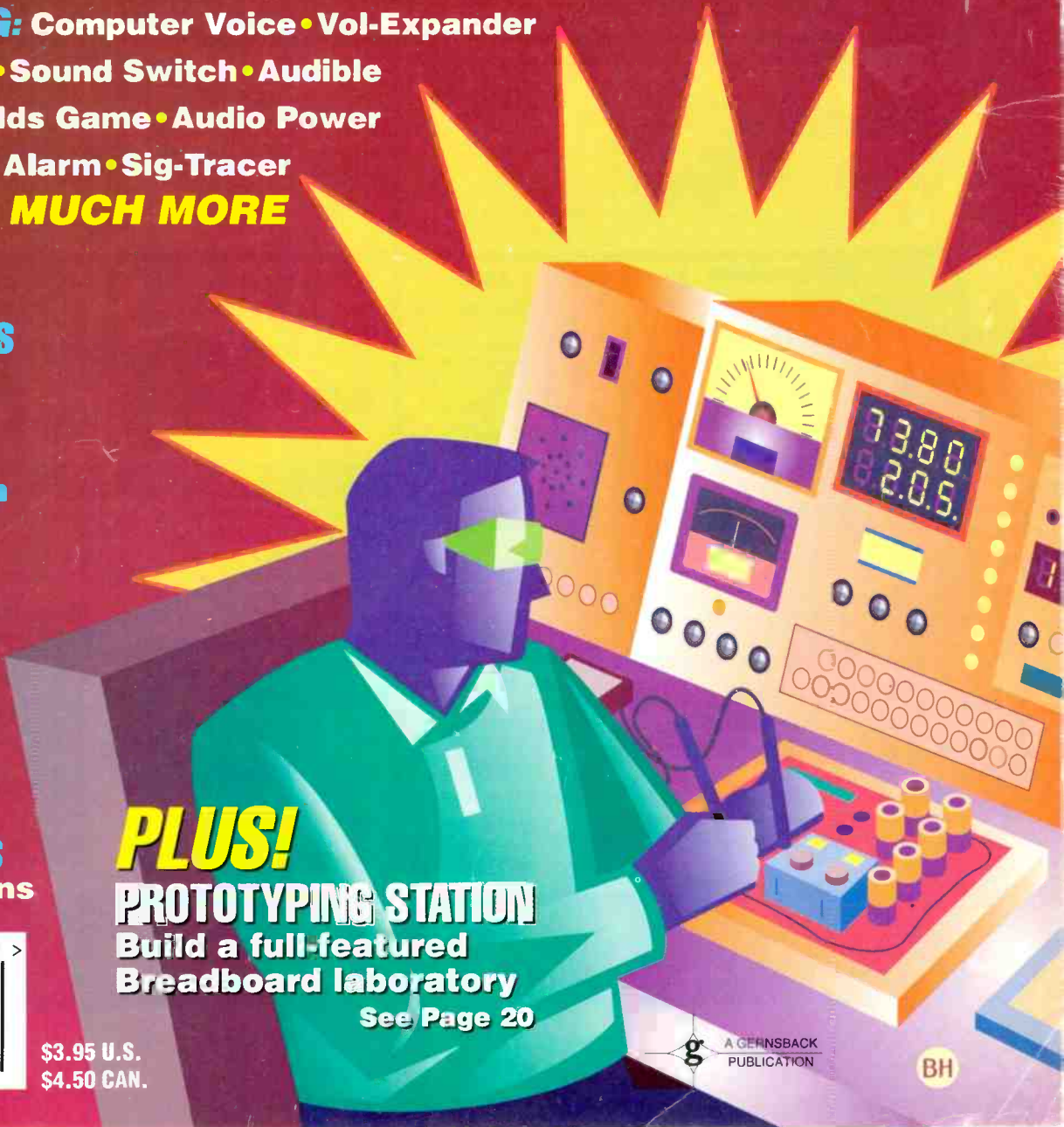
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See Page 20



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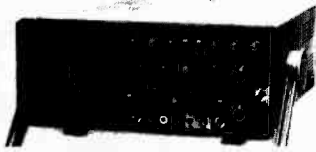


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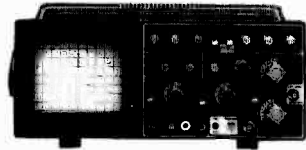
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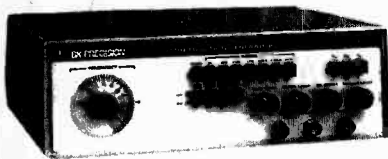
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1996

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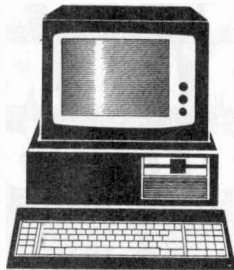
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Editorial

There are many and varied good reasons for building a project from plans published in a magazine. I won't go into listing all these reasons because I would probably leave your motivation off the list. Now then, can you think of one bad reason for building a project from a magazine plans? Think about it.

I find that too many project builders follow the plans scrupulously, not varying from the schematic diagram. They even produce a project that mirrors the photographs supplied in the construction article. Admittedly, editors prefer that readers build projects than not. Albeit, why not show some creativity. Every project can be improved upon in some way. A cosmetic change to suit your fancy may not be an electronic-design advancement, but it does show some individualism.

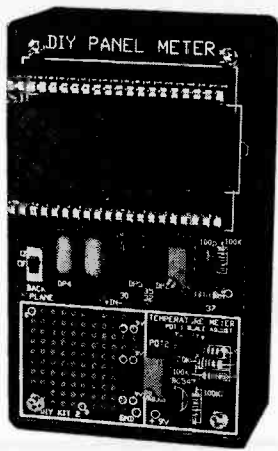
To encourage the builder's development of published instruction articles, the editors decided to publish The Project Anthology that appears in the center of this magazine. This Anthology is a Lilliputian compilation of varied projects that are bound to excite the builder into assembling more than one of them. Since the complete plans are not provided (in most cases only schematic diagrams and parts lists are provided), the plans leave the final assembly design up to the builder. Also, the circuits themselves are simple enough so that the introduction of new electronic design features can be added.

What the editors are attempting to do is promote your sculpturing of the project to suit on-site needs. We want you to build what you need from our plans. The foray into designing circuits eventually becomes habitual and rewarding.

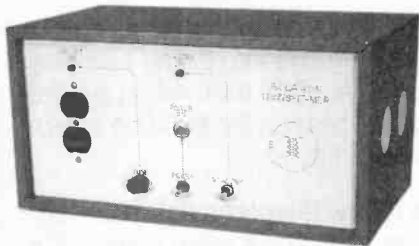
Who knows! You may become one of our authors when your projects are designed from your original plans!

A handwritten signature in cursive script that reads "Julian S. Martin".

Julian S. Martin,
Editor



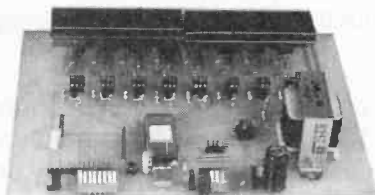
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Isolation Transformer
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Milliohm Tester
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ELECTRONICS EXPERIMENTER'S handbook™ 1996

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Introducing...
The Projects
Anthology
18 Electronic Gadgets
You Can Build!

The Project Anthology

A collection of eighteen projects that will add spice to your project building pleasure.pages 49-80

1—**Twinkle Tree**, LED light jollies, 2—**One-Second Flasher**, for the shutter-buff bug, 3—**5-Volt Power Supply**, to build more projects, 4—**Sound-Switch**, a must for voice actuated action, 5—**Light Alarm**, for dark-only areas, 6—**Sig-Tracer**, discover where the signal disappears, 7—**CW Filter**, for better code reception, 8—**Vol-Expander**, squeezes sound to tape, 9—**Computer Voice**, a fun voice effect, 10—**Audio Power Booster**, double your power, double your listening pleasure, 11—**Pit Stop**, a racy game, 12—**Minefields**, a boomy game, 13—**Kapellmeister**, a simple transmission-line loudspeaker system, 14—**Helix**, apartment-dweller's hidden antenna, 15—**Inverted V Antenna**, a modified half-wave antenna that pulls in the signals, 16—**Audible Timer**, this beep is for you, 17—**Long Interval Timer**, up to two weeks long, 18—**Twangy Distortion Unit**, in tribute to Jerry Garcia.

Mini Logic Analyzer87

With about \$30 worth of parts and an IBM/compatible computer you are ready for the troubleshooting big leagues

Magnetic Field Meter95

Determine your exposure to line-frequency magnetic-fields with this portable ELF gaussmeter.

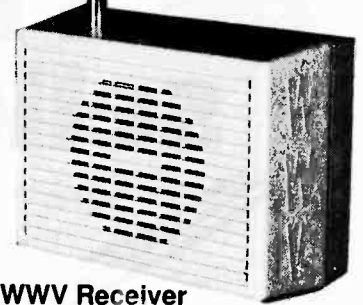
Power Controller100

Control eight channels of 120-volt AC with a 68705 microcontroller.

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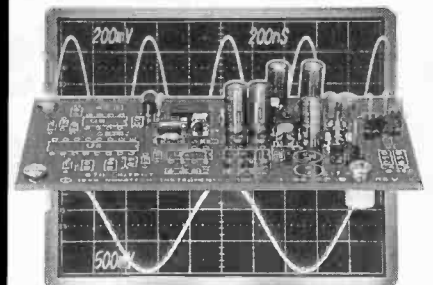
Free Information Coupon 15, 108, 111



WWV Receiver
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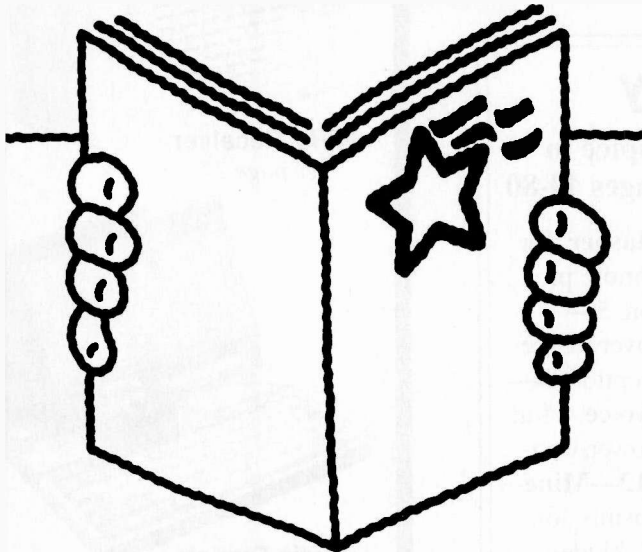


Sinewave Doubler
See page 32



Magnetic Field Meter
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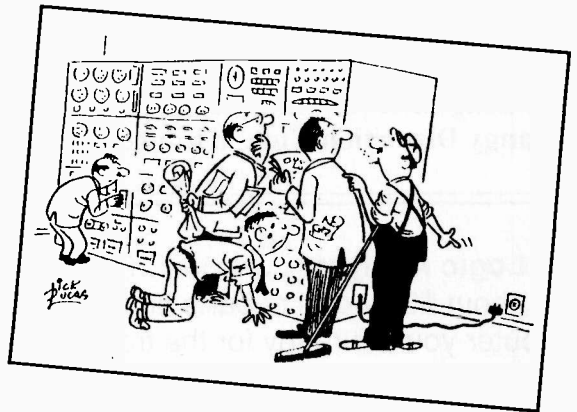
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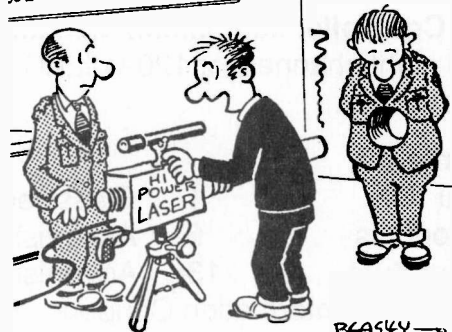
*Starting off
with a few chuckles!*



"Meow!"



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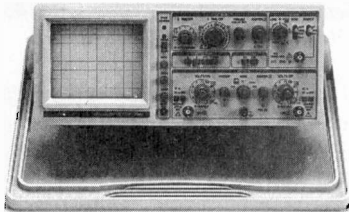
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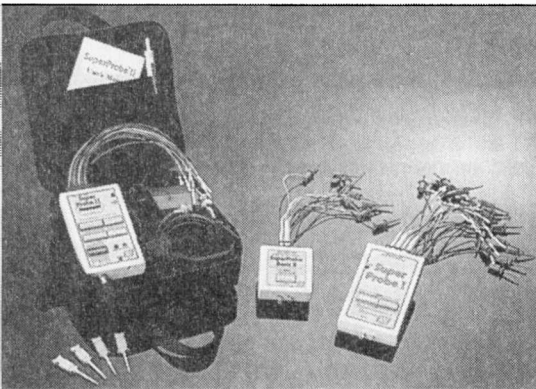
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THE SUPERPROBE OSCILLOSCOPE triggering devices from Programmable Designs are instruments that can trigger complex events in digital circuitry and simplify circuit debugging and testing. They will work with any oscilloscope to provide a wide range of event-triggering options. Four different models are available.

The SuperProbe II has 18 digital logic inputs and a clock input. It



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supports three clocked triggering modes and one combinatorial (pattern-match) triggering mode. The device works with flexible logic combinations for specifying triggering events. These include no-match triggering for triggering when certain unexpected events occur. This model has separate "pattern select" and "don't care" configuration DIP switches.

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SuperProbe I is a pattern-match or word-recognition version with 17 digital inputs. It allows any logical combination with up to 17 sig-

nals to be specified for the trigger event. This model is offered in two versions. The standard version includes an interface cable with permanently attached grabbers for through-hole component leads. The deluxe version has a cable identical to the one included with the SuperProbe II.

The SuperProbe Basic-8 permits pattern-match triggering with up to eight signal inputs. It includes a cable with permanently attached through-hole component grabbers.

SuperProbe pricing ranges from \$99.00 to \$549.00, depending on the model.

PROGRAMMABLE DESIGNS INC.

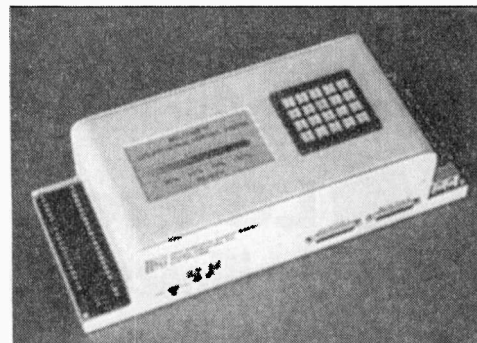
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INDUSTRIAL CONTROL SYSTEM

THE QED INDUSTRIAL Control System (ICS) from Mosaic Industries is a single-board computer with either a character or graphics LCD display, and a keypad or touchscreen. It has a battery-backed memory, real time clock, analog and digital I/O, board area for prototyping, and provision for serial communications. The system is packaged in an industrial-style enclosure with screw-terminal connections.

This packaged system is intended for many different applications including machine automation, data acquisition, and robotics. The ICS can interpret data from temperature, pressure, and optical sensors; process the input data; and control stepper motors, valves, relays, and other actuators.

Palm-sized plug-in cards introduce isolated high-current outputs and high-voltage inputs, 4 to 20-milliampere signalling, and analog-to-



CIRCLE 37 ON FREE INFORMATION CARD

digital or digital-to-analog conversions. The system modules can be programmed in C or Forth from a personal computer with on-board multitasking software.

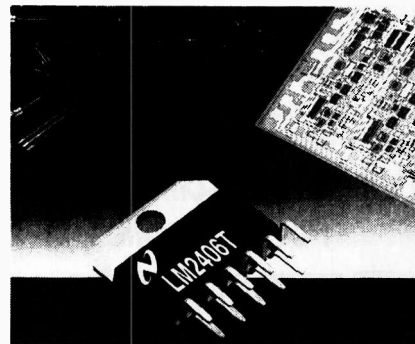
The QED Industrial Control System with character display and keypad (ICS-AK) is priced at \$995.00. With a graphics display and keypad (ICS-GK), it is priced at \$1190.00.

MOSAIC INDUSTRIES, INC.

5437 Central Avenue, Suite 1
Newark, CA 94560
Phone: 510-790-1255
Fax: 510-790-0925

MONOLITHIC CRT DRIVER

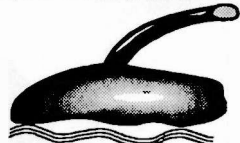
THE LM2406T FROM NATIONAL Semiconductor is advertised as the industry's first monolithic IC cathode-ray tube driver. This triple-channel, 40-MHz CRT driver, designed for SVGA and XGA monitors. The bipolar device is capable of supporting scan frequencies up to 58 kHz/72 Hz.



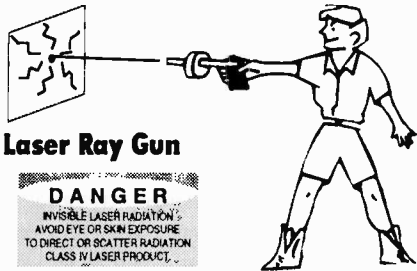
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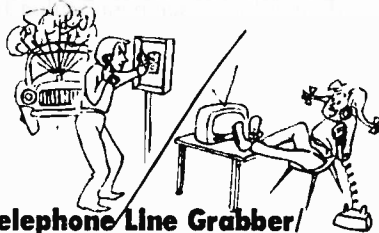
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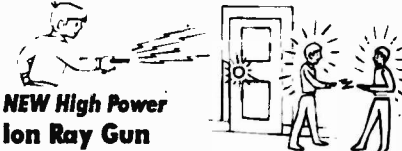
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TELECON10 Ready to Use \$199.50

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1000 Ft++ Potato Cannon

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 (Dangerous Product)

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4,000 volts in the palm of your hand! Experiment with anti-gravity, hovercraft, ion guns, force fields, plasma guns, shock devices, wireless energy and electrical pyrotechnics. Input: 9-14VDC.
MINMAX4 Ready to Use \$19.50

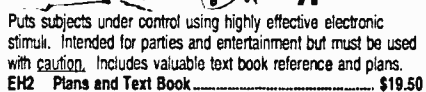


"Laser Bounce" Listener System

NEW - Latest Technology! Allows you to hear sounds from a premises without gaining access. Aim at room window and listen to sounds from within via reflected laser light. Not for illegal use. Requires video tripods.
LWB3K 5mw Laser and Receiver Kit \$149.50
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5mw Visible Red Pocket Laser

Utilizes our touch power control!
VRL5KM Kit / Plans \$74.50



Electronic Hypnotism

Puts subjects under control using highly effective electronic stimuli. Intended for parties and entertainment but must be used with caution. Includes valuable text book reference and plans.
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NEON

Easy-to-Install 4-Tube Kit for Cars, Trucks, Vans! Available in Pink, Purple, Blue or Green - please specify color when ordering.
RG4K (Specify Color) \$129.50
 Flash-To-Music Option for above kit **FMU1 \$29.50**



License Frame Kit (Specify Color)
LIC1K \$24.50

3 Mi FM Wireless Microphone



Subminiature! Crystal clear, ultra sensitive pickup transmits voices and sounds to FM radio. Excellent for security, monitoring of children or invalids. Become the neighborhood disk jockey!
FMV1 Plans \$7.00 FMV1K Kit and Plans \$39.50

Telephone Transmitter - 3 Mi

Automatically transmits both sides of a telephone conversation to an FM radio. • Tunable Frequency • Undetectable on Phone • Easy to Build and Use • Up to 3 Mile Range • Only transmits during phone use. **VVPM7K Plans \$7.00**
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The LM2406T can drive a cathode capacitance of 8 pF with a voltage swing of 40 volts peak-to-peak, and it has a rise and fall time of 9 nanoseconds. When paired with National Semiconductor's LM1203N or LM1207N video amplifiers, the combination forms a complete video channel for SVGA and XGA computer monitors.

The monolithic IC includes internal protection to prevent momentary short circuiting. It reduces monitor component count, simplifies system design and manufacture, and increases system reliability. It is offered in a reduced-size TO-220 package.

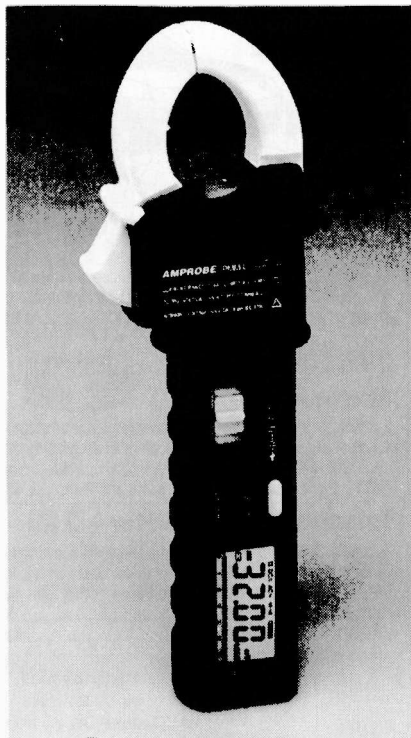
The LM2406T monolithic CRT driver is priced at \$2.50 in quantities of 1000.

NATIONAL SEMICONDUCTOR CORPORATION

2900 Semiconductor Drive
Santa Clara, CA 95052-8090
Phone: 1-800-272-9959

MULTIMETER WITH CLAMP-ON ADAPTER

THE AMPROBE MODEL PMM-1 is designed so that a clamp-on adapter can be connected, allowing it



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to measure up to 300 amperes. The basic DMM is a 3200-count instrument that measures AC and DC voltage to 600 volts and ohms to 30 megohms. It has an annunciated LCD readout and a 65-segment analog bargraph. The DMM offers auto and manual ranging, audible continuity testing and data hold. It also performs diode checks. The PMM-1 has 600-volt AC and DC protection on all ranges.

With the addition of the PMM-C clamp-on adapter, the PMM-1 can measure up to 300 amperes AC. The adapter jaws will close over conductors up to 1.14-inch in diameter. The combination has an output of 1 millivolt AC per 0.1-ampere AC. With additional optional accessories, the PMM can do infrared scanning and measure up to 1000 amperes AC, 600 amperes DC, temperature, and up to 400 kilowatts.

The PMM-1 digital multimeter with carrying case, test leads, batteries, and a user's manual is priced at \$69.85. The PMM-C clamp-on accessory is priced at \$49.85.

AMPROBE INSTRUMENT

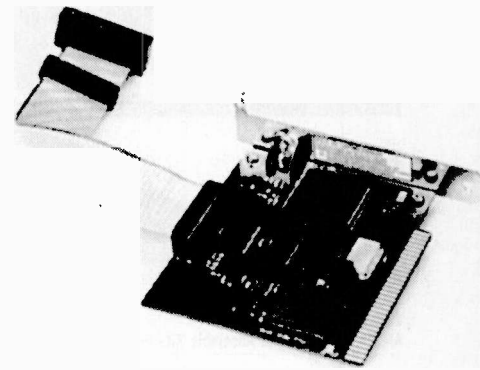
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Lynbrook, NY 11563
Phone: 1-800-477-VOLT
or 516-593-5600
Fax: 516-593-5682

COMPUTER CARD FOR MULTIMEDIA PRESENTATIONS.

THE MODEL ME1000 (VGA2-NTSC) plug-in computer card from Methode Electronics allows multimedia presentations to be displayed on a standard television receiver or recorded on a VCR. The card converts VGA computer graphics, computer-aided designs, and multimedia presentations to standard NTSC video output.

The card automatically detects and switches between 640x480 pixel, 320x200 pixel, and 80-column text modes. The plug-in card works with any IBM or compatible personal computer that has an Intel 386, 486, or Pentium processor, an ISA bus, and a graphics card with the appropriate connector.

The ME1000 also provides flicker-



CIRCLE 33 ON FREE INFORMATION CARD

free images, CAD-drawing output with no missing lines, and sharp 80-column text mode. The card conforms to multimedia standards, and it is compatible with AutoCAD and 3D Studio CAD software. It is also compatible with DOS and Windows operating systems. The cards can display 256 colors and are easily installed with the included internal cable.

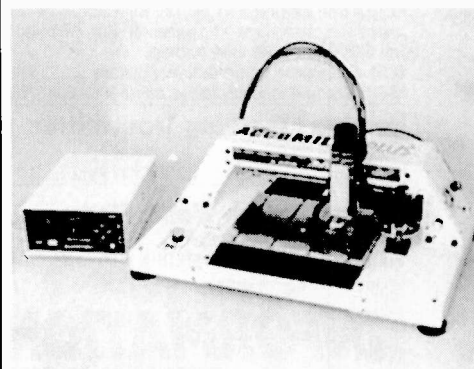
The ME1000 (VGA2NTSC) plug-in card is priced at \$525.00

METHODE ELECTRONICS, INC.

dataMate Division
7444 West Wilson Avenue
Chicago, IL 60656
Phone: 708-867-9600
or 1-800-323-6858
Fax: 708-867-3149

DESKTOP MACHINING CENTER

KEPRO CIRCUIT SYSTEMS has introduced the AccuMILL/Plus, a miniature automated X-Y-Z desktop machining center. It can drill, mill, route, and engraves circuit boards. The machine can be fitted with eight different tools. It can drill through both single- and double-sided circuit



CIRCLE 50 ON FREE INFORMATION CARD

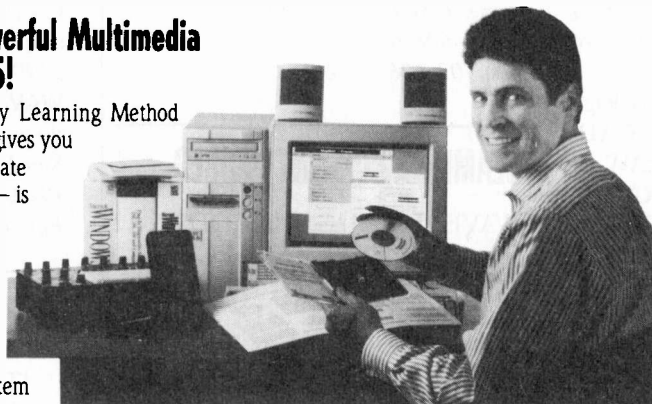
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circuits, modify them, and then diagnose and repair faults.

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boards to 0.00025-inch resolution for short-production runs or prototyping. It can also mill circuit patterns and machine complex three-dimensional objects from plastic, aluminum, brass, wood, or modeling wax.

The worktable for the AccuMILL/Plus measures 10x14-inches. Its automated tool carousel has eight tool motors. These include one fully automatic, fixed/floating position for accurate milling of irregular surfaces. Adjustments can be made to 0.001 inch. The machine has three different motor speeds: 7000, 28,000, or 50,000 rpm. Three-axis mounting of the tools permits the fabrication of three-dimensional parts.

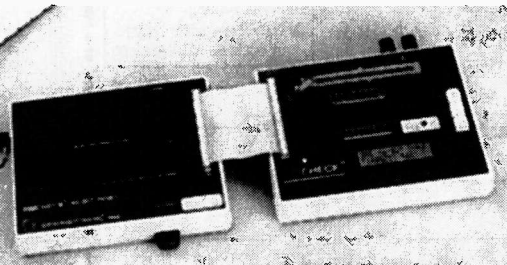
The AccuMILL software package is compatible with AutoCAD, AutoSKETCH, and CoreDRAW. It can interpret ASCII and HPLG plotter-files running under MS-Windows. The AccuSTEPPER controller is an automated computer interface that controls all three axes.

The AccuMILL/Plus desktop machining center is priced at costs xx.

KEPRO CIRCUIT SYSTEMS, INC.
630 Axminister Drive
Fenton, MO 63026-2992
Phone: 1-800-325-3878
Fax: 314-343-0668

MEMORY TEST PACKAGE

THE SIMCHECK PLUS MEMORY tester from Aristo Computers combines the SIMCHECK memory module tester with a 40-bit port adapter in a single package. Together, they can do complete testing of both 30-pin and 72-pin single-in-line memory modules (SIMM). The enhanced memory tester includes a universal power supply that can be plugged directly into the tester or into the 40-bit port.



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The basic SIMCHECK memory tester tests all standard SIMM and single-in-line (SIP) memory modules with eight or nine bits of 64- and 256-kilobit and 1-, 4-, and 16-megabit memory. The 40-bit port enhances the tester's ability to test 72-pin SIMM modules that have a data bus with up to 40 bits and a maximum memory capacity of 128 megabytes.

SIMCHECK Plus is priced at \$1490.00

ARISTO COMPUTERS INC.
6700 SW 105th Avenue, Suite 300
Beaverton, OR 97008
Phone: 1-800-3-ARISTO
or 503-626-6333
Fax: 503-626-6492

CLAMP-ON CURRENT PROBES

WAVETEK HAS INTRODUCED its CT235, CT237, and CT238 AC/DC clamp-on current probes that will measure AC or DC current noninvasively from 5 milliamperes to 1000 amperes peak with 1% accuracy. The broad AC bandwidth and 1% accuracy of the probes permit the precise measurement of complex waveforms distorted by harmonics or power-line anomalies.

The current probes can be used



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with different test instruments including analog or digital multimeters, dataloggers, chart recorders, and power analyzers. Current measurements are obtained with Hall-effect sensing, and the zero-adjust feature cancels residual mag-

netic fields, so DC measurement accuracy is unaffected.

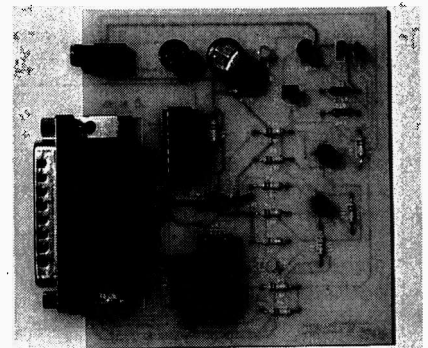
Applications for the probes include the analysis of current waveforms for harmonics, the testing of banks of batteries, the analysis of inverter power output, the recording of UPS charge and discharge rates, and the diagnosis of automotive electrical systems. The probes have IEC1010-1, Category III, 300-volt, pollution degree 2 safety approval.

The pricing on the probes is: CT235 (1000-ampere)—\$179.00; CT237 (200-ampere)—\$249.00, and the CT238 (20-ampere)—\$299.00

WAVETEK CORPORATION
9045 Balboa Avenue
San Diego, CA 92123
Phone: 619-279-2200
Fax: 619-565-9558

LOW-COST PIC PROGRAMMER

ITU TECHNOLOGIES Model PIC-1 PIC programmer will



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program the Microchip family of PIC16C6, 16C7 and 16C8 microcontrollers in conjunction with an IBM or compatible personal computer host. An 18-pin socket is provided on board for programming 18-pin PIC devices; and 28/40-pin adapters are available from the manufacturer. An expansion header is provided for adapters and in-system programming of PICs with on-chip EEPROM.

The Model PIC-1 includes all accessories needed to do microcontroller programming. It is recommended for students, hobbyists, and novice programmers. It is supplied

with a cable for interfacing to the personal computer's parallel port, a power supply, programming software for the computer, and a user's manual.

The PIC-1 is available as a kit or fully assembled and tested. The kit, including a PC board and construction manual, is priced at \$29.00. The assembled programmer is priced at \$49.00.

ITU TECHNOLOGIES

3477 Westport Court
Cincinnati, OH 45248-3026

DIRECT DIGITAL SYNTHESIZER MODULE

THE MODEL DDS4M DIRECT digital synthesizer (DDS) module from Novatech Instruments generates a precise sinewave and an accurate TTL clock signal. It is packaged on a 3.5x4.5-inch circuit board. The output frequency is programmable from 1 Hz up to a maximum of 34 MHz in steps as small as 0.02 Hz.

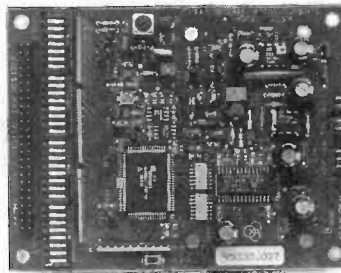
The typical phase noise for the module is -190 dBc at 1-kHz offset from carrier. The desired frequency can be selected by setting a 31-bit binary number, either manually with DIP switches or remotely with HCMOS-compatible parallel input lines. The DDS4m contains a quartz crystal oscillator that provides stability of 10-ppm/year.

The DDS4m direct digital synthesizer module is priced at \$395.00
NOVATECH INSTRUMENTS, INC.

1530 Eastlake Avenue East, No. 303
Seattle, WA 98102

Phone: 206-322-1562

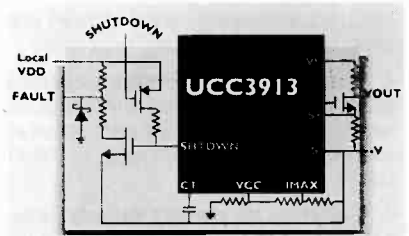
Fax: 206-328-6904



CIRCLE 40 ON FREE INFORMATION CARD

NEGATIVE-VOLTAGE CIRCUIT BREAKERS

THE UCC3913 FAMILY OF BiCMOS electronic circuit breakers from Unitrode is intended for negative power supplies. The circuit breakers are intended for mainframe computer systems, telecommunications equipment, fault-tolerant and point-of-sale computers, banking ATMs, mass data storage equipment, and industrial-control systems.



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According to Unitrode, the electronic circuit breakers react faster and have more accurate thresholds than the large bus fuses it is designed to replace. Their protection levels

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LC-5	150	150	75	50.00	54.00		
LC-6	200	150	75	55.00	59.00		
LC-7	300	150	75	60.00	64.00		
LC-8	400	150	75	65.00	69.00		
LC-9	200	200	75	60.00	64.00		
LC-10	250	200	75	65.00	69.00		
LC-11	300	200	75	70.00	74.00		
LC-12	400	200	75	75.00	79.00		
LC-13	250	250	100	70.00	76.00		
LC-14	300	250	100	75.00	81.00		
LC-15	350	250	100	80.00	86.00		
LC-16	425	250	100	85.00	91.00		

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AT-3	150	60K	B	LINE OUTPUT	46.75 48.50

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MPB-4	1.5	2.1	1.5	2.65	2.86		
MPB-5	1.5	2.1	3.00	2.65	3.15		
MPB-6	1.5	2.1	2.25	2.55			
MPB-7	1.5	2.1	2.25	2.55			
MPB-8	1.5	2.1	2.25	2.55			
MPB-9	1.5	2.1	4.00	4.50			
MPB-10	1.2	2.1	2.5	3.00			
MPB-11	1.5	4.1	2.5	3.50			
MPB-12	1.5	4.1	2.5	3.50			
MPB-13	1.5	4.1	2.5	3.50			
MPB-14	2.4	4.2	2.65	3.15			
MPB-15	2.4	4.2	2.65	3.15			
MPB-16	2.4	4.2	2.65	3.15			
MPB-17	3.2	4.3	2.85	2.95			
MPB-18	3.2	4.3	2.85	2.95			
MPB-19	3.0	4.3	4.20	4.90			
MPB-20	3.0	4.3	4.20	4.90			
MPB-21	4.6	4.3	4.55	5.15			
MPB-22	4.1	10.3	4.55	5.15			
MPB-23	4.1	12.3	6.70	8.90			
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MC-6A	8	5	3	18.00 20.00	
MC-7A	4	7	4	18.00 20.00	
MC-8A	6	7	4	20.00 24.00	
MC-9A	8	7	4	20.00 24.00	
MC-10A	8	7	4	20.00 24.00	
MC-11A	8	3	10	1.75 34.50 36.50	
MC-12A	8	3	10	1.75 34.50 36.50	
MC-13A	8	5	14	1.75 35.50 38.00	
MC-14A	8	5	14	1.75 35.50 38.00	
MC-15A	8	3	14	3.75 40.00 42.00	
MC-16A	17	7	1.75	34.50 36.50	
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exceed those of fuses. Under fault conditions, the UCC3913 devices quickly limit overcurrent, preventing damage to host circuitry. They open the circuit automatically and reset with a 2% duty cycle to limit power dissipation during extended-duration faults.

An automatic reset feature reduces field maintenance. The auto-reset feature also prevents overheating that could lead to circuit failure. The UCC3913 devices manage power by permitting full logic control of each module's power. Their programmable start delays are especially important in "hot-swap" situations such as when power supply modules are being replaced in fault-tolerant computer systems.

The electronic circuit breakers keep the power off, then "soft-start" the module in hot-swap applications. That controlled start prevents the module from excessively loading the bus as it powers up, preventing power and data glitches. The UCC3913 family is offered in eight-pin SOIC and DIP packages in three temperature ranges.

The UCC3913 is priced at \$1.40 in 1000-piece quantities. EP

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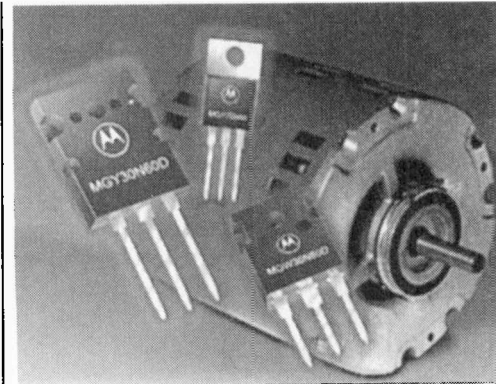
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(Continued on page 109)

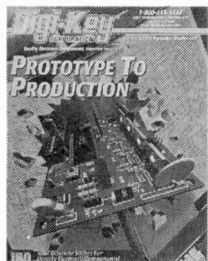
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Mail-order distributor Digi-Key offers more than 1400 new products from 15 different manufacturers in its latest catalog. Newly introduced

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A Quick Index on the first page will speed up finding references to the products being offered. This is supplemented by detailed manufacturer and product indexes. Digi-Key sells just about everything a manufacturer or serious electronic hobbyist needs and its catalog is a valuable reference for the professional designer as well as all advanced hobbyists.

The catalog is arranged alphabetically by manufacturer with alphabetical tabs on the outside edges of the pages for quick reference. A comprehensive index both by product and by manufacturer makes it easy to find what you are looking for in this huge 368-page compendium of electronic parts.

Digi-Key's product line card includes all the basic passive electronic components, discrete and integrated semiconductor devices, and connectors and cable assemblies and much more. The company offers hand tools, soldering materi-

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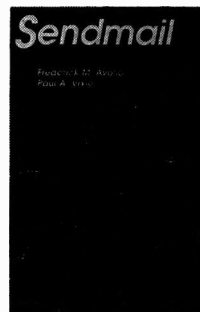
Sendmail: Theory and Practice

by Frederick M. Avolio and Paul A. Vixie.

Digital Press
313 Washington Street
Newton, MA 02158-1626
Phone: 617-928-2500
Fax: 617-928-2620

\$29.95

This book explains the history, architecture, configuration, and maintenance of Sendmail, a standard mail deliverer on Berkeley-Unix systems. Widely used on the Internet,



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many consider Sendmail impossible to understand. The authors have tried to correct that.

Avolio and Vixie explain how and why Sendmail works and offer practical advice

on designing and maintaining an electronic mail system. There are "cookbook recipes" and simplified explanations of how to manage a mail system. It compares E-mail and Sendmail and defines key terms. This book is great for computer system managers and readers who want to

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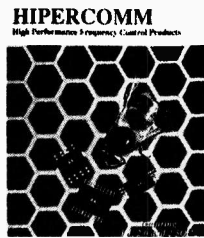
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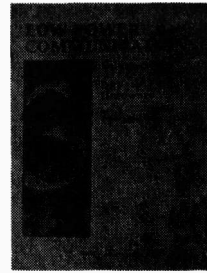
This is a revised edition of Motorola's Hipercomm Databook. It contains device specifications in the form of data sheets and applications information for Motorola's frequency-control products. It contains technical data on a broad line of integrated circuits for phase-locked loop circuits. An introductory section simplifies the selection of the right components for a given set of applications requirements.

Motorola's line of low-power prescalers includes products with more than 40 different combinations of frequency, divide ratio, and power to meet the needs of most designs. Information is also included on Motorola's integrated, single-chip synthesizers that conserve power, making them suitable for handheld, battery-operated communications products.

Low Power Communications

Volume 3: QRP Hardware
by Richard Arland, K7YHA.
Tiare Publications
P. O. Box 493
Lake Geneva, WI 53147
Phone: 1-800-420-0579
\$14.95

This is the third volume of three in a series on QRP, an international radio Q signal that means "reduce your power". Previous titles were "QRP Basics" and "Advanced QRP Operat-



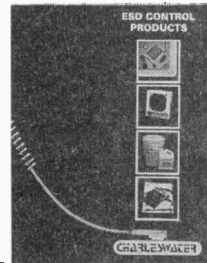
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ing." This book on low-power communications examines the new and used equipment available for the radio amateur who is planning to upgrade a QRP station that might be communicating with microwatts of power. It includes tips on buying and trading used equipment, and discusses operating accessories of value to the QRP operator.

Arland's book includes a chapter on the planning and erection of antenna towers and another on how to start and run a QRP club. The addresses of QRP clubs and suppliers and manufacturers of QRP equipment are listed in the appendix.

ESD Control Products.

Charleswater
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Canton, MA 02021-1407
Phone: 617-821-8370
Fax: 617-575-0172
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This is the latest catalog from Charleswater on its products for the control of electrostatic discharge (ESD). Many new ESD control products and training aids are included. It also provides up-to-date information on existing product categories.

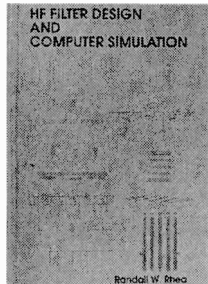
Charleswater's product line does include all of the standard accessories necessary to ESD-proof a designated ESD-protected workstation: conductive workplace mats, grounded wrist straps, conductive floor mats, and instruments for testing the integrity of the ground. Also included are conductive tote boxes, protective bags and packaging for vulnerable components and circuits, air ionizers, and conductive sprays.

This catalog also includes a basic tutorial on electrostatic discharge,

explaining what it is and how it is controlled by grounding, shielding, and moving-air neutralization.

HF Filter Design and Computer Simulation

by Randall W. Rhea.
McGraw-Hill Book Company
11 West 19th Street
New York, NY 10011
Phone: 1-800-2-MCGRAW.



CIRCLE 54 ON FREE INFORMATION CARD

This book is a complete design guide for printed and LC filters for RF and microwave applications. It includes easy to understand discussions of high-frequency filter theory and accurate

computer simulation models for many different filters. Rhea's book includes a review of the classic design formulas as well as the more recent filter design concepts developments.

The first chapters are devoted to fundamental concepts, with greater emphasis given to lumped-elements than distributed elements. Those chapters are followed by a review of available computer-aided filter-design techniques, including both simulation and synthesis.

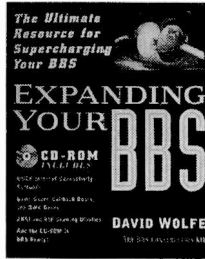
The author goes on to discuss distributed low-pass, bandpass, high-pass, and bandstop filters, and he explains how to select the appropriate design for specific applications.

Expanding Your BBS

Volume 3: QRP Hardware
by Richard Arland, K7YHA.
Tiare Publications
P. O. Box 493
Lake Geneva, WI 53147
Phone: 1-800-420-0579

\$14.95

This book and an included CD-ROM gives bulletin board system (BBS) administrators all the information they need to maintain an active, attractive bulletin board. There are an esti-



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mated 10-million BBS users around the world whose interests are as diverse as scuba diving to gourmet cooking. Wolfe's book offers the software and expert advise needed to add the most wanted features to your BBS. For example, Wolfe explains how to add UUCP Internet connectivity, fax capability, and QWK networking and mail. Wolfe also explains how to add improved graphics and speed, and multimedia applications. The topics covered include the integration of high-speed modems, digiboards, intelligent I/O boards, and telephone caller ID.

The companion BBS-ready CD-ROM contains game doors such as "Tradewars 2002, Baron Realms Elite, Land of Devastation, Battle Grid, Murder Motel," and "Yankee Trader." Call back doors increase BBS security and automate the registration process, while Waffle and Waffle utilities are for Internet UUCP connectivity.

The CD-ROM also includes upload checkers that scan for viruses, purge old files, insert BBS ads, and check file integrity. Batch file power is increased with four DOS utilities. ANSI and RIP screen-drawing utilities include "The Draw, Dead Paint," and "Tombstone Artist." Other BBS utilities included are Fossil drivers, external protocols, QWK mail doors, hard-to-find compression utilities, and port and modem diagnostics.

Zworykin, Pioneer of Television

by Albert Abramson.
University of Illinois Press
1325 South Oak Street
Champaign, IL 61820
\$36.95

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(Continued on page 109)

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CUSTOM METER FACES

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EVEN IN TODAY'S WORLD OF DIGITAL electronics there are still times when an analog meter is the better choice for displaying voltage, current, or other signal levels. With the use of a personal computer and a laser printer, this article shows how you can customize analog meters from your junk box or local surplus dealer to display almost any scale and units. Gone are the days of trying to draw meter scales by hand; you can make your computer and laser printer do the work for you.

Any laser printer that understands HPGL (Hewlett-Packard Graphics Language) commands is compatible with the techniques presented here. The BASIC programming language is used to assemble the commands which are then sent to the printer. The printer prints the new scale on a whole-page laser label and then the label is applied to the old meter. Figure 1 shows a meter, purchased for \$2 at a surplus electronics outlet, before and after modification.

Finding the right meter

The first step to successfully making a newly labeled meter is to start with the right meter. Although many meters can be found for very reasonable prices in the surplus market, not every meter is a candidate for a new scale. Several specifications, such as the full-scale current and the meter movement's resistance, are helpful in determining whether the meter is a suitable choice.

To change the scale of a meter, the face must be accessible. Some inexpensive meter movements have cases that can't be opened, and these should be avoided. Generally the cover of a meter face can either be removed by simply prying it off, or by removing several small screws on the outside of the meter. The second task is to remove the meter face itself. Again, some inexpensive meters might have their faces mounted permanently, but the majority of meters have several small screws that hold the meter face in place. The ability to remove the meter face is essential.

Other things that must be known about the meter before it can be used in a circuit properly are its full-scale current and the resistance of its movement coil. For a new meter, these are easy to determine from the meter's specification sheet. Sometimes you will be lucky enough to find information printed on an old meter face that will help determine the full-scale reading.

If you know nothing about a meter's electrical specifications, they can be determined rather easily. Generally most meters have a full-scale current between 100 microamperes and 1 milliamperes. Coil resistance generally varies between about 40 and 1000 ohms. The setup to measure full scale current and coil resistance is simple. The value of the power supply is not critical. A potentiometer between the supply and the unknown meter should be large enough to limit current to about 50 microamperes (about 200K). First set the potentiometer to its maximum value, turn on the power supply, then decrease the resistance until the meter reads full scale. Measure

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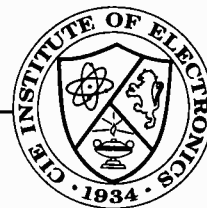
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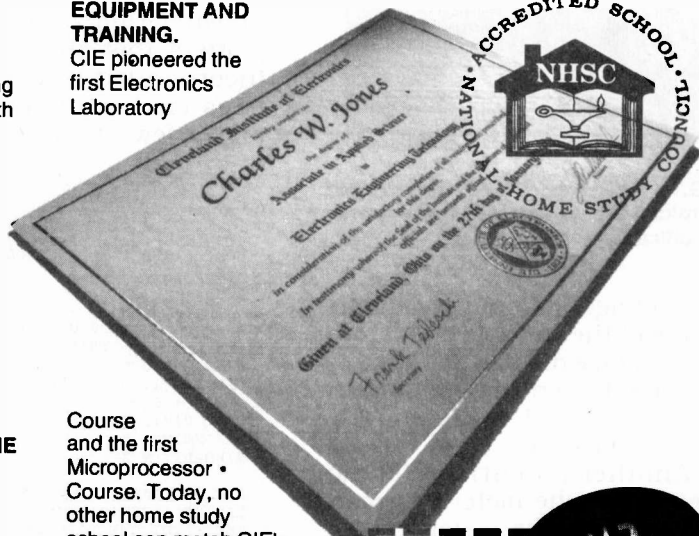
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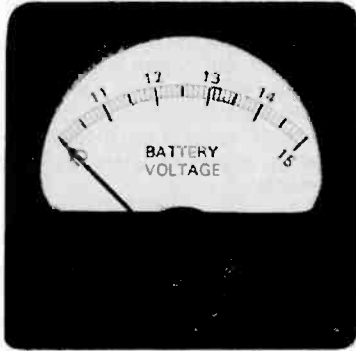
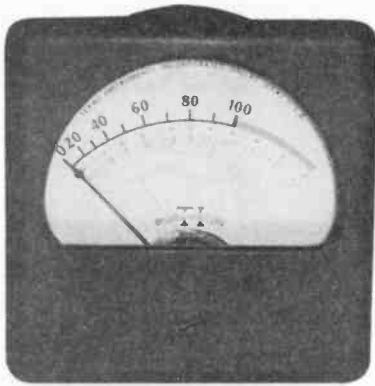


FIG. 1—A VOLTMETER, purchased for \$2 surplus, shown before (top) and after modification (bottom).

the voltage of the supply and the value of the variable resistance. The voltage divided by the resistance will then give you the current required to deflect the meter full scale.

Another potentiometer can determine the meter coil resistance. With the meter indicating full-scale current, place a 1K potentiometer across the meter and adjust until the meter reads exactly 1/2 scale. Remove this potentiometer and measure its value. This will be the value of the coil resistance of the meter. The meter in Fig. 1 had a full-scale current reading of 229 microamperes and a coil resistance of 819 ohms.

Making faces

A protractor is the best tool for measuring the total angle of movement of the meter needle, which generally runs from 90 to 120 degrees. Also measure the distance from the pivot point to the scale of the old meter face and the location of the face-plate mounting holes with respect to the pivot point. Those measurements will be input to

the program that draws the new meter face.

The next step in putting a new face on your meter is to carefully remove the old meter face plate. After opening up the meter case it is usually just a matter of removing the small screws holding the face plate on. A set of jeweler's screw drivers can sometimes be helpful for particularly small meters. Once the face plate is loose it can be removed by very carefully sliding it from under the needle of the meter. Be careful not to bend or bump the needle.

Using HPGL

HPGL is a graphics language of short, simple statements that allows lines, arcs, and text to be drawn. Originally developed for plotters, this language has been incorporated into many of today's laser printers. By using just a few of the many HPGL

statements, professional looking meter scales can be created with customized features.

The BASIC language can send HPGL commands to the printer for drawing the various features of the scale. Using a computer language to send the commands to the printer is helpful because many commands can be generated using program loops with an incrementing variable. This lets rather short programs generate many different individual graphic elements to compose the new meter face plate.

Listing 1 is the BASIC program that draws the meter face in Fig. 2. Only a few of the many HPGL commands are used in the program. Most are two-letter commands followed by arguments. In Listing 1 many of the arguments are calculated by the BASIC program. The program plots points on a graph that has

LISTING 1

```

REM - PUT THE ORIGIN IN THE MIDDLE OF THE PAGE.
REM - THIS IS THE NEEDLE PIVOT POINT
XORG = 4000
YORG = 5500

REM - CONSTANTS USED FOR PLOTTING
IRAD = 1.4 * 1016
ORAD = 1.5 * 1016
IIRAD = 1.33 * 1016
ANGLE = 90
K = .0174533
MAJORDIV = 5
MINORDIV = 50

REM - CLEAR THE PRINTER
LPRINT CHR$(27); "E"
REM - PUT THE PRINTER INTO HPGL MODE
LPRINT CHR$(27); "%OB"
REM - INITIALIZE HPGL MODE
LPRINT "IN;"

REM - SELECT A PEN SO IT WILL PRINT AND SET THE WIDTH
LPRINT "SP1;"
LPRINT "PW0;"

REM - DRAW THE UPPER AND LOWER ARCS FOR THE METER SCALE
LPRINT "PA"; XORG - SIN(ANGLE / 2 * K) * ORAD; ",,"; YORG + COS(ANGLE / 2 * K)
* ORAD; ",,PD;"
LPRINT "AA"; XORG; ",,"; YORG; ",,"; -ANGLE; ",,"
LPRINT "PU;"
LPRINT "PA"; XORG - SIN(ANGLE / 2 * K) * IRAD; ",,"; YORG + COS(ANGLE / 2 * K)
* IRAD; ",,PD;"
LPRINT "AA"; XORG; ",,"; YORG; ",,"; -ANGLE; ",,"

REM - PUT IN THE 50 TICK MARKS FOR TENTHS OF VOLTS
FOR I = -ANGLE / 2 TO ANGLE / 2 STEP ANGLE / MINORDIV
LPRINT "PU;"
LPRINT "PA"; XORG + SIN(I * K) * IRAD; ",,"; YORG + COS(I * K) * IRAD; ",,"
LPRINT "PD;"
LPRINT "PA"; XORG + SIN(I * K) * ORAD; ",,"; YORG + COS(I * K) * ORAD; ",,"
LPRINT "PU;"
NEXT I

REM - PRINT THE VOLT MARKS USING HEAVIER LINES AND EXTENDING BELOW THE ARC
LPRINT "PW.5;"
FOR I = -ANGLE / 2 TO ANGLE / 2 STEP ANGLE / MAJORDIV
LPRINT "PU;"
LPRINT "PA"; XORG + SIN(I * K) * IIRAD; ",,"; YORG + COS(I * K) * IIRAD; ",,"
LPRINT "PD;"
LPRINT "PA"; XORG + SIN(I * K) * ORAD; ",,"; YORG + COS(I * K) * ORAD; ",,"
LPRINT "PU;"
NEXT I

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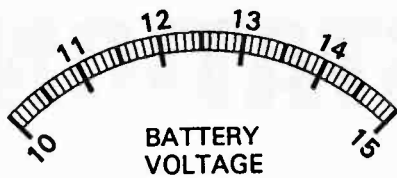



FIG. 2—THIS METER FACE is the result of the BASIC program in Listing 1.

1016 points (pixels) per inch in both the X and Y directions.

Here's a list of the commands that are used and short descriptions:

- IN—Initialize
- SP—Select Pen
- PW—Set Pen Width
- PA—Plot Absolute
- AA—Arc Absolute
- PU—Pen Up
- PD—Pen Down
- SD—Standard Font Definition
- DT—Define Label Terminator
- SS—Select Standard Font
- LO—Label Origin
- LB—Label

The syntax of those com-

mands is explained in the technical reference section for the HPGL language in your printer manual. Since some commands take X and Y coordinate locations, some simple trigonometry is used to calculate the arguments from the index angle in the program of Listing 1.

Developing your own meter face is a simple matter of running the program and printing the resulting graphics on the printer. You probably won't get it right the first time, but making modifications is easy. Writing the program in blocks that add a new graphic after each iteration works best. Printing locating marks on the new face for the mounting holes helps to align the new face properly on the old face plate.

Once everything looks the way you want it on paper, print the results on a full-page laser label. It's best to apply the

new label on the reverse side of the old face plate since it's usually a nice clean surface. Punch pinholes in the location marks to help locate them from the

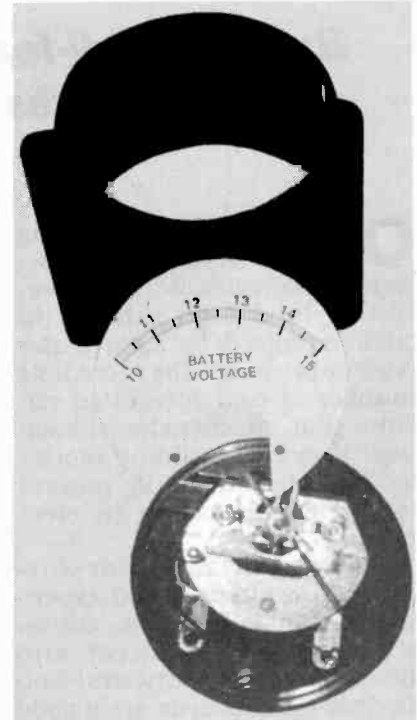


FIG. 3—HERE IS THE NEW LABEL pasted onto the surplus meter.

```

REM - PRINT THE HALF VOLT MARKS USING A HEAVY LINE BETWEEN THE TWO ARC LINES
LPRINT "FW.5;"
FOR I = -ANGLE / 2 TO ANGLE / 2 STEP ANGLE / MAJORDIV / 2
LPRINT "PU;"
LPRINT "PA"; XORG + SIN(I * K) * IRAD; ", "; YORG + COS(I * K) * IRAD; ","
LPRINT "PD;"
LPRINT "PA"; XORG + SIN(I * K) * ORAD; ", "; YORG + COS(I * K) * ORAD; ","
LPRINT "PU;"
NEXT I

REM - SET UP TO LABEL THE METER AND PRINT "BATTERY VOLTAGE"
LPRINT "SD1,21,2,1,4,10,7,4148;"
LPRINT "DT*,1;"
LPRINT "SS;"
LPRINT "PA"; XORG; ", "; YORG + 900; ","
LPRINT "LO4;"
LPRINT "LBBATTERY*;"
LPRINT "PA"; XORG; ", "; YORG + 750; ","
LPRINT "LBVOLTAGE*;"

REM - PUT THE LOW AND HIGH VALUE BELOW THE SCALE ARC
LPRINT "LO16;"
LPRINT "PA"; XORG + SIN((-ANGLE / 2) * K) * IIRAD; ", "; YORG + COS((-ANGLE / 2) * K) * IIRAD; ","
LPRINT "DI"; COS(ANGLE / 2 * K); ", "; SIN(ANGLE / 2 * K); ","
LPRINT "LB10*;"
LPRINT "PA"; XORG + SIN(ANGLE / 2 * K) * IIRAD; ", "; YORG + COS(ANGLE / 2 * K) * IIRAD; ","
LPRINT "DI"; COS((-ANGLE / 2) * K); ", "; SIN((-ANGLE / 2) * K); ","
LPRINT "LB15*;"

REM - PUT THE INTERMEDIATE VALUES ABOVE THE SCALE ARC
LPRINT "LO14;"
FOR I = -(ANGLE / 2) + ANGLE / MAJORDIV TO ANGLE / 2 - ANGLE / MAJORDIV STEP ANGLE / MAJORDIV
LPRINT "PA"; XORG + SIN(I * K) * ORAD; ", "; YORG + COS(I * K) * ORAD; ","
LPRINT "DI"; COS(-I * K); ", "; SIN(-I * K); ","
LPRINT "LB"; INT(I / (ANGLE / MAJORDIV) + 12.5); "+";
NEXT I

REM - PUT IN THE LOCATION DOTS FOR THE MOUNTING HOLES
LPRINT "PA"; XORG - 508; ", "; YORG; ","
LPRINT "PD;"
LPRINT "PU;"
LPRINT "PA"; XORG + 508; ", "; YORG; ","
LPRINT "PD;"
LPRINT "PU;"

REM - RESET THE PRINTER
LPRINT CHR$(27); "80A"
LPRINT CHR$(27); "E"
END

```

back side of the label. Peel off the backing of the new scale label and place the label face down. Then stick the face plate to the label, lining up the locator holes in the center of the face plate mounting holes. After applying the label use a modeling knife to trim the excess paper from around the meter face plate and mounting holes. Figure 3 shows the new label applied to the old meter.

Reassembly finishes the job. Carefully slide the face plate under the meter needle and replace the mounting screws. Next, replace the meter cover.

Creativity is the key to adding an exciting meter display to your next project. Expanded-scale voltmeters are an ideal application for this technique. Power supply current meters are also nice to have. This technique can also create non-linear meter scales such as decibel meters for audio or RF applications. Meter recycling can enhance your projects with just a small investment in time. Ω

PROTOTYPING STATION

Build this full-featured breadboard laboratory, and add custom features to suit your own needs.

One of the most gratifying benefits of being an electronics hobbyist is the opportunity to design and build custom projects for a particular need or purpose. The incredible number of new integrated circuits that are introduced each year provides building blocks for circuits and fertile ground for experimentation in electronics.

One requirement for successful prototyping and experimentation is a quick, convenient way to connect and disconnect components. Solderless breadboards are a good start, but all too often one is likely to end up with the board in the center surrounded by a maze of wires that connect switches, potentiometers, meters, power supplies, and any number of other components that dangle in all directions. The arrangement of components can be both frustrating and irritating. The solu-

tion is to combine the breadboard, power supply, and other commonly used parts into a self-contained unit.

Factory-made laboratories like that are available, but they can be quite expensive. The lab described in this article, however, combines economy, expansion, and easy customization—you can use many of the parts you might already have on hand in your junkbox.

Design

The prototyping station base consists of a 20-inch length of 1-by-12-inch pine board that is sanded, stained and finished. The various power supplies are located to the right; the center section is reserved for three breadboards and the main equipment backboard. The left side is left open to accommodate additional modular backboards, or any other peripherals such as keypads or data-entry terminals. The base

can be raised to make room for plastic drawers, power transformers, or other equipment. Rubber feet can be used to ensure that the lab is stable on the bench. That basic layout is shown in Fig. 1.

Power supplies

Since the availability of power is always a requirement for successful prototyping, a variety of different power sources is incorporated on the right-hand section of the station (Fig. 2 shows a close-up view of the power section). The first power supply on the upper left is a surplus Texas Instruments computer board, bought at a clearance sale for \$5. With the addition of an LED indicator, it provides a good clean source of ± 5 volts and +12 volts. Being a computer-grade supply, the outputs are well-regulated, well-filtered, and can output about 1 ampere each. Power for this supply comes from an off-board wall-outlet transformer, and it is input to the supply via a two-position pushbutton terminal (the kind you might see on the back of a speaker).

Since a standard dry cell is appropriate to power many circuits, the second supply shown on the upper right of Fig. 2 consists of four AA cells and one 9-volt battery. The case from an old nickel-cadmium battery charger holds the AA cells, and a rotary switch and power indicator were added. The battery holder is tapped at each of the four positive battery pads, and each pad is wired to one pole of the rotary switch. The 9-volt battery is wired to a fifth pole on the rotary switch. This allows the selection of 1.5, 3, 4.5, or 6 volts DC from the AA pack, and

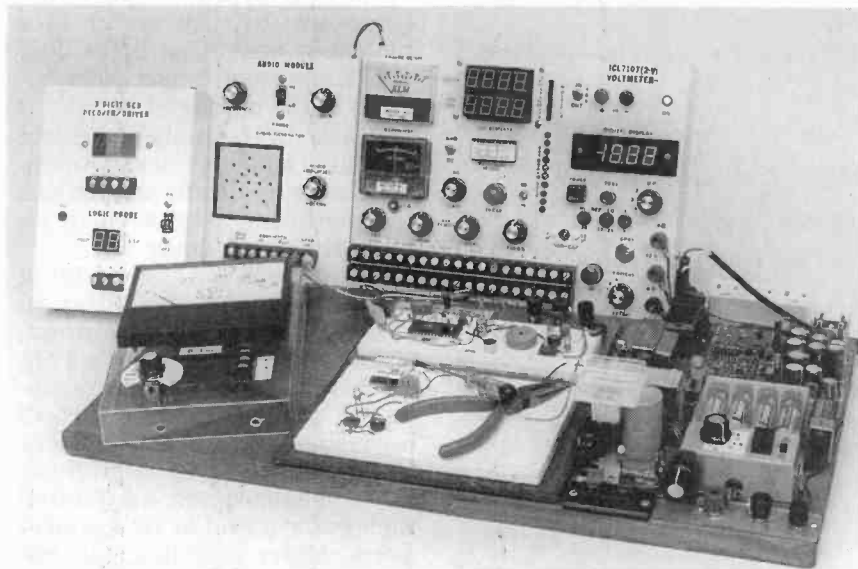
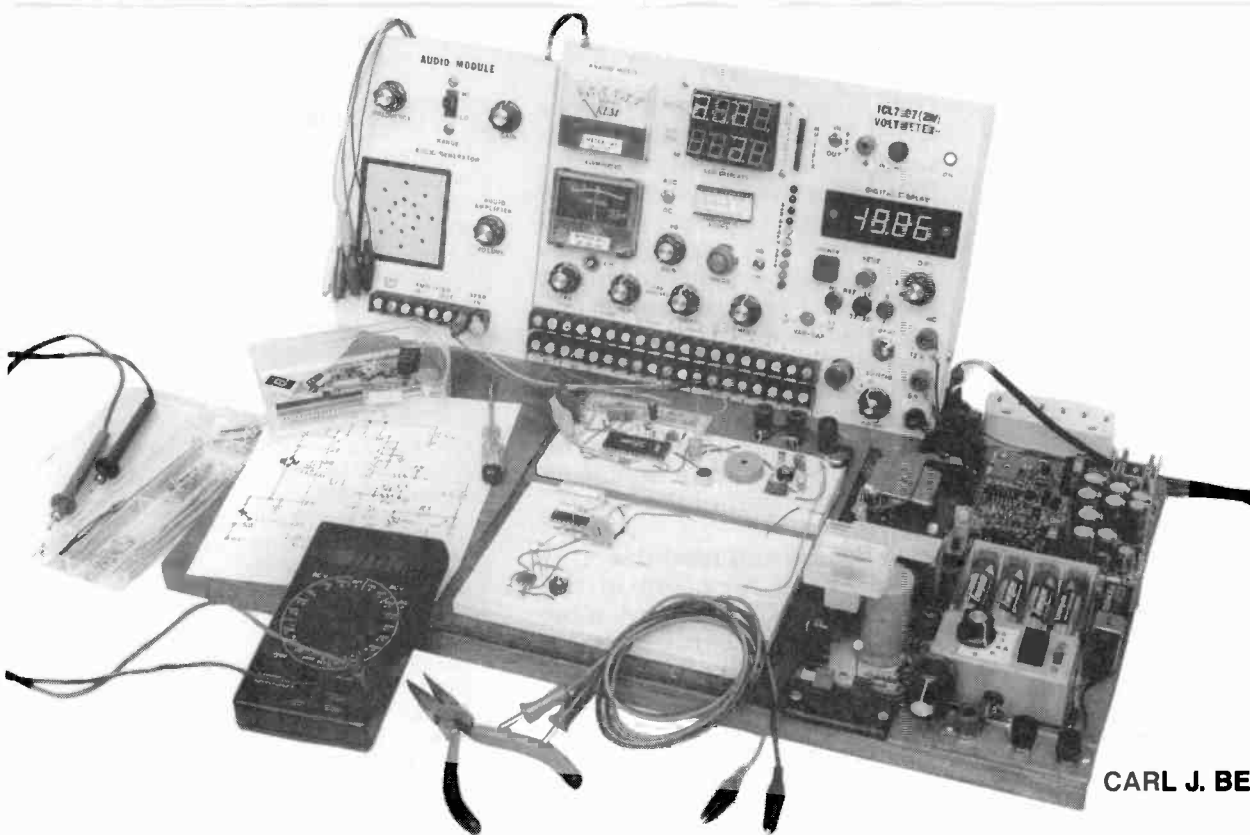


FIG. 1—BASIC PROTOTYPING LAYOUT. The base can be raised to make room for plastic drawers, power transformers, or other equipment.



CARL J. BERGQUIST

9 volts from the 9-volt battery. The LED indicator is a 0.3-inch high, seven-segment display, with all segments turned on to form an "8," which is a more noticeable reminder of the "on" status of the battery pack than a single LED. The output from this supply is connected to two of three binding posts for easy access. The third binding post is the negative 5-volt supply from the TI computer supply.

Another voltage source is provided by a +1.2- to 20-volt DC

variable power supply that was built from a kit some years ago. The potentiometer next to the battery pack allows for adjustment of the output voltage, which is available at another two-position pushbutton terminal. An analog meter indicates the voltage at the pushbutton terminals.

Next to the variable supply is a 12.6-volt, center-tapped transformer, complete with a switch and indicator LED, that provides 6- and 12-volts AC. An

SPST slide switch is connected to one side of the 120-volt AC input to the transformer primary. The outputs are wired to multipurpose posts on the main backboard.

AC power is made available at a triple-outlet AC strip, which gets its power via a heavy-duty line cord. The power inputs for the AC and variable supplies are also connected to this line cord.

The five separate power supplies can be customized to suit your needs. If you decide to enclose the power supplies, be sure to provide for adequate ventilation to allow heat to escape. The main 120-volt AC input should be protected against surges and spikes if you anticipate prototyping computer circuits.

Breadboards

In the center of the base board are three 640-point solderless breadboards, laid out side-by-side (see Fig. 3). The top breadboard is a Radio Shack unit on a metal base with three multipurpose posts. The other two breadboards are plug-in panels mounted on a plywood base. All three breadboards have dual two-connection bus lines at their tops and bottoms, and will accommodate SIPs, DIPs, dis-

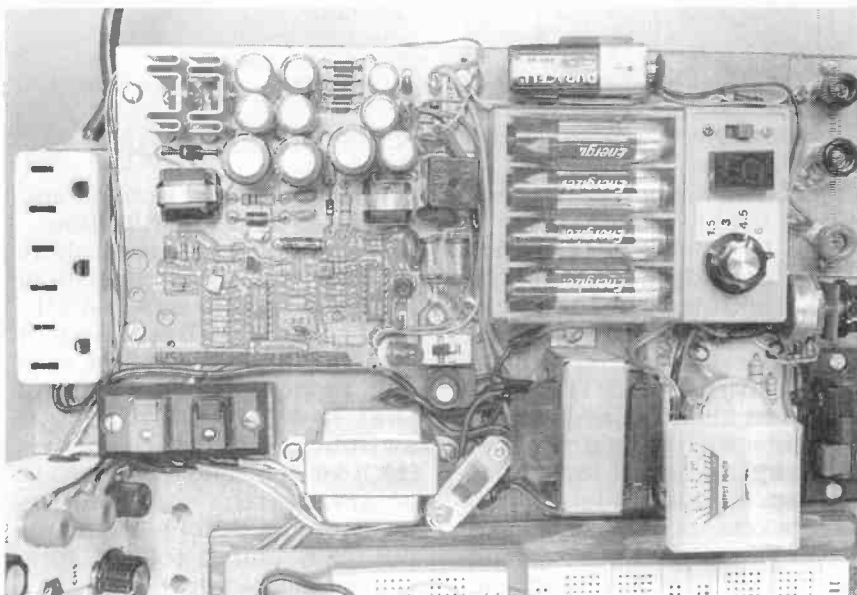


FIG. 2—A VARIETY OF POWER SOURCES is incorporated into the lab.

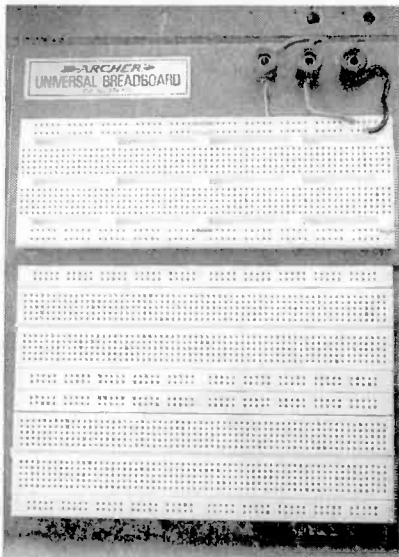


FIG. 3—THREE 640-POINT breadboards are laid out side-by-side. The top breadboard is on a metal base with three plug-in panels, and the other two are plug-in panels mounted on a plywood base.

crete components, and jumper wires. While this breadboard arrangement has provided the author with enough space and has been versatile enough for all of his projects to date, it is certainly not the only arrangement possible. The breadboards are available in a variety of shapes and sizes, with from 250 contact points to 2500 or more. Some thought about the types of circuits you'll be working on will help you make a final decision on this part of the lab.

Backboards and modules

The main function of the backboard is to support more cumbersome components, modules, and any other circuits that the builder wants to add—items such as switches, potentiometers, meters, displays. The main backboard occupies

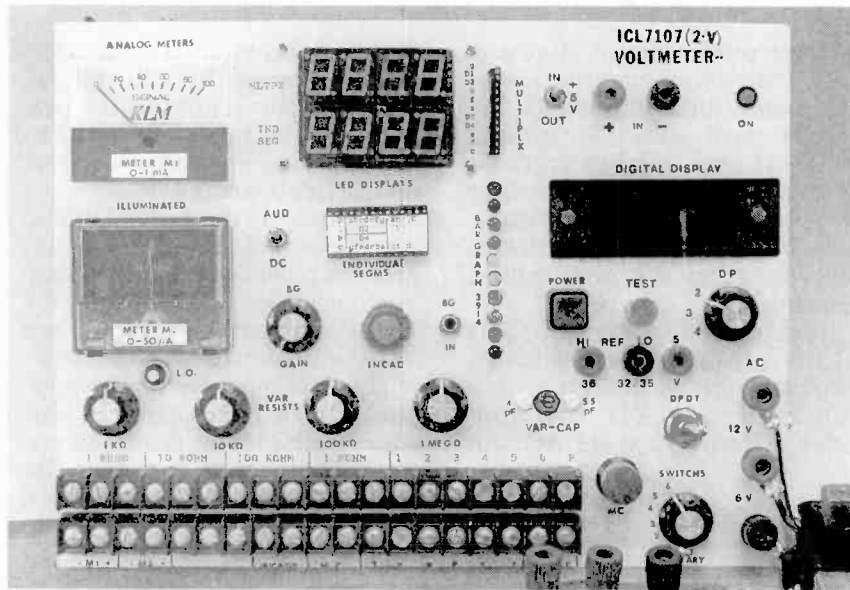


FIG. 4—THE MAIN BACKBOARD occupies about 10 inches across the back edge of the base. The backboard holds many of the accessories.

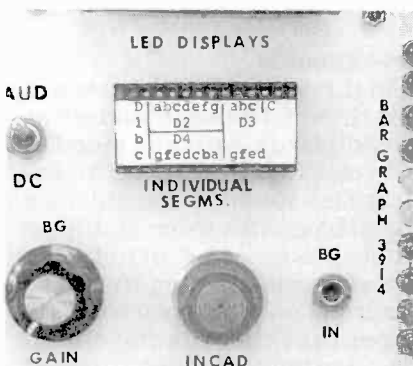


FIG. 5—A BARGRAPH is mounted in the center of the backboard.

about 10 inches across the back edge of the base (see Fig. 4).

Two 19-position terminal strips provide access to the parts mounted on the backboard. The strips on the prototype were removed from a surplus alarm board. The screw terminals allow connections to be made with alligator clips, bare wire, and spade lugs. However, spring-loaded terminals, SIP sockets, or any other connector you might have on hand can be used here. Each point on the terminal strips is wired to a

PARTS LIST—MAIN UNIT

Resistors

- 1K panel-mount potentiometer
- 10K panel-mount potentiometer
- 100K panel-mount potentiometer
- 1 megohm panel-mount potentiometer

Capacitors

- 4 to 55 pF variable capacitor

Semiconductors

- One 0.3-inch 7-segment display, common anode
- Four 0.56-inch 7-segment displays, common anode (MAN6710) or four 0.56-inch 7-segment displays, common cathode (MAN6740)

Power supplies

- Texas Instrument surplus computer power supply, or equivalent
- 12.6-volt AC transformer
- 4-AA battery holder
- 9-volt battery connector
- 1.2 to 20 volt variable DC supply
- 120 VAC power strip

Other components

- Two spring-loaded speaker-type terminals, six binding posts, 6-foot AC line-cord, plastic project cases, three 640-point breadboards, two 19-point terminal strips, heavy-duty DPDT toggle switch, momentary pushbutton switch, 6-position rotary switch, 0 to 1 mA analog meter movement, small push-on push-off switch, 11-pin SIP socket, 28-pin DIP socket, bayonet lamp socket with lens and bulb assortment, hookup wire and zip cord, hardware, seven panel knobs, TO-220 10-watt heatsink, 4-contact tie point.

PARTS LIST—BARGRAPH

- IC1—LM3914 bargraph driver and 18-pin DIP socket, National Semiconductor
- R1—1000 ohms, 1/4-watt resistor
- R2—5000 ohms, panel-mount potentiometer with switch
- T1—audio transformer, 1K primary, 8-ohm secondary (Radio Shack 273-1380)
- J1—1/8-inch phono jack and plug
- D1—1N4001 diode
- LED1—LED10—light-emitting diode, any color
- S1—DPDT switch

connection on the component, and labeled for identification.

The row of components above the terminal strips consists of four potentiometers (1-, 10-, and 100-kilohms and 1 megohm) and a 4- to 55-pF variable capacitor. To the right of that row is a DPDT toggle switch, momentary control (MC) switch, and six-position rotary switch. The binding posts on the extreme right output the 6- and 12-volts AC, previously mentioned.

On the left side are two analog

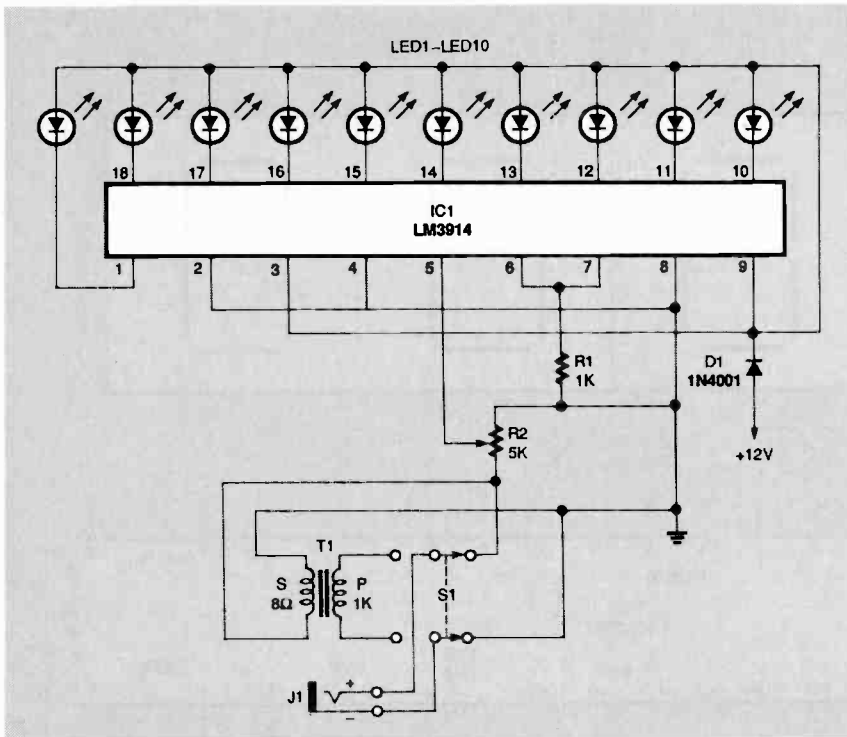


FIG. 6—LED BARGRAPH SCHEMATIC. The circuit consists mainly of an LM3914 bargraph display driver IC.

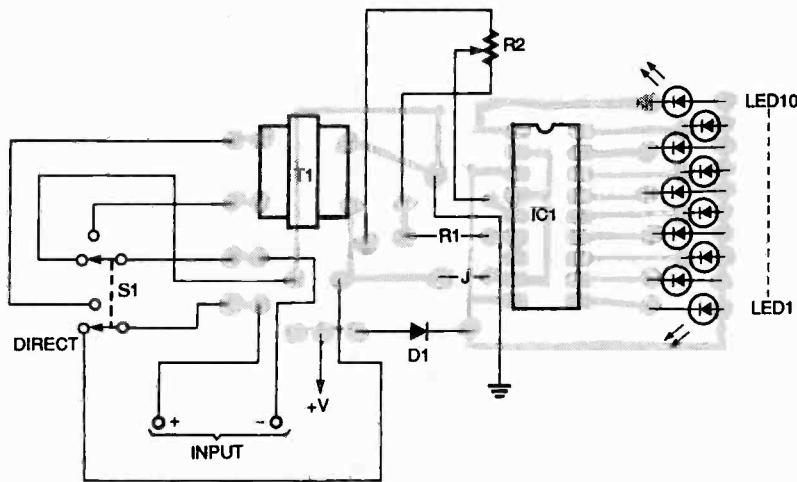


FIG. 7—PARTS-PLACEMENT DIAGRAM for the bargraph circuit.

meters (M1 and M2). Meter M1 is rated for 0 to 1 milliampere, which is a useful value for many circuit designs, and M2 is 500 microampere, \pm center scale unit. This is essential when designing a circuit where the output can swing either positive or negative. Meter M2 is illuminated, and the small push-button switch labeled L.O. activates the 6-volt lamp.

A bank of seven-segment LED displays is mounted in the top center of the backboard. The

first row of four is in a multiplexed arrangement, with all like segments tied together. Connection to the multiplexed displays is accomplished via the SIP socket to the right, which is labeled accordingly. The second row of seven-segment displays is wired as a 3½-digit display that allows individual access to each of the 24 segments and the common anode. Connections to this display row are made via the DIP socket below it, which is marked appropriately for use

with digital circuits having that type of output.

Below the DIP socket is an incandescent lamp indicator with a bayonet-type socket. Bulbs are easily changed, and they are available in 6-, 12-, 14-, and 28-volt versions.

The author installed a ten-step LED bargraph and a 3½-digit voltmeter on the backboard, both as a matter of personal preference. The bargraph is mounted in the center of the backboard as shown in Fig. 5. A schematic of the LED bargraph circuit is shown in Fig. 6. The circuit consists mainly of an LM3914 bargraph display driver IC. Switch S1 allows signals to be input to the driver chip

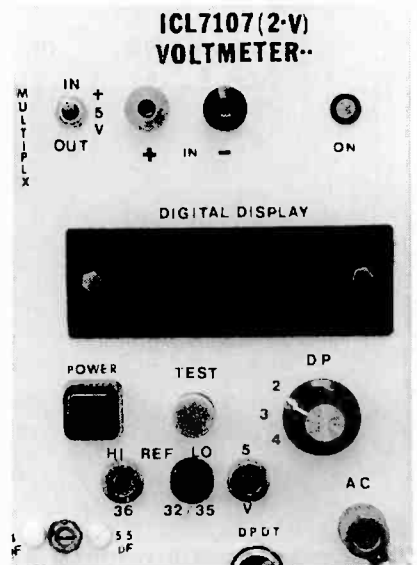


FIG. 8—A 3½-DIGIT VOLTMETER occupies the upper right hand corner of the backboard.

PARTS LIST—VOLTMETER

- IC1—ICL7107CPL A/D converter/LED display driver, Harris
- DISP1—two 2-digit common-anode 7-segment displays (MAN6710 or equiv.)
- C1—0.22 μ F, mica capacitor
- C2—0.047 μ F, mica capacitor
- C3—0.01 μ F, mica capacitor
- C4—0.1 μ F, mica capacitor
- C1—100 pF, ceramic disc capacitor
- R1—470,000 ohms, ¼-watt, 5% resistor
- R2—1 megohm, ¼-watt, 5% resistor
- R3—25,000 ohms, PC-mount potentiometer
- R4—22,000 ohms, ¼-watt, 5% resistor
- R5—100,000 ohms, ¼-watt, 5% resistor
- S1—SPDT toggle switch
- Miscellaneous: pushbutton switch, 3-position rotary switch, five banana jacks, green LED

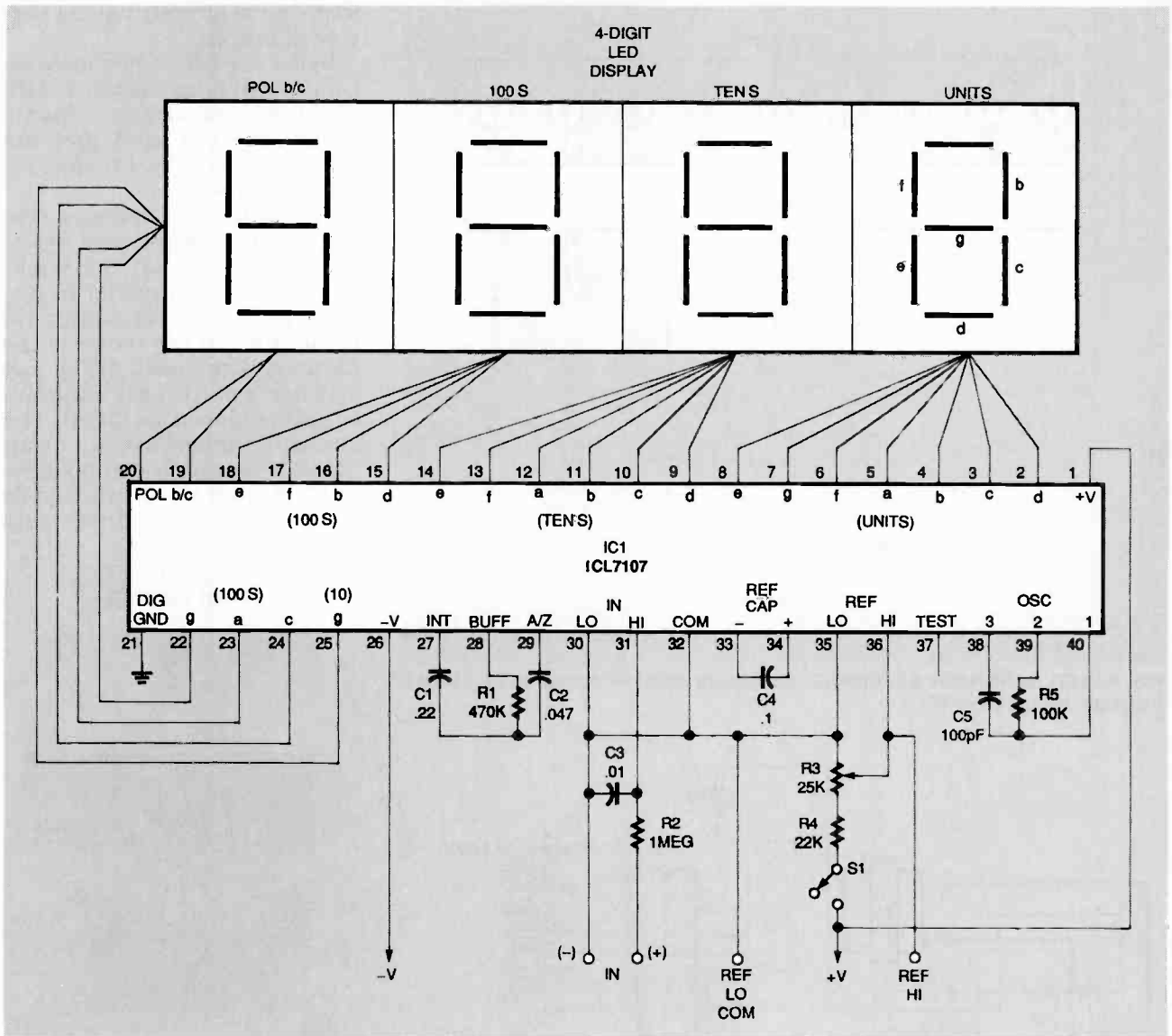


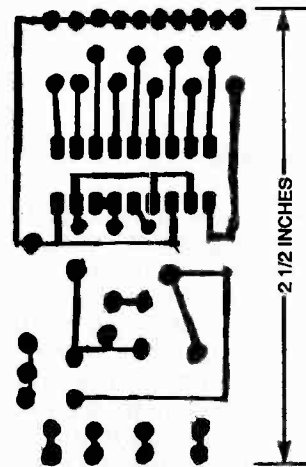
FIG. 9—THE SCHEMATIC DIAGRAM of the voltmeter circuit.

PARTS LIST—BCD DECODER

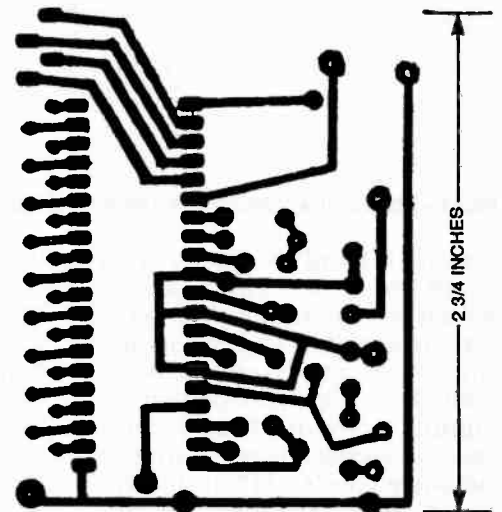
- IC1—74LS48 BCD to 7-segment decoder
- IC2—CD4553 3-digit BCD counter, Harris
- Q1—Q3—2N3906 PNP transistors
- R1—R7—220 ohms, ¼-watt, 5% resistor
- R8—R10—1000 ohms, ¼-watt, 5% resistor
- C1—0.001 µF, ceramic disc capacitor
- DISP1—three common-cathode 7-segment displays

directly, or through a matching transformer T1 for audio.

Signals are input to the bargraph circuit at J1, a ½-inch mini phono jack. The 5-kilohm potentiometer (R2) controls gain. The author used a potentiometer with a built-in on/off switch so that power to the bargraph display could be turned



BARGRAPH FOIL PATTERN.



VOLTMETER FOIL PATTERN.

on and off independently. You can either do the same, or use a separate switch for power.

Power for the bargraph circuit is provided by the TI computer supply.

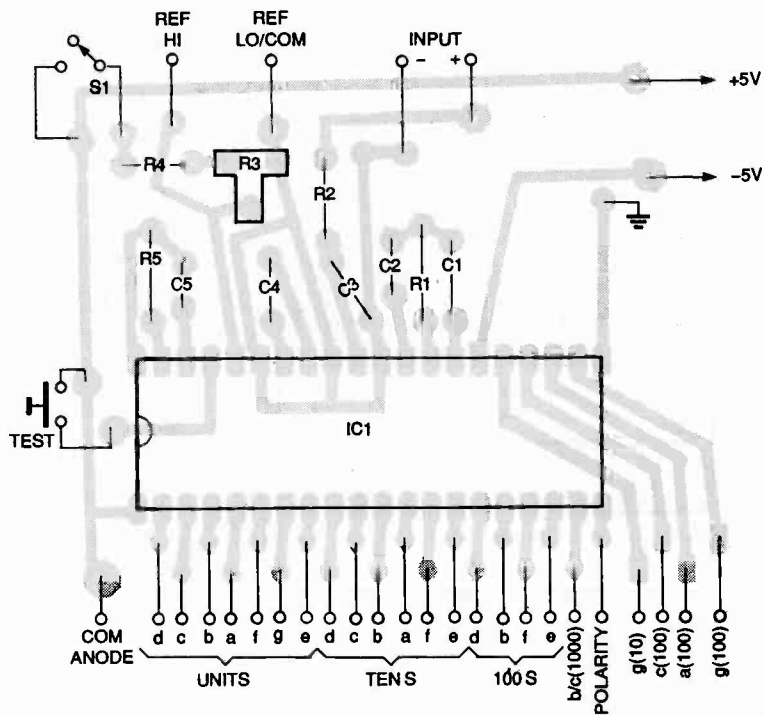


FIG. 10—PARTS-PLACEMENT DIAGRAM for the voltmeter circuit.

PARTS LIST AUDIO AMPLIFIER

IC1—LM386 audio amplifier, National Semiconductor
 R1—10,000 ohms, panel-mount potentiometer with switch (or use separate potentiometer and switch)
 C1—20 μ F, 25 volts, electrolytic
 8-position terminal strip
 1½-inch, 8-ohm speaker

PARTS LIST—METER

M1—4- to 6-inch, 0 to 1 mA analog-meter movement
 S1—8-position rotary switch
 D1—1N4002 diode
 R1—10 ohms, ¼-watt, 5% resistor
 R2—100 ohms, ¼-watt, 5% resistor
 R3—1000 ohms, ¼-watt, 5% resistor
 R4—10,000 ohms, ¼-watt, 5% resistor
 R5—100,000 ohms, ¼-watt, 5% resistor
 R6—1 megohm, ¼-watt, 5% resistor
 R6—10 megohms, ¼-watt, 5% resistor
 Two banana jacks

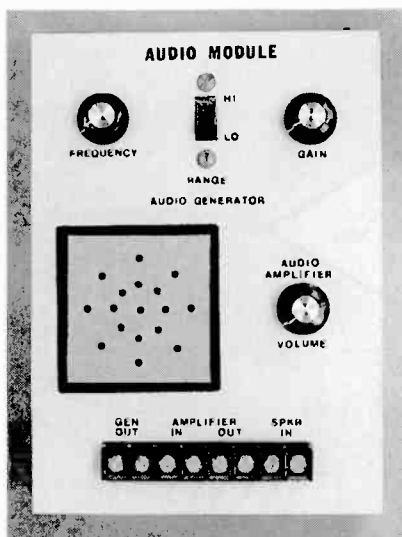


FIG. 11—THE AUDIO MODULE consists of an audio generator, an amplifier, a speaker, and a terminal strip.

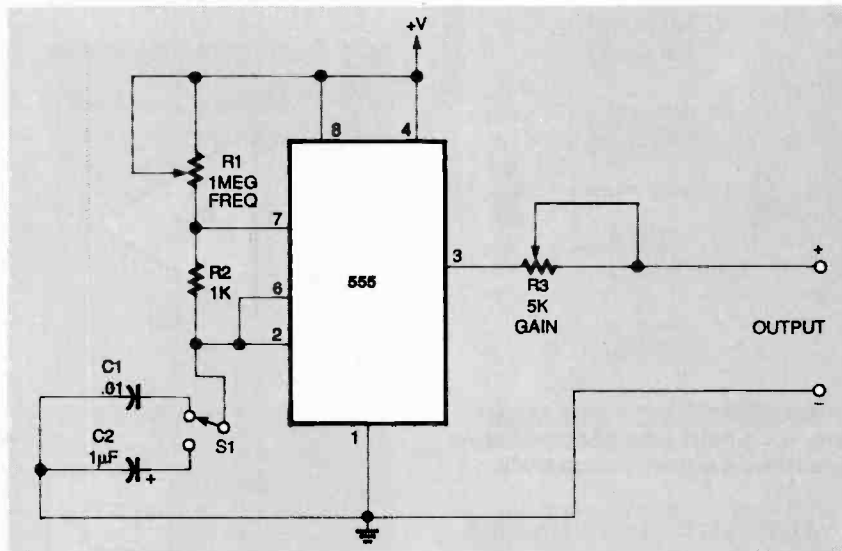


FIG. 12—SIGNAL GENERATOR. Potentiometer R1 sets the output frequency.

A foil pattern is provided for the bargraph circuit, and the parts-placement diagram for it is shown in Fig. 7.

The 3½-digit voltmeter occupies the upper right hand corner of the backboard, as shown in Fig. 8. Figure 9 is the schematic diagram of the voltmeter circuit. A foil pattern is provided for this circuit, and Fig. 10 is its parts-placement diagram. This circuit can also be point-to-point wired. The circuit contains a Harris ICL 7107

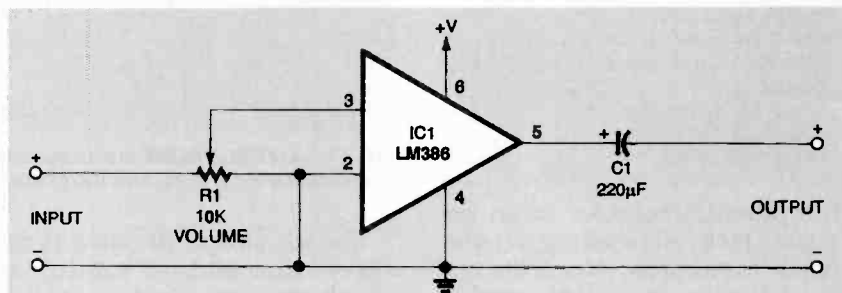


FIG. 13—AUDIO AMPLIFIER. This circuit has a gain of about 20.

analog-to-digital converter/display driver. A standard 2-volt configuration was chosen for

this circuit. Switch S1 allows the +5-volt source to be routed either to the on-board 25-kilo-

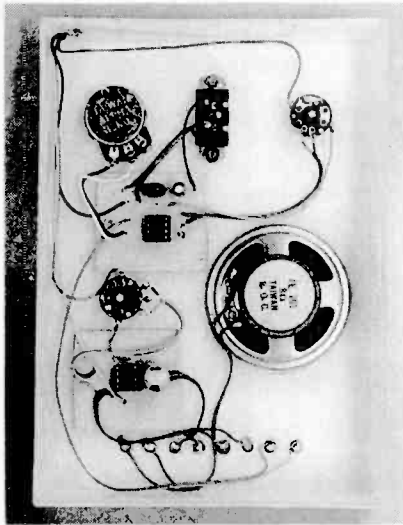


FIG. 14—THE AUDIO MODULE is too simple to call for a PC board, so point-to-point wiring was used.



FIG. 15—3-DIGIT BCD DECODER-driver is another practical function block.

PARTS LIST—AUDIO MODULE

- IC1—LM555 timer
- R1—1 megohm, panel-mount potentiometer with switch
- R2—1000 ohms, ¼-watt, 5% resistor
- R3—5000 ohms, panel-mount potentiometer
- C1—0.01 µF, Tantalum
- C2—1 µF, Tantalum
- S1—SPDT switch

hm potentiometer, or to an external jack, depending on the need. To calibrate the meter, apply 1.2 volts from the variable power supply to the input, and adjust R3 until the display reads 1.200. Then, switch the input leads, and the display should read -1.200.

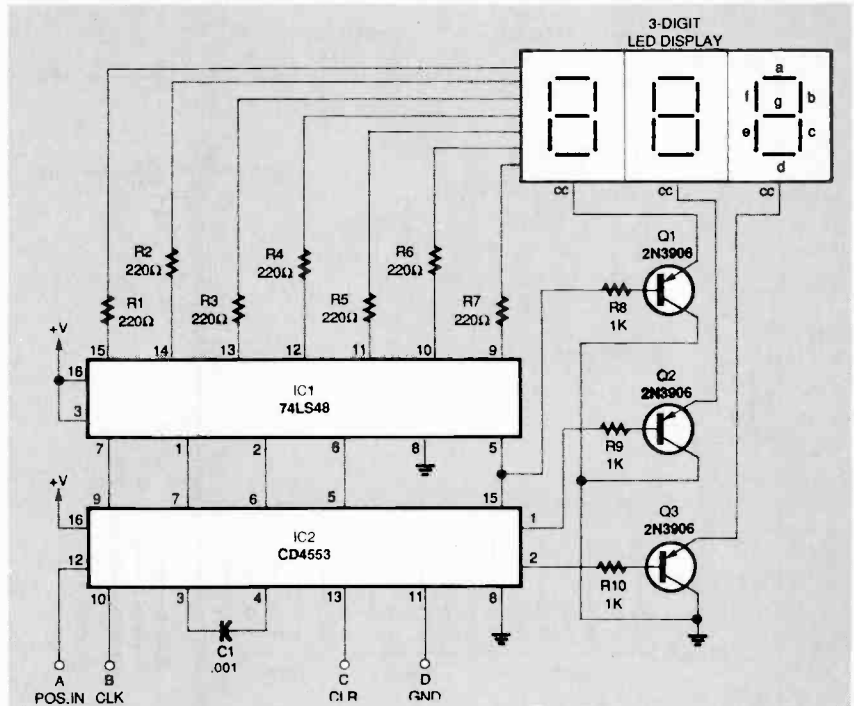


FIG. 16—THE BCD DECODER-DRIVER circuit will interface with any standard BCD output to produce a digital display.

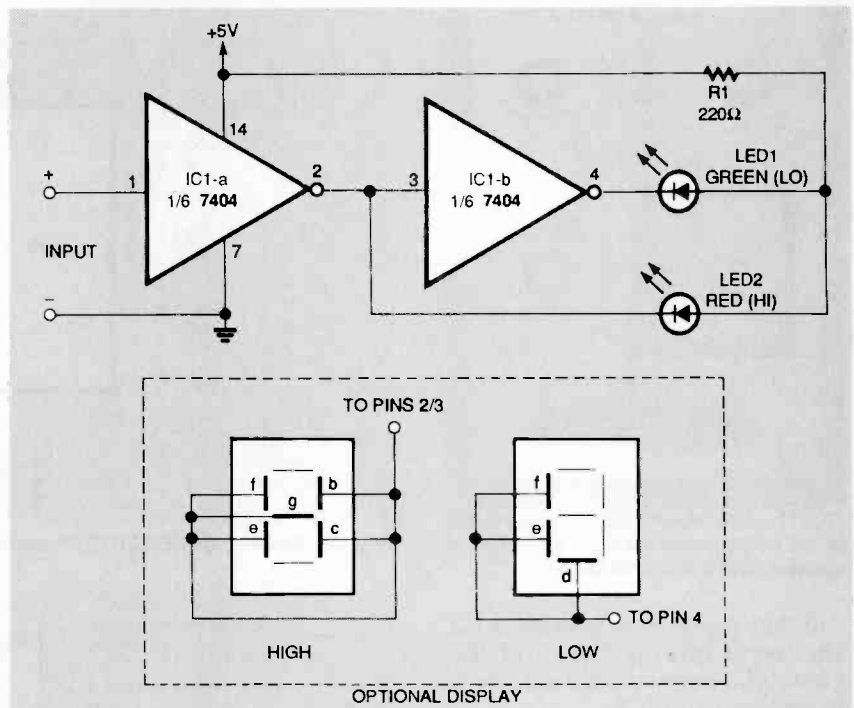


FIG. 17—A LOGIC PROBE is also included in BCD decoder module. The red LED lights to indicate a logic high, and the green LED lights to indicate a logic low.

PARTS LIST—LOGIC PROBE

- IC1—7404 hex inverter
- R1—220 ohms, ¼-watt, 5% resistor
- LED1—green light-emitting diode
- LED2—red light-emitting diode
- Two common-anode 7-segment displays (optional, see text) source

The left side of the base is reserved for add-on modules, which can have a number of different functions depending on what is needed. The audio module shown in Fig. 11 consists of an audio signal generator, an

(Continued on page 112)

BROADCASTING THE EXACT TIME OF day is just one of the many services provided by radio stations WWV and WWVH operated by the National Institute of Standards and Technology (NIST). Their ultra-accurate 10-megahertz carrier frequencies can be used to calibrate signal generators in a process called "zero beating" against the carrier frequency. The stations also transmit many other accurate frequencies, storm warnings for mariners at sea, and GPS (Global Positioning Satellite) position data.

This article explains how to build a simple, inexpensive superheterodyne radio receiver for WWV and WWVH signals. The objective in the design of this receiver was to obtain reliable reception with an antenna only 3- to 6-feet long. The sensitivity obtained with this receiver equals that obtainable from a \$1000 communications receiver operating from a 60-foot antenna.

Can the performance of a receiver made from \$30 worth of parts equal the performance of a \$1000 factory-built receiver? The answer is no because sensitivity is only one measure of receiver performance. The most significant difference between receivers is in their overall signal-to-noise ratios. However, the WWV/WWVH receiver described here has sufficient sensitivity to achieve its dedicated function.

This receiver economizes in the quality of its filters. Most factory-made communications receivers contain expensive precision crystal intermediate frequency (IF) filters which greatly improve the signal-to-noise ratio by screening out most of the noise in the radio-frequency spectrum. Moreover, those communications receivers also have superior intermodulation distortion (IMD) and dynamic range not required for WWV/WWVH reception.

WWV/WWVH transmissions

The WWV transmitter is located in Fort Collins, Colorado, and its signal can be identified by male voice announcements.



Build this simple superheterodyne receiver to receive time and other useful signals from NIST's WWV and WWVH.

WWV RECEIVER

NEIL HECKT

TABLE 1—UTC TIME ZONE CONVERSION

UTC	Eastern	Central	Mountain	Pacific Alaska	Alaska Hawaii
0000	7:00PM	6:00PM	5:00PM	4:00PM	2:00PM
0100	8:00PM	7:00PM	6:00PM	5:00PM	3:00PM
0200	9:00PM	8:00PM	7:00PM	6:00PM	4:00PM
0300	10:00PM	9:00PM	8:00PM	7:00PM	5:00PM
0400	11:00PM	10:00PM	9:00PM	8:00PM	6:00PM
0500	Midnight	11:00PM	10:00PM	9:00PM	7:00PM
0600	1:00AM	Midnight	11:00PM	10:00PM	8:00PM
0700	2:00AM	1:00AM	Midnight	11:00PM	9:00PM
0800	3:00AM	2:00AM	1:00AM	Midnight	10:00PM
0900	4:00AM	3:00AM	2:00AM	1:00AM	11:00PM
1000	5:00AM	4:00AM	3:00AM	2:00AM	Midnight
1100	6:00AM	5:00AM	4:00AM	3:00AM	1:00AM
1200	7:00AM	6:00AM	5:00AM	4:00AM	2:00AM
1300	8:00AM	7:00AM	6:00AM	5:00AM	3:00AM
1400	9:00AM	8:00AM	7:00AM	6:00AM	4:00AM
1500	10:00AM	9:00AM	8:00AM	7:00AM	5:00AM
1600	11:00AM	10:00AM	9:00AM	8:00AM	6:00AM
1700	Noon	11:00AM	10:00AM	9:00AM	7:00AM
1800	1:00PM	Noon	11:00AM	10:00AM	8:00AM
1900	2:00PM	1:00PM	Noon	11:00AM	9:00AM
2000	3:00PM	2:00PM	1:00PM	Noon	10:00AM
2100	4:00PM	3:00PM	2:00PM	1:00PM	11:00AM
2200	5:00PM	4:00PM	3:00PM	2:00PM	Noon
2300	6:00PM	5:00PM	4:00PM	3:00PM	1:00PM

(add one hour during daylight savings time)

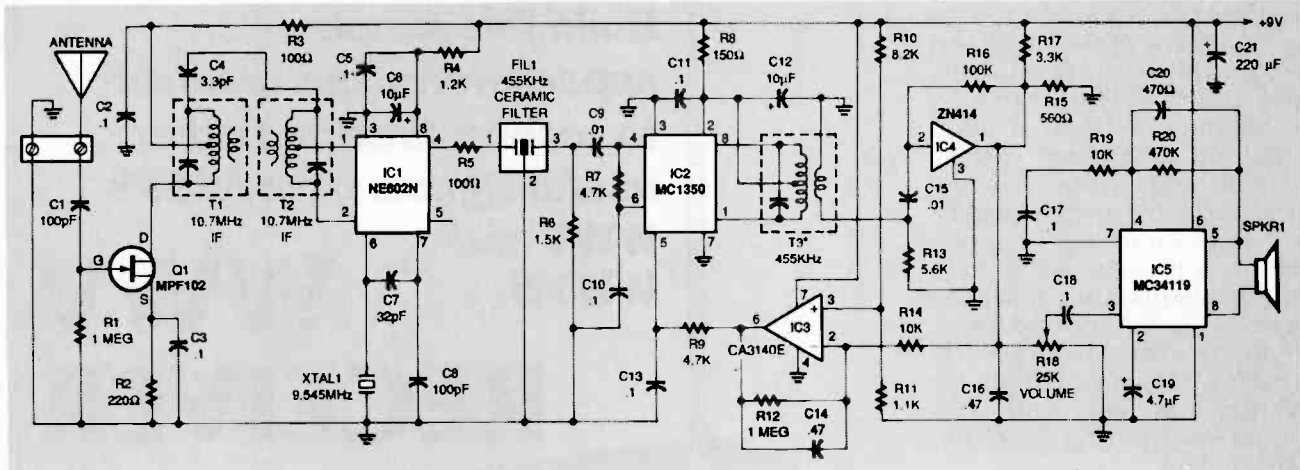


FIG. 1—SCHEMATIC OF THE WWV RECEIVER. A short antenna from three to six feet long is sufficient.

WWVH's transmitter is located in Kauai, Hawaii, and its signal can be identified by female voice announcements. Both stations broadcast on exactly the same frequencies, but they do not interfere with each other because their bands are so narrow they sound like a single station when both are received with equal signal strength.

Stations WWV and WWVH operate on a carrier frequency of 2.5 MHz. Station WWV broadcasts with 2.5 kilowatts (kW) of power, while WWVH broadcasts with 5 kW of power. Other frequency-power relationships are 5, 10, and 15 MHz at 10 kW and 20 and 25 MHz at 2.5 kW. The receiver described in this article was designed to receive 10-MHz signals because the author has found that they provide the most reliable reception.

Carrier frequency and all other time-related data is derived from cesium-controlled oscillators that are accurate to within ± 1 part in 10^{11} . Daily deviations are less than one part in 10^{12} from day-to-day. Phenomena such as Doppler and diurnal shifts can degrade the accuracy at the receiver, but long-term accuracy of one part in 10^9 can easily be obtained.

There are many different time zones around the world, so it would be impractical to broadcast time for each time zone. To simplify matters, WWV/WWVH transmit time data in *Coordinated Universal Time (UTC)*, also known as Greenwich Mean

Time (GMT), World Time and Zulu Time.

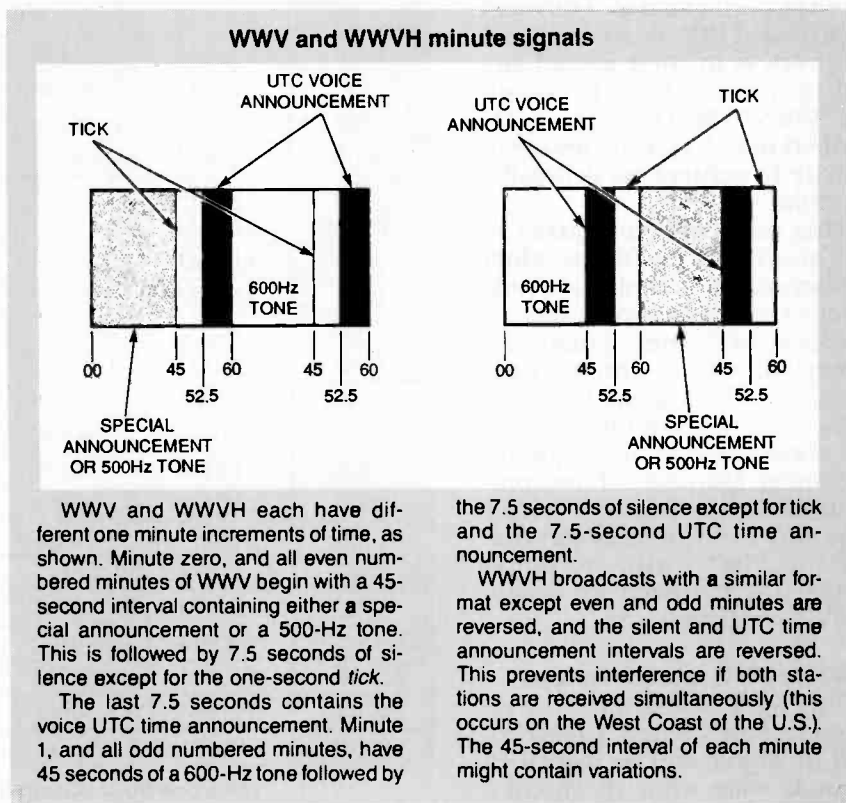
What is UTC? It is the time in England, uncorrected for daylight savings time, and it is always stated in a 24-hour format. It is called GMT because the zero or Greenwich meridian passes through England, west of London. Table 1 provides information that will permit you to determine the local time-of-day from the UTC announced by WWV and WWVH.

Refer to the sidebar for more

technical details on the WWV and WWVH transmission formats. More information on the services of WWV and WWVH can be obtained by writing Frequency-Time Broadcast Services Section, Time and Frequency Division, National Institute of Standards and Technology, Boulder, CO 80302.

Circuit description

A schematic of the WWV receiver is shown in Fig. 5. A short antenna (three to six feet) represents a high-impedance source. Transistor Q1, a Motorola



WWV and WWVH each have different one minute increments of time, as shown. Minute zero, and all even numbered minutes of WWV begin with a 45-second interval containing either a special announcement or a 500-Hz tone. This is followed by 7.5 seconds of silence except for the one-second tick.

The last 7.5 seconds contains the voice UTC time announcement. Minute 1, and all odd numbered minutes, have 45 seconds of a 600-Hz tone followed by

the 7.5 seconds of silence except for tick and the 7.5-second UTC time announcement.

WWVH broadcasts with a similar format except even and odd minutes are reversed, and the silent and UTC time announcement intervals are reversed. This prevents interference if both stations are received simultaneously (this occurs on the West Coast of the U.S.). The 45-second interval of each minute might contain variations.

MPF102 JFET, provides input impedance matching and some gain. A double-tuned input filter, consisting of T1, T2, and C4, provides adequate selectivity to attenuate the image frequency of 9.09 MHz.

A Philips NE602N mixer (IC1) contains a double-balanced mixer and oscillator which supplies approximately 14 dB of conversion gain. The oscillator section is crystal controlled to provide stability and eliminate the need for tuning. The output of the NE602N is coupled to a 455-kHz ceramic IF filter (FIL1) with about a 4-kHz bandwidth. The filter's 1500-ohm input and output impedance is matched by resistors R5 and R7. The output impedance of IC1 is 1500 ohms which, with R5, equals about 1500 ohms.

A Motorola MC1350P IF amplifier (IC2) provides about 60 dB of gain with about 80 dB of

automatic gain control (AGC) control range. The output is coupled through 455-kHz IF transformer T3. The output impedance of IC2 at 455 kHz is about 200 kilohms. Transformer T3 has a turns ratio of 6:1, and it provides an impedance transformation of 36:1.

Resistor R13 terminates the secondary of T3 with 5600 ohms, to provide the proper primary matching impedance. Other turns ratios can be used for T3 provided that R13 is also changed to maintain the proper impedance match. The input impedance of IC4 is high and it does not significantly affect the impedance match.

The GEC Plessey ZN414Z, an amplifier detector, is packaged in a typical plastic transistor case, but it is actually a ten-transistor IC which provides about 70 dB of gain, detection and some AGC response. It is

PARTS LIST

All resistors are ½-watt, 5%, unless otherwise noted.

R1, R12—1 megohm
 R2—220 ohms
 R3—100 ohms
 R4—1200 ohms
 R5—100 ohms
 R6, R17—1500 ohms
 R7, R9—4700 ohms
 R8—150 ohms
 R10—8200 ohms
 R11—1100 ohms
 R13—5600 ohms
 R14, R19—10,000 ohms
 R15—560 ohms
 R16—100,000 ohms
 R18—25,000 ohms, potentiometer PCB-mount
 R20—470,000 ohms

Capacitors

C1, C8—100 pF, ceramic
 C2, C3, C5, C10, C11, C13, C17, C18—0.1 µF, ceramic
 C4—3.3 pF, ceramic
 C6, C12—10 µF, 10 volts, aluminum electrolytic
 C7—33 pF, ceramic
 C9, C15—0.01 µF, ceramic
 C14, C16—0.47 µF, ceramic
 C19—4.7 µF, 10 volts, aluminum electrolytic
 C20—470 pF, ceramic
 C21—220 µF, 10 volts, aluminum electrolytic

Semiconductors

IC1—NE602AN mixer, Philips or equiv.
 IC2—MC1350P IF amplifier, Motorola or equiv.

IC3—CA3140E operational amplifier, Harris or equiv.
 IC4—ZN414Z amplifier/detector (GEC Plessey)
 IC5—MC34119P power amplifier, Motorola or equiv.
 Q1—MPF102 JFET, Motorola or equiv.

Other components

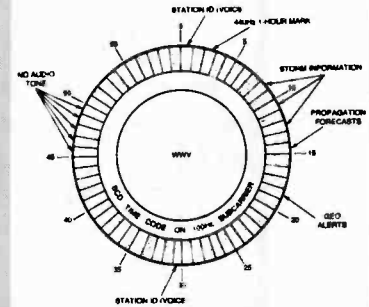
FIL1—455-kHz ceramic filter, Toko HCFM2-455A or equiv.
 T1, T2—10.7-MHz IF transformer (Toko or equivalent)
 T3—455-kHz IF transformer, 6:1 ratio (Toko or equivalent)
 XTAL1—9.545-MHz crystal
 SPKR1—speaker, square, 2.5-inch, 8-ohms
 S1—SPDT switch, PCB mount
Miscellaneous: 5.3 × 4 × 2-inch plastic project case, PC board, 9-volt battery, battery clip, hookup wire, solder.

Note: The following items are available from Almost All Digital Electronics, 1412 Elm Street S.E., Auburn, WA 98092:

- Complete kit—\$39.95 + \$4.00 S&H
- Partial kit (includes all electronic components, PC board, and crystal—does not include project case, speaker, or antenna)—\$29.95 + \$4.00 S&H
- PC board and crystal, only—\$10.00 + \$2.90 S&H

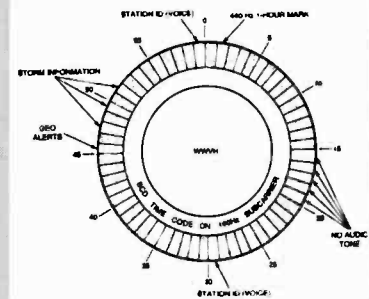
Send check or money order. Washington State residents add local sales tax.

WWV hour signals



The figure shows how the WWV hour is divided. The beginning of each hour is identified by a 0.8-second, 1500-Hz tone. The beginning of each minute is identified by a 0.8-second, 1200-Hz tone. The 29th and 59th second pulse of each minute is omitted.

WWVH hour signals

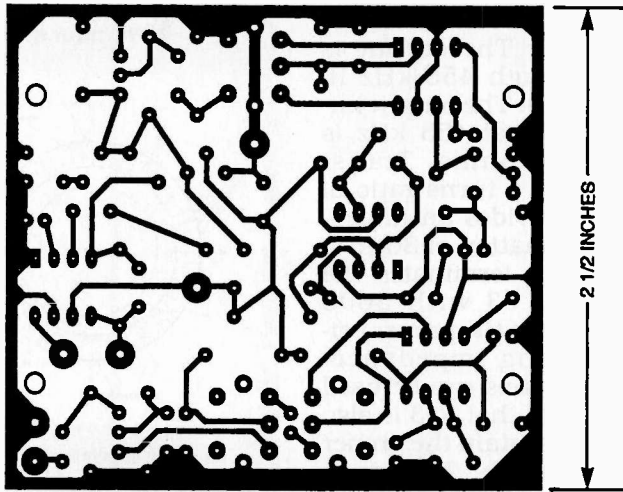


The figure illustrates how the WWVH hour is divided. The beginning of each hour is identified by a 0.8-second, 1500-Hz tone. The beginning of each minute is identified by a 0.8-second, 1200-Hz tone. The 29th and 59th second pulse of each minute is omitted.

WWV and WWVH broadcasts are approximate mirror images of each other. This prevents the two stations from creating interference during voice announcements.

designed to be powered from a 1.5-volt DC power supply with a 500-ohm load. This is emulated by resistors R15 and R17 whose equivalent circuit is 1.5-volts DC flowing through 500 ohms. The DC level at the output of IC4 is about 1.1-volts DC with no signal, and 0.9-volt DC with a strong signal.

The output signal is amplified, inverted, and filtered by IC3. Capacitor C14 removes any audio from the signal before it is applied to the gain control input



WWV RECEIVER FOIL PATTERN.

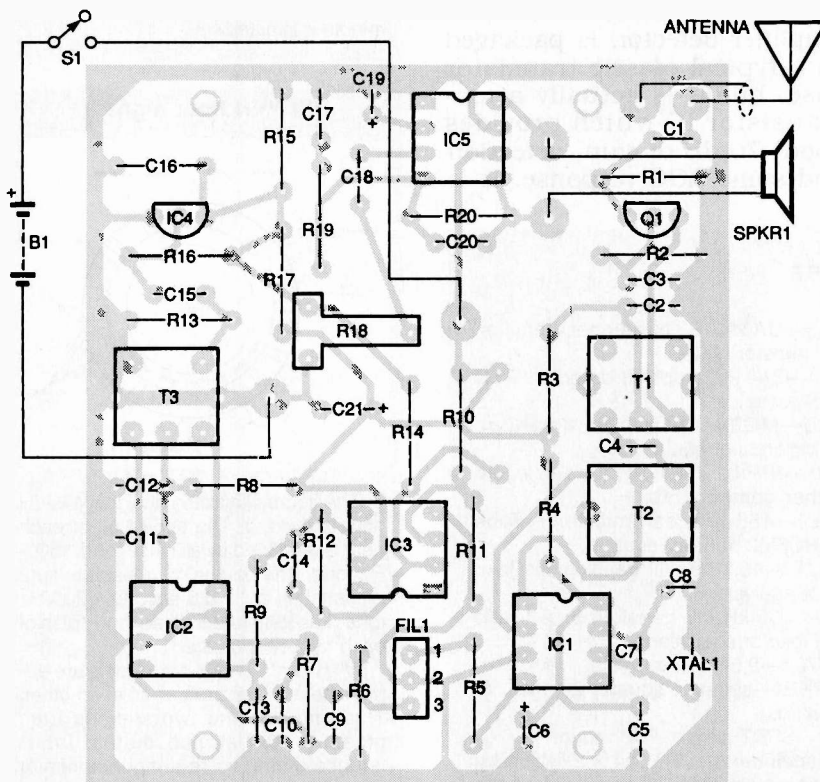


FIG. 2—PARTS-PLACEMENT DIAGRAM. The volume control is mounted on the PC board and adjusted before closing up the case.

pin 5 of the Motorola MC1350P IF amplifier (IC2). When the voltage at the output of IC4 exceeds the 1-volt DC reference level set by R10 and R11, the gain of IC2 starts to roll off. As a result, the AGC response of IC2 and IC3 tries to maintain the signal level so that the DC level at the output of IC4 is 1-volt DC.

The gain of the Motorola MC34119P audio amplifier (IC5) is set by the ratio of R20 to R19, which equals 47 (about 16 dB).

This audio amplifier was selected because it is a bridge amplifier and does not require a large coupling capacitor to drive the speaker.

The overall maximum gain of the receiver is about 144 dB. This is the sum of a -10 dB in the input filter, +14 dB from IC1, -6 dB from FIL1, +60 dB from IC2, +70 dB from IC3, and +16 dB from IC4. Ordinarily a gain of 144 dB is too much. Normal operation can be expected

to be with about a 120 dB maximum gain, which is typical of a high-quality communications receiver. However, the gain is usually less than that, as set by the volume-control potentiometer R18 and AGC loop.

Building the receiver

You can build the receiver on a single-sided PC board that you make yourself from the foil pattern provided here. Alternatively, partial and complete kits containing a finished PC board, as well as complete receivers, are available from the source given in the Parts List.

Figure 6 is a parts-placement diagram. The order of assembling the components to the circuit board and soldering them is not critical. Pay particular attention to the orientation of the semiconductors, that is the location of pin 1. Mount the volume control on the PC board. Keep in mind that it cannot be adjusted after it is installed in the case.

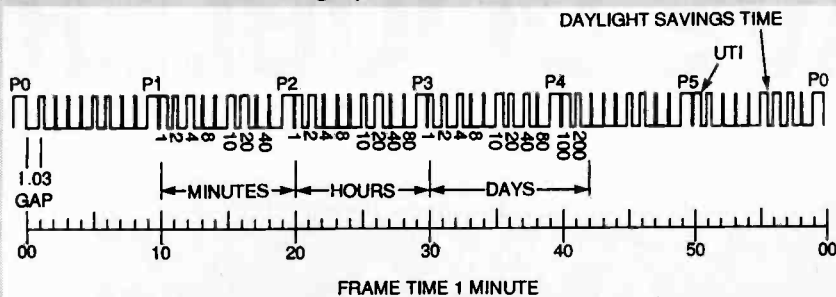
The author designed the circuit assuming that the receiver would be turned on only for brief periods to obtain the correct time, and that convenient access to the volume control would not be necessary. However, if you want an external volume control, one can be mounted on the case and wired directly to the pads intended for the PCB-mounted control.

After all the electronic components are inserted and soldered to the circuit board, wire the speaker, battery clip, power switch, and antenna. Install the completed circuit board in the case as shown in Fig. 7. Install a 9-volt battery.

Circuit alignment

To align the circuit, adjust transformers T1, T2, and T3 for peak AGC voltage at pin 6 of IC3. The desired tuning is broad for receiving a strong signal. Attach an antenna that is as short as practical to pick up an extremely weak signal for the alignment procedure. Even with those precautions, the tuning range of the IF transformers will appear to be quite broad.

Dividing Up Time For Broadcast



The figure illustrates the pulse format for the BCD time code (100-Hz subcarrier). During the passage of a minute, both stations broadcast the time of year on a pulse-width modulated 100-Hz subcarrier. Three different pulse widths are used:

1. P0-P5—position identifiers—0.8 seconds (80 cycles)
2. Logic 1—data bit—0.5 seconds (50 cycles)
3. Logic 0—data bit—0.2 seconds (20 cycles)

In addition there is a 1.03 second (103 cycles) "hole" in the code for synchronization at the beginning of each minute signal. The minute is divided into six parts of 10 seconds duration. Each part consists of nine data bits and a position identifier pulse. The following listing is the contents of the various sections.

- 1.—Synchronization "hole" and eight

logic zeros.

- 2.—Four data bits encoding the unit minutes in binary-coded decimal (BCD), a logic 0, three data bits encoding the tens of minutes in BCD and another logic 0.

- 3.—Four data bits encoding the unit hours in BCD, a logic 0, and two data bits encoding the tens of hours in BCD and two logic 0's.

- 4.—Four data bits encoding the unit days in BCD, a logic 0, and four data bits encoding the tens of days in BCD.

- 5.—Two data bits encoding the hundreds of days in BCD and seven logic 0's.

- 6.—One data bit if UT1 correction should be applied, four logic 0's, a data bit which is logic 1 if daylight saving time and three data bits with the UT1 correction in tenths of a second. The UT1 correction accounts for the Earth's rotation which varies slightly over time.

Antenna considerations

The author lives near Seattle, Washington—about 1000 miles from Fort Collins, Colorado. Moreover, there are several mountain ranges between Seattle and Fort Collins. The quality of reception is usually excellent during the day with an antenna consisting of a 3- to 6-foot length of wire. When the signal is particularly strong, no antenna is needed.

The prototype receiver shown in the photographs has a 30-inch telescopic rod antenna that works quite well, but this a convenience feature rather than a requirement. There are two pads on the board for the connecting the antenna: one is connected to the antenna and the other is the ground connection. While a single wire on the antenna terminal usually works well, reception can generally be improved with a simple dipole antenna formed by a second wire connected to ground. Ω

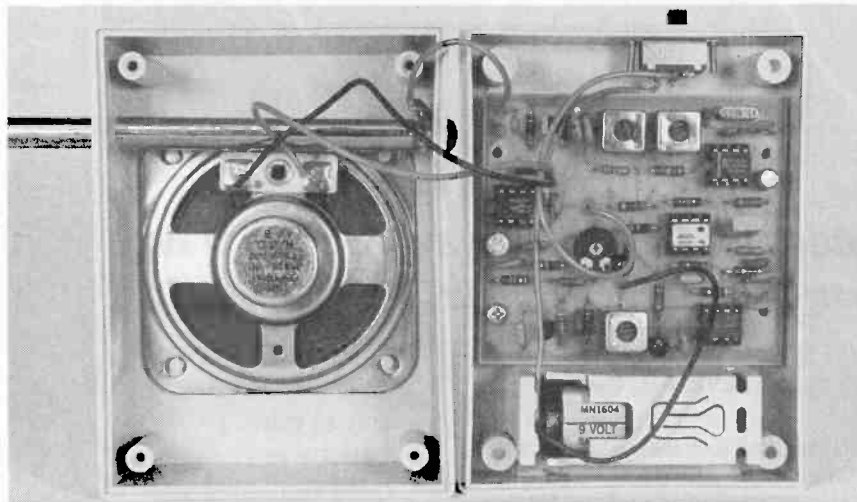


FIG. 3—THE FINAL ASSEMBLY consists of wiring the speaker, battery clip, power switch, and antenna. The author's prototype is shown here.

As an alternative to "on-air tuning," set up a 10-megahertz signal source. It will make the task of circuit alignment easier by providing a constant, local, easy to control signal. The author set a frequency counter at 10-megahertz and its internal oscillator provided sufficient ambient signal leakage to act as an excellent signal source for

alignment.

The most difficult step is the alignment of the double-tuned input filter, T1/T2. To overcome that obstacle, all of the transformers that are supplied with the kit from the source listed in the Parts List are pre-aligned. Only slight adjustments are then necessary for the transformers after assembly.

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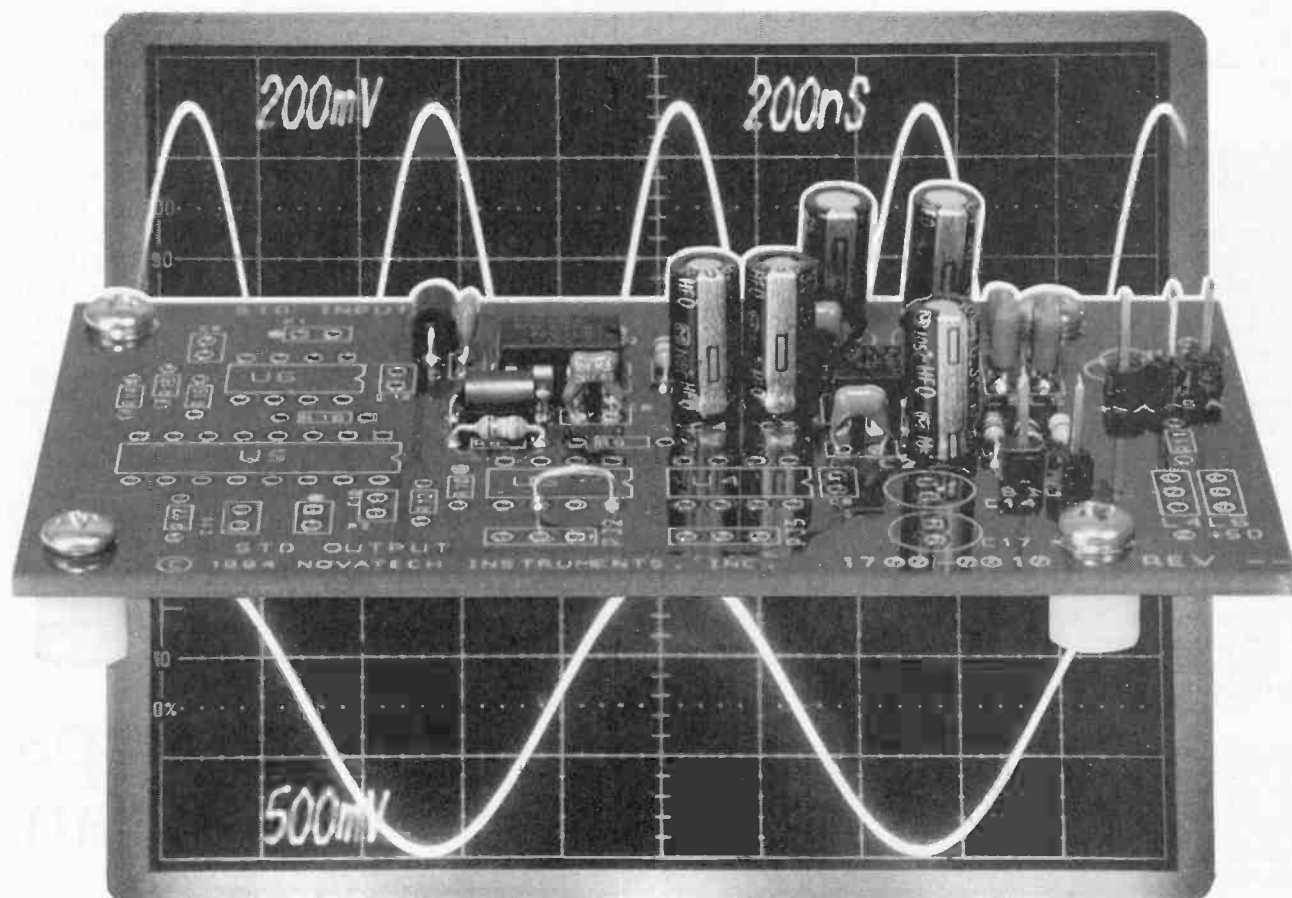
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Theory of operation

A schematic of the frequency doubler module is shown in Fig. 1. The core of the module is IC1,

STEVEN D. SWIFT

an Analog Devices AD834 wide-band four-quadrant multiplier. This IC provides wideband analog multiplication of two input signals, regardless of their polarity. In this circuit both X and Y inputs are tied together to provide a squaring function.

The operation of IC1 is best understood with the aid of simple mathematics. If the input is assumed to be a normalized (amplitude of 1) sinewave of frequency f , then the input can be written as:

$$\text{Input} = \sin(2\pi f)$$

where

$$\pi = 3.14159\dots$$

f = frequency

t = time

The AD834 performs the following function:

$$XY = \sin(2\pi f) \times \sin(2\pi f) \\ = (\sin(2\pi f))^2$$

A fundamental trigonometric identity gives:

$$(\sin(2\pi f))^2 = (1 - \cos(2(2\pi f)))/2 \\ = (1 - \cos(2\pi 2f))/2$$

The last term shows a DC offset as well as a cosine term with twice the frequency as the input. This performs the frequen-

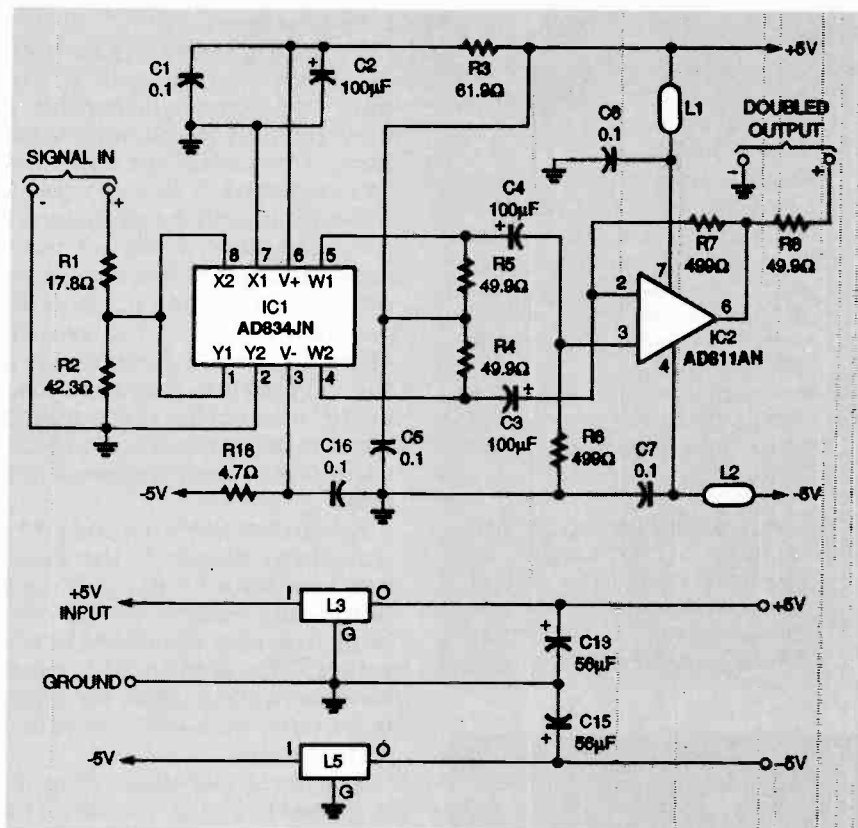


FIG. 1—SCHEMATIC OF THE FREQUENCY DOUBLER. An Analog Devices AD834 wideband, four-quadrant multiplier (IC1) provides wideband analog multiplication of two input signals.

this circuit. Note, however, that the amplitude is cut in half.

Since the AD834 provides differential current-mode outputs, load resistors R4 and R5, gain resistors R6 and R7, and IC2 are added to convert the signal to an amplified and buffered single-ended output. The AD811 wideband current-mode feedback amplifier (IC2) is configured as a differential amplifier. Capacitors C3 and C4 remove the DC offset from the output. Resistor R8 provides a nominal 50-ohm output impedance, and R1 and R2 attenuate the input signal and provide a low-impedance source to IC1.

Inductors L1, L2, L3, and L5 and capacitors C5, C6, C7, C13, and C15 perform high-frequency filtering and decoupling. Resistors R3 and R18 and capacitors C1, C2, and C16 provide decoupling and biasing for IC1.

The circuit requires a +5-volt supply at about 30 milliamperes and -5 volts at about 40 milliamperes. Higher voltages, up to ± 9 volts, can be used if the by-

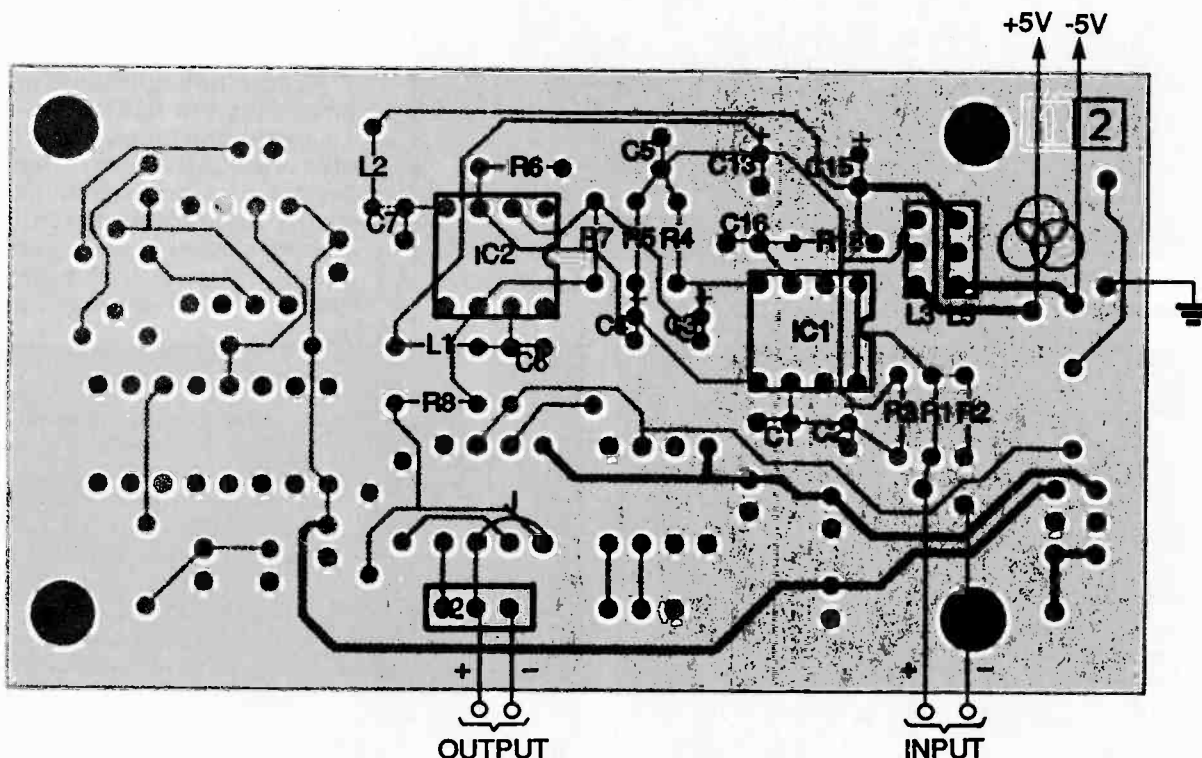


FIG. 2—PARTS-PLACEMENT DIAGRAM. Square pads are on pin 1 of all ICs and on the positive leads of all polarized capacitors.

cy doubling function. The cosine term exhibits a 90° phase

shift from the original input, but phase is of no concern in

pass capacitor voltage ratings are increased. Higher voltages provide higher bandwidths with higher power dissipation.

PARTS LIST

All resistors are 1/8-watt, 1%, metal film, unless noted.

R1—17.8 ohms
R2—42.3 ohms
R3—61.9 ohms
R4, R5, R8—49.9 ohms
R6, R7—499 ohms
R18—4.7 ohms, 1/8-watt, 5%

Capacitors

C1, C5—C7, C16—0.1 μ F, ceramic
C2—C4—100 μ F, 6.3 volts, high-frequency aluminum electrolytic
C13, C15—56 μ F, 16 volts, high-frequency aluminum electrolytic

Semiconductors

IC1—AD834JN wideband multiplier (Analog Devices)
IC2—AD811AN current mode amplifier (Analog Devices)

Other components

L1, L2—Leaded EMI bead (Panasonic EXC-ELSA35, Digi-Key P9820BK-ND)

L3, L5—3-terminal EMI filter (Panasonic EXC-EMT103DT, Digi-Key 9809CT-ND);
L4—not used

Miscellaneous: PC board, wire jumpers, seven 0.025-inch square posts (if desired), solder.

Note: The following items are available from Novatech Instruments, Inc., 1530 Eastlake Ave. East, Suite 303, Seattle, WA 98102:

- Complete kit of all parts (Model DOUB-1, includes PC board and documentation)—\$50.00

Please add \$5 shipping and handling for US and Canada. \$10 overseas. Add \$10 for COD orders. Washington State residents must add 8.2% sales tax. Check or money order only.

Construction

Because IC1 and IC2 are high-frequency components, you must be extremely careful to prevent high-frequency oscillations if you build the circuit on a breadboard. It is preferable to use a PC board. A foil pattern is provided here. Keep all wires short and place the bypass capacitors as close to IC1 and IC2 as possible. A solid ground plane on the component side of the PC board is recommended, and IC sockets are discouraged. If you must use sockets, use machined-pin, open-frame sockets only.

As can be seen from the parts-placement diagram, the board has locations for extra components not related to the doubling function discussed in this article. The additional features were included to allow the board to be used with other Novatech synthesizers.

The parts-placement diagram is shown in Fig. 2. Install all the components as shown, taking care to observe polarity on diodes and capacitors. Square pads indicate pin 1 of all ICs and the positive leads of all polarized capacitors.

All resistors specified for this circuit (except R18) are 1/8-watt, 1% metal-film types. Their small size and tight tolerance improves high-frequency performance and circuit matching. If resistors other than metal-film are substituted, the performance of the frequency doubler

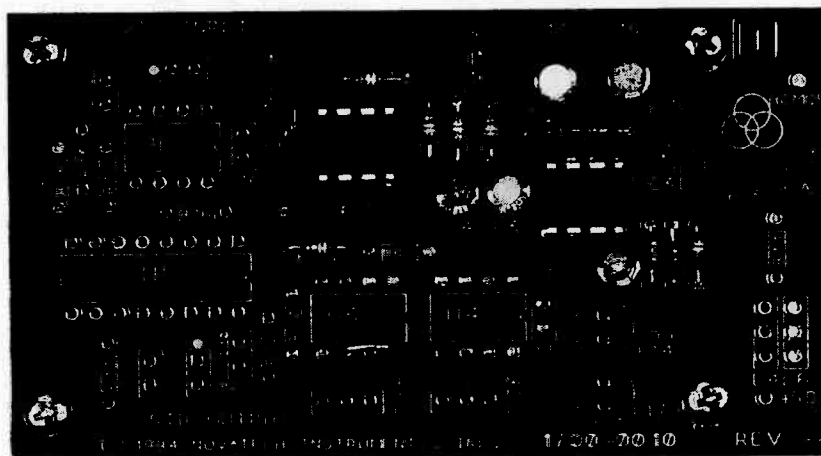


FIG. 3—THE COMPLETED BOARD. The locations for extra components are for other board applications.

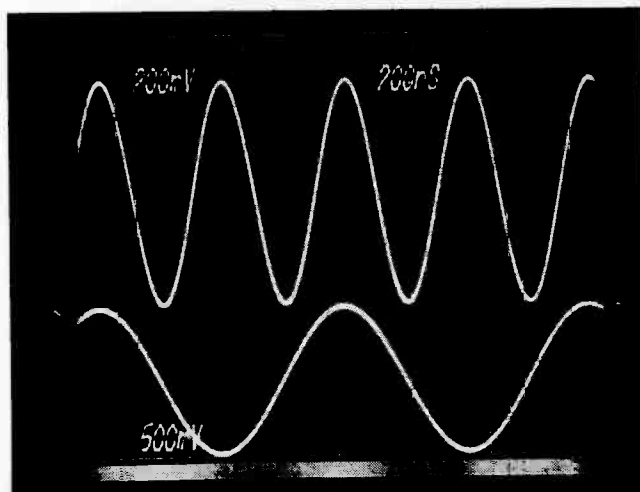


FIG. 4—INPUT AND OUTPUT. The top trace is the output of the doubler with a 1-megahertz, 1.5-volt peak-peak input signal, and the bottom trace is the input signal.

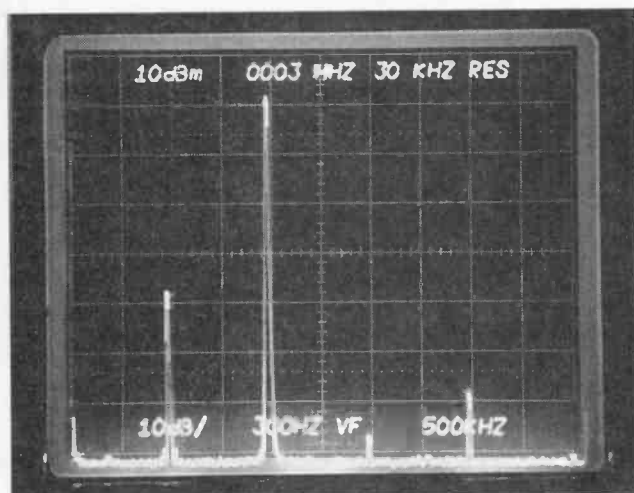


FIG. 5—FREQUENCY SPECTRUM of the output signal in Fig. 4. The fundamental frequency is about 40 dB down from the doubled frequency.

will be degraded. In particular, its distortion will increase, and its bandwidth will decrease.

As mentioned before, C3 and C4 provide DC blocking. The values specified allow operation down to about 10 hertz. If you intend to use this circuit exclusively above 5 kilohertz, better high-frequency performance can be obtained by substituting 0.1 μ F ceramic capacitors. The extra capacitors are included with the kit for this purpose. Figure 3 shows the board.

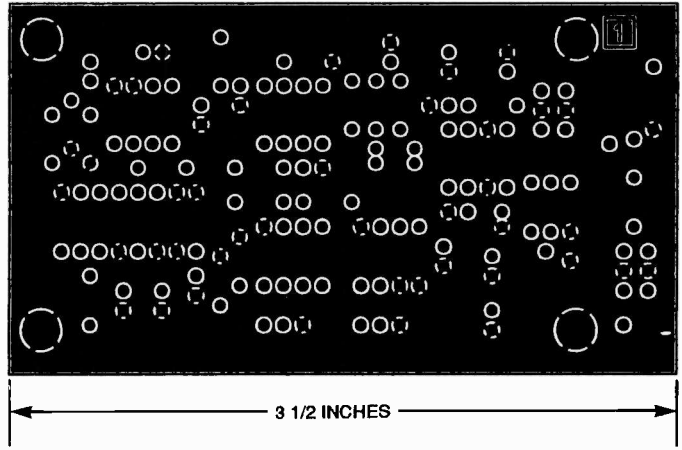
Checkout

Verify that all components are installed properly and that there are no solder bridges. Apply power to the board as indicated in Fig. 2 (plus and minus 5 volts DC, both ± 0.25 volt). Also connect a function generator set to approximately 1 volt RMS to the signal input as shown. Connect an oscilloscope or frequency counter to the output pin (the center pin of J2).

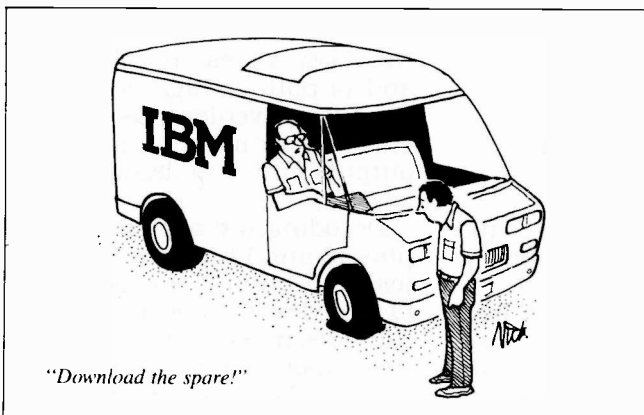
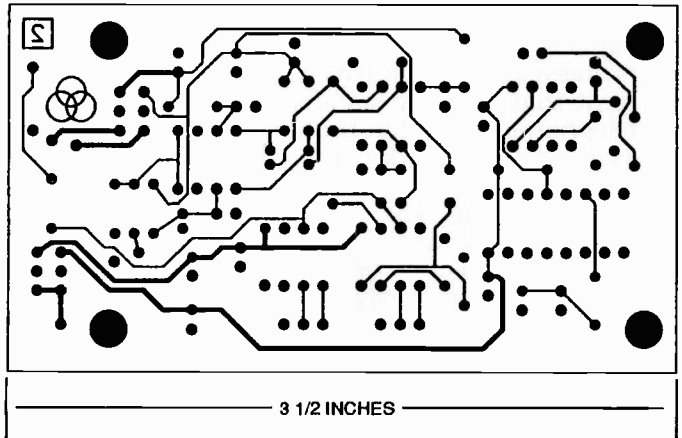
Observe that the output is double the frequency of the input signal as the input is varied. The typical 3 dB point of the doubler is greater than 30 megahertz at the output. You can adjust the input to vary the output, but with an input above about 1.5 volts RMS, the output might be clipped.

The top trace in Fig. 4 is the output of the doubler with a 1-megahertz, 1.5-volt peak-to-peak input signal, shown at 200 millivolts per division. The bottom trace is the input signal at 500 millivolts per division. Figure 5 shows the frequency spectrum of the output signal in Fig. 4. The fundamental frequency is about 40 dB down from the doubled frequency, the second harmonic is more than 65 dB down, and the third is about 60 dB down. This fundamental frequency feedthrough increases to about -20 dB below the carrier as the output is increased to 50 megahertz. Ω

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IF YOU HAVE TOUCH-TONE TELEPHONE service, you can now put a call on hold from any phone in your house by plugging this simple device into any telephone jack. The universal hold circuit works with any phone that has a keypad with a # key. To put a call on hold, press the # key and hang the phone up. A timer extends the #-key function while you hang up phones that have a keypad built into the handset.

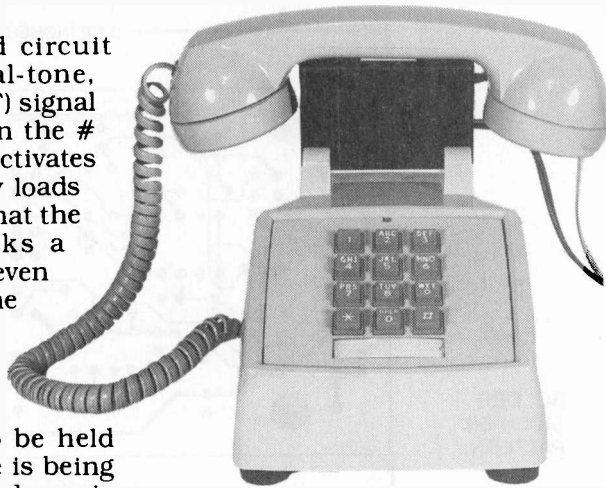
The universal hold circuit first detects the dual-tone, multifrequency (DTMF) signal that is generated when the # key is pressed. It then activates a circuit that partially loads the telephone line so that the central office thinks a phone is still off-hook even after it is hung up. The hold circuit remains active for five seconds after the # key is released, so the key does not have to be held down while the phone is being hung up. When any phone is again picked up, the hold function is canceled.

How it works

Figure 1 shows the schematic diagram of the universal hold circuit. The telephone line is connected to the hold components through bridge rectifier BR1 so that the input is not polarity sensitive. The positive side of the line is always connected to Zener diode D2, and the negative side of the line is always connected to IC2. The telephone line also connects to tone-decoder IC4 through C4 and T1. Power is supplied to the circuit by a 12-volt DC power adapter and by IC5, a 78L05 5-volt regulator, and is filtered by C2 and C3.

Optoisolator IC1 contains a silicon-controlled rectifier (SCR) that latches on after it's turned on by current flowing through an optically coupled LED within the IC. The SCR continues to conduct even after the LED current is removed, providing that enough anode current is available to sustain it. When the SCR anode voltage is removed and conduction

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stops, it will not resume until the SCR is again triggered by the internal LED.

When all phones on the line are on-hook, the voltage across the telephone line is about 48 volts. When a phone is taken off-hook, it places a load on the line

and a current of about 20 milliamps flows through the phone, which causes the line voltage to drop to about 3 to 8 volts, depending on the telephone. Current also flows through circuits at the central office, indicating that a phone has been picked up.

A call is put on hold when all phones are hung up and the SCR in IC1 is triggered on by circuits driving its LED. When the SCR conducts, current flows through BR1, D2, LED1, IC1, IC2 and back through BR1, placing a load on the line that keeps the central-office circuits active. A 15-volt drop across D2, a 2-volt drop across D1, a 1.5-volt drop across the LED in IC2, and about a 1.5-volt drop across the diodes in BR1 result in the normal 48-volt line voltage being clamped to about 20 volts. That allows line current to flow, but at a higher voltage than normal. The LED lights to indicate that a call is on hold. When a phone is picked up and the line voltage drops to 8 volts or less, there is no longer enough voltage to keep current flowing through D2, D1, IC1, IC2, and BR1, and the hold function is canceled.

The telephone line also connects through capacitor C4 and transformer T1 to capacitor C8, which couples the DTMF signal to the input of IC4, a Motorola MC145436 DTMF decoder used to detect the #-key tone. Zener diode D6 clamps IC4's input voltage to 9.1 volts to prevent damage from transients. The decoder has four outputs that produce a hexadecimal code corresponding to the tones it receives when a key is pressed (see Table 1). Notice that only when the # key is pressed will pins 13 and 14 both go high (logic "1"). That is convenient, as the circuit has to monitor only two outputs of IC4 to decode the # key.

Decoding the outputs of IC4 pins 13 and 14 is done by a logical AND circuit consisting of two diodes, D4 and D5, whose cathodes must both be high for their anodes to be pulled high by R5. That discharges C1 through R4 into the positive

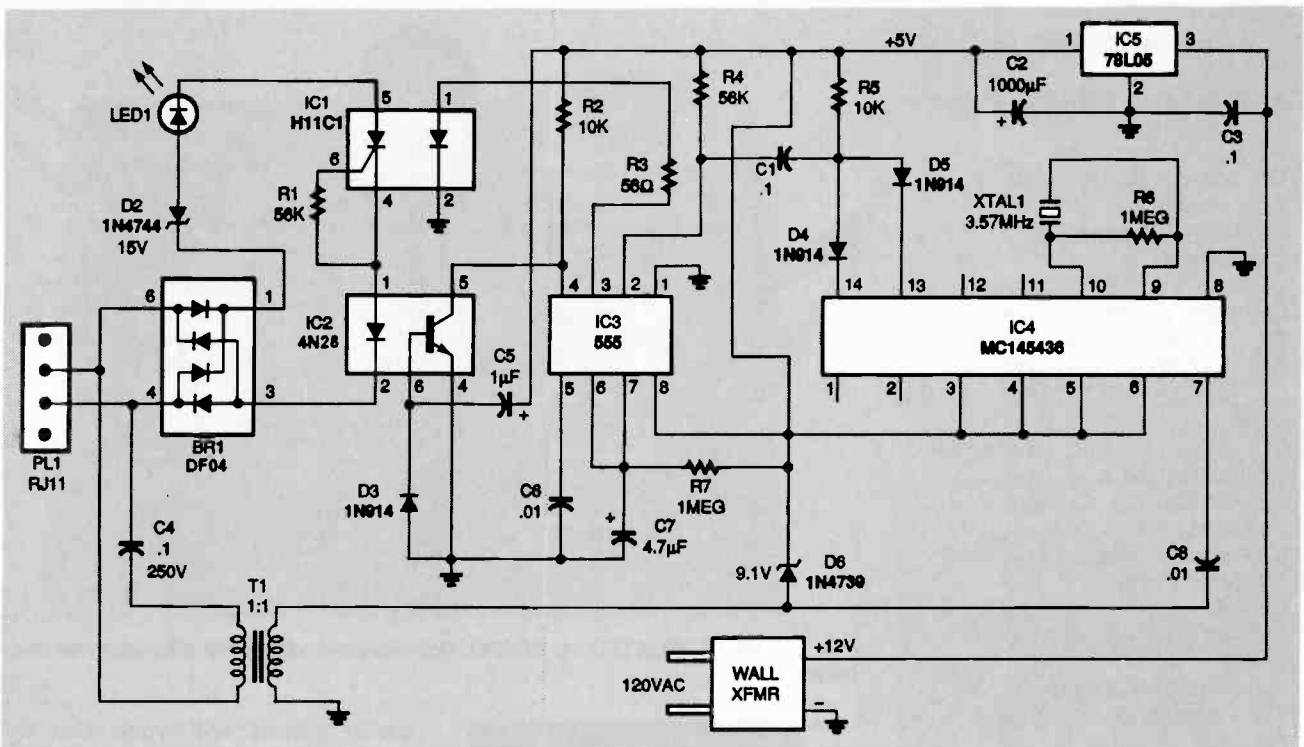


FIG. 1—SCHEMATIC DIAGRAM of the universal hold circuit. The telephone line is connected to the hold components through bridge rectifier BR1, so that the input is not polarity sensitive.

supply. When the # key is released, pins 13 and 14 go low again and a negative pulse is produced by C1 and R4 at the trigger input (pin 2) of 555 timer IC3. That starts IC3's timing cycle where pin 3 goes high for about five seconds. That drives current through R3 into the LED within IC1, latching the internal SCR. The five-second output from IC3 keeps current flowing long enough to hang up the phone. The 5-second duration is controlled by R7 and C7 and may be altered by changing the value of R7.

Optoisolator IC2 has a transistor output. After the # key is pressed and the phone is hung up, telephone line current flowing through the LED in IC2 turns its transistor on, which resets timer IC3.

The reset function removes current from the LED in IC1 and allows a hold to be canceled immediately after initiating it without having to wait for the five-second cycle to complete. The transistor within IC2 also performs a power-on reset by having its base coupled through C5 to the positive supply. When

TABLE 1—IC4 OUTPUTS

Key	IC pin 13	IC pin 14	IC pin 1	IC pin 2
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
.	1	0	1	0
*	1	0	1	1
#	1	1	0	0

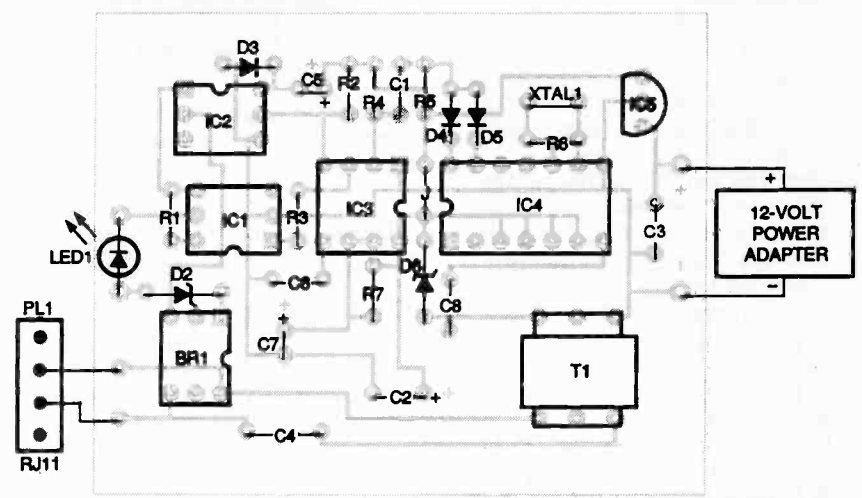


FIG. 2—PARTS-PLACEMENT DIAGRAM. Leave LED1's leads long and bend them in an "S" shape so its position can be adjusted later to fit through a hole in the top of the case.

PARTS LIST

All resistors are 1/8-watt, 5%, unless noted.

R1, R4—56,000 ohms

R2, R5—10,000 ohms

R3—56 ohms

R6, R7—1 megohm

Capacitors

C1, C3—0.1 μ F, 50 volts, metal film

C2—1000 μ F, 16 volts, electrolytic

C4—0.1 μ F, 250 volts, polyester

C5—1 μ F, 50 volts, electrolytic

C6, C8—0.01 μ F, 50 volts, metal film

C7—4.7 μ F, 35 volts, electrolytic

Semiconductors

IC1—H11C1 SCR optoisolator (Harris or equiv.)

IC2—4N28 transistor optoisolator (Harris or equiv.)

IC3—555 timer

IC4—MC145436 (Motorola or equiv.) or CD22204 (Harris or equiv.) DTMF decoder

IC5—78L05 voltage regulator

BR1—DF04 1-ampere, 400 volt, DIP bridge rectifier (Allied Electronics or equiv.)

D1—not used

D2—1N4744 Zener diode, 15-volts, 1 watt

D3—D5—1N914 silicon diode

D6—1N4739 Zener diode, 9.1 volts, 1 watt

LED1—light-emitting diode, any color, T1-3/4

Other components

XTAL—3.579545 MHz crystal

T1—matching transformer, 600-ohm primary, 600-ohm secondary (Jameco P/N 105902)

PL1—RJ11 modular plug attached to telephone wire

Miscellaneous: three 6-pin IC sockets, one 8-pin IC socket, one 14-pin IC socket, 120-volt AC to 12-volt DC, 100 milliamp, power adapter, 2- x 3- x 1-inch plastic project box (Jameco P/N 18921), two cable ties, PC board, wire solder

Note: The following items are available from American Electromechanical Inc., 134 Van Voorhis Terrace, Wappingers Falls, NY 12590:

- Complete kit of parts including PC board and pre-drilled enclosure—\$49.95
- Etched and drilled PC board only—\$6.95

Check or money order, only. Add \$4.00 shipping and handling. NY State residents must add sales tax

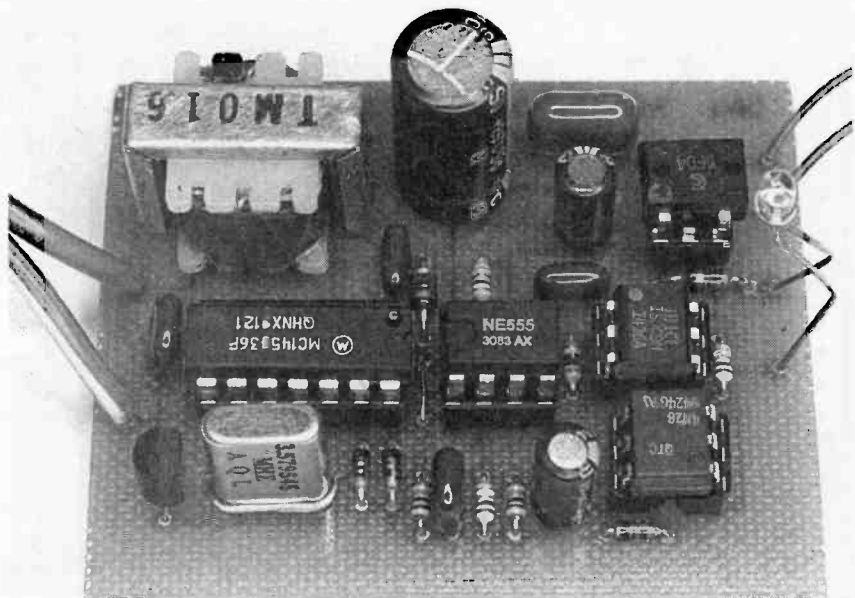


FIG. 3—THE COMPLETED PC BOARD. Point-to-point wiring will also work for this project.

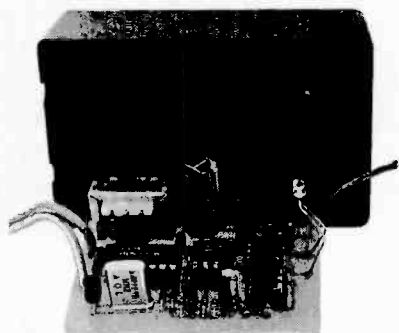
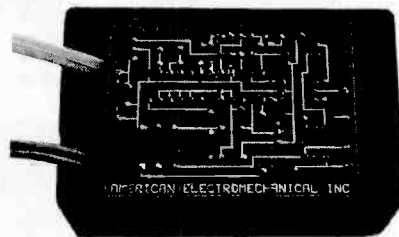


FIG. 4—THE BOARD FITS tightly in a 2- x 3- x 1-inch plastic case, and is held securely without any hardware.

power is turned off, C5 discharges through D3.

Construction

Since this is a low-frequency circuit, parts layout and wiring are not at all critical, parts tolerances are not critical, and equivalent types may be substituted.

The prototype was built on a small PC board for which we've provided a foil pattern. Point-to-

point wiring will work just as well, however.

If the printed-circuit board is used, use Fig. 2 as a guide to install the parts. It's always best to use IC sockets for all ICs, although they aren't absolutely necessary.

When installing LED1, leave its leads long and bend them in an S shape so its position can be adjusted later on to fit through a hole in the top of the case. After all parts are installed, plug the ICs into their sockets. Keep in mind that IC4 is a CMOS device that is sensitive to ESD or electrostatic discharge. Figure 3 shows the completed PC board.

The author installed the board in a 2- x 3- x 1-inch plastic case (see Parts List), in which the board fits perfectly and is held securely without any hardware. You are free to use any case you like, but the installation details are up to you if you decide to go that route.

Place a nylon tie around the power leads and the telephone wire to act as strain reliefs, or tie knots in them to serve the same purpose. Cut and file slots in the edge of the case to pass the wires through and drill a hole in the top of the case directly above where the LED will be once the board is installed. Figure 4 shows how the board fits into
(Continued on page 110)

SOLID STATE THERMOMETER

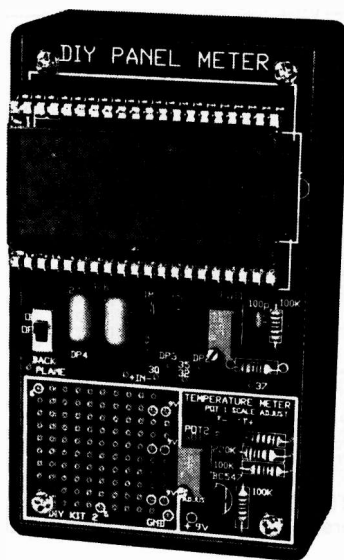
THE LIQUID-CRYSTAL DISPLAY (LCD) and the single-chip analog-to-digital converter (ADC) have made possible an almost endless list of battery-powered, handheld test instruments. The most prominent of these are the digital multimeter (DMM) and the digital panel meter (DPM), but others include digital capacitance meters, thermometers, timers, sound-level meters, and light meters.

The single chip ADC eliminated a slew of discrete components and increased circuit reliability, while the LCD presents large characters that are easily seen in daylight. But of more importance in battery-powered instruments, both of these components are miserly in power consumption. This is especially important for battery conservation.

Within recent years the prices of single-chip ADC ICs and large-character LCDs have fallen, and they are now readily available as low-cost, off-the-shelf items from electronics stores and distributors.

The digital thermometer described here can be made from an available kit or the parts can be obtained from most electronics distributors. By building the thermometer, the builder will gain experience in working with advanced ICs and display modules, and at the same time gain insight into circuitry common to many different instruments.

The digital thermometer can make accurate, reliable, and repeatable temperature measurements in the laboratory or in the field over a wide range of temperatures. It will save money over the price of a factory-built instrument and, as a bonus, it provides circuit board space for



Build an accurate, 3½-digit, handheld thermometer from a kit or from scratch.

MARC SPIWAK

adding extra components for experiments.

The basic digital thermometer circuit displays temperature in degrees Celsius to an accuracy of a tenth of a degree on its 3½-digit LCD in half-inch high characters. The PC board can be purchased as part of the kit or made with the foil pattern included here. The electronic components are visible on the top surface of the instrument case, as shown in the illustration of the meter.

How does it work?

Figure 1 is a schematic for the digital thermometer. The key semiconductor device in the circuit is IC1, an ICL7106CPL single-chip analog-to-digital converter from Harris Semiconductor. It is a 3½-digit ADC with a built-in LCD display driver, BCD to seven-segment de-

coders, clock and voltage reference. The ADC is packaged in a 40-pin plastic DIP. In the digital thermometer described in this article, IC1 will be set to display 200 millivolts full scale (199.9), plus or minus.

The temperature sensor for this digital thermometer is an NPN transistor modified to act like a silicon diode. The base of transistor Q1 is short-circuited to the collector, so it functions as a diode. However, it has a response curve that is more linear over a wider temperature range than a diode.

Transistor Q1 provides a variable input voltage to IC1. The voltage drop across the effective diode, typically about 0.7 volt, depends on the temperature of the diode's junction and the current flowing through it. The voltage drop is nearly linear, and will typically vary by 2.2 millivolts per degree Celsius.

A silicon diode has a negative temperature coefficient. Thus, in this application, as the temperature rises, voltage falls, and as the temperature falls the voltage rises. For example, if the ambient temperature rises by 2° Celsius, the voltage drop across the diode will decrease by about 4.4 millivolts. This linear voltage drop is measured to determine temperature.

The kit for the digital thermometer includes two transistors (Q1 and Q2) identified as BC-547s (but marked C547B). Pin identification is shown in Fig. 1. However, more readily available, industry-standard 2N2222 transistors can be substituted, although they have different pinout arrangements. Refer to the instructions given later if you want to make this substitution.

Trimmer potentiometers R9

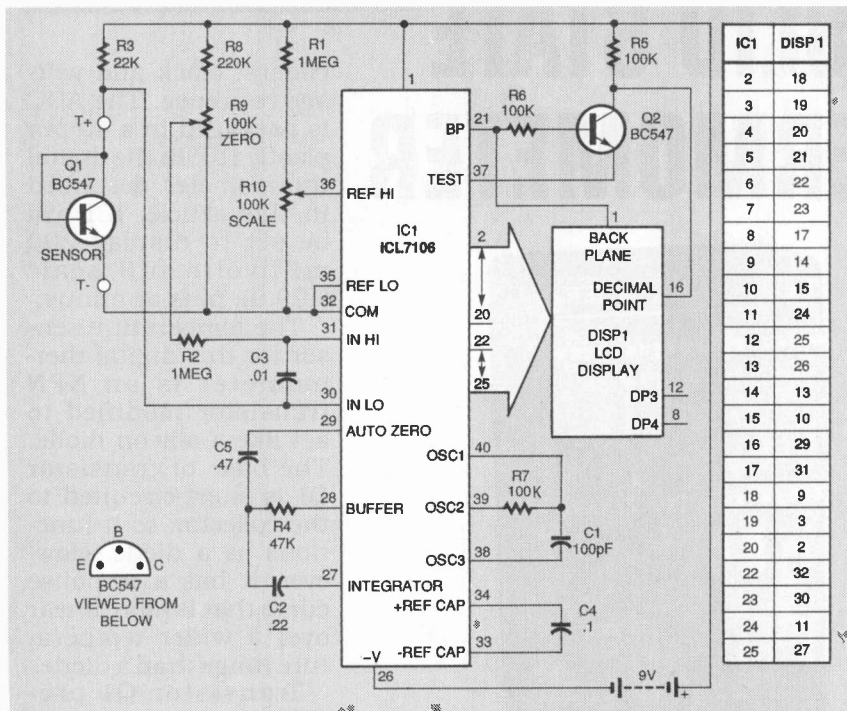
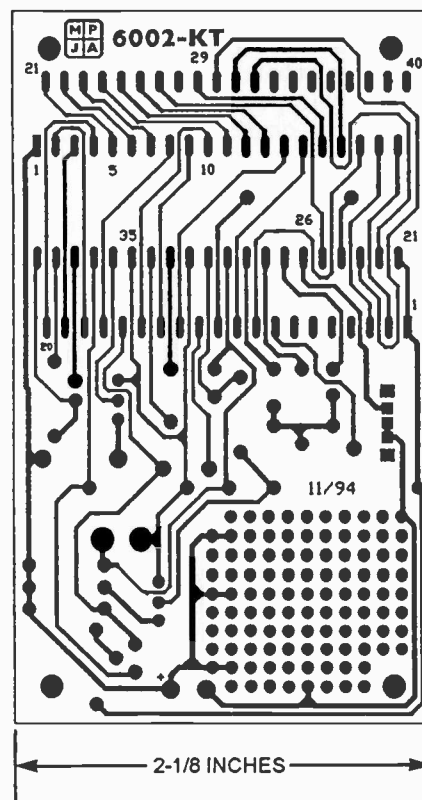
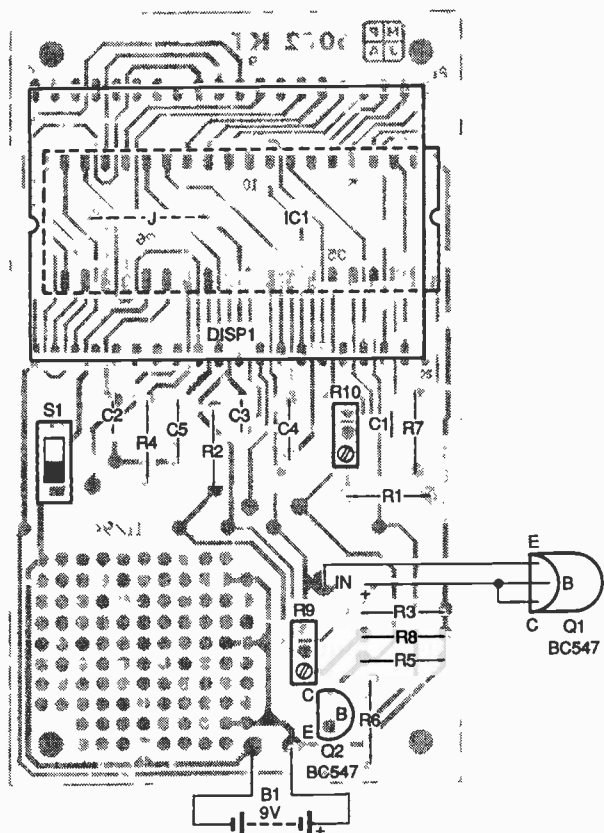


FIG. 1—SOLID-STATE THERMOMETER SCHEMATIC. The ICL7106 contains an analog-to-digital converter, BCD to 7-segment decoders, display drivers, a clock, and a reference voltage source.

and the display temperature must increment in degrees Celsius. The multiturn potentiometers permit precise settings.

Because IC1 can also indicate the polarity of the input voltage, the digital thermometer is theoretically capable of displaying temperature measurements from -200 to $+200$ degrees Celsius. However, the transistor used as a temperature sensor and its leads could be damaged by those temperature extremes.

The digital thermometer is effectively a solid-state voltmeter that could be adapted for making other measurements such as voltage, current, power, light level, and sound intensity, and more. If the output of the sensor for the variable you want to measure can be scaled between 0 and 200 millivolts, the circuit presented here can display that variable in appropriate standard units with little or no circuit modification.



THERMOMETER FOIL PATTERN.

FIG. 2—PARTS-PLACEMENT DIAGRAM. IC1 is located beneath the liquid-crystal display module.

(ZERO control) and R10 (SCALE control) can be set to zero the meter and make scale adjust-

ments in the input voltage to IC1. A display of 00.0 must correspond to zero degrees Celsius

The PC board for this project contains a small space where additional components can be

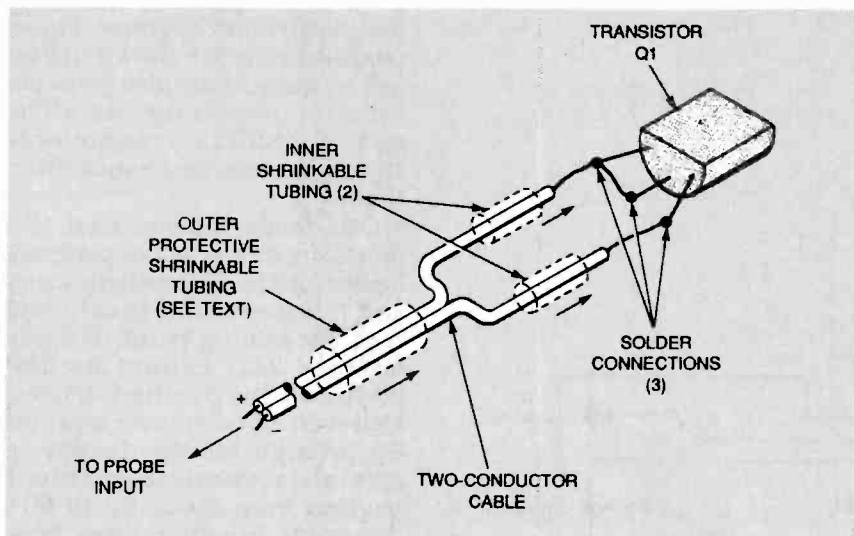


FIG. 3—THERMAL PROBE. The base and collector leads of transistor Q1 are bent together and soldered near the transistor's base and a two-conductor cable is attached.

PARTS LIST

All resistors are ¼-watt, 1%, unless otherwise noted.

- R1, R2—1 megohm
- R3—22,000 ohms
- R4—47,000 ohms
- R5—R7—100,000 ohms
- R8—220,000 ohms
- R9, R10—100,000 ohms, potentiometer 10-turn PCB

Capacitors

- C1—100 pF, polyester
- C2—0.22 μF, polyester
- C3—0.01 μF, polyester
- C4—0.1 μF, polyester
- C5—0.47 μF, polyester

Semiconductors

- IC1—ICL7106CPL ADC, Harris or equiv.
- Q1, Q2—BC547 NPN transistor (or 2N2222, see text and Fig. 5)

Other components

- S1—slide switch, SPST, PCB-mount
- DISP1—VI-302-DP-RC LCD module, 3½-digit, 40-pin package, Varitronix or equivalent)

Miscellaneous: PC board; three 40-pin IC sockets (see text); five machined pin sockets (optional); insulated hookup wire, 9-volt battery, battery clip with wires, project case with cover; miscellaneous hardware; solder.

Note: A kit for the digital thermometer (No. 6002-KT) can be purchased for \$29.95 plus \$4.00 for shipping and handling from Marlin P. Jones & Associates, Inc., P.O. Box 12685, Lake Park, FL 33403-0685, Phone: 407-848-8236, Fax: 407-844-8764. Florida residents please add local sales tax.

Figure 2 is the parts placement diagram for this meter. The circuit could be wired point-to-point, but that would call for a lot of wiring, especially in the display section. Consequently, the use of a PC board is recommended.

Insert all leaded components and sockets, and solder them in place on the solder side of the board. Insert resistor R1 and trimmer potentiometer R10 in individual machined pin sockets (two for R1 and three for R10) if you might want to replace those components with others having different values for different applications.

However, if you have no intention of experimenting with the finished meter, solder all resistors directly to the board. If you intend to substitute 2N2222 transistors, insert Q2 with its flat side opposite that shown in Fig. 2. More instructions on the substitution of 2N2222s will be given later.

Notice that analog-to-digital converter, IC1, is located under the LCD display, DISP1. When IC1 is installed, mount the LCD directly above it while orienting it to the opposite polarity (the notches are on opposite sides of the board). First install a socket for IC1. Then cut two 40-pin sockets apart along their long axes to provide four single in-line (SIP) sockets. Insert one SIP socket within another to form two double-height SIP sockets.

These will leave enough "head-room" for positioning IC1.

Solder the two double-deck SIP sockets to the board for DISP1, as shown in Fig. 2, and then install IC1. Then insert DISP1 in the double-height SIP sockets. This arrangement makes it easy to remove DISP1 by leaving the upper socket strips attached to the LCD and prying them away from the two lower socket strips that are soldered to the board. **CAUTION:** Do not attempt to remove the LCD from the upper sockets because the display pins can bend, and the glass body can break.

Cut a scrap of tinned lead wire to form jumper "J," insert and solder it. If you buy the digital thermometer kit, a case is included. The PC board fits securely in the top of the case to form a cover. Therefore, the inside the case provides enough space for the 9-volt battery. Solder the battery clip leads to the solder side of the board at the points shown in Fig. 2.

Refer to Fig. 3 and short-circuit Q1's base lead to its collector lead near the body of the transistor by bending them together and soldering them. Slip short lengths of heat shrinkable tubing over each input end of a two-conductor cable. Solder the two shorted transistor leads to the positive sensor input wire and

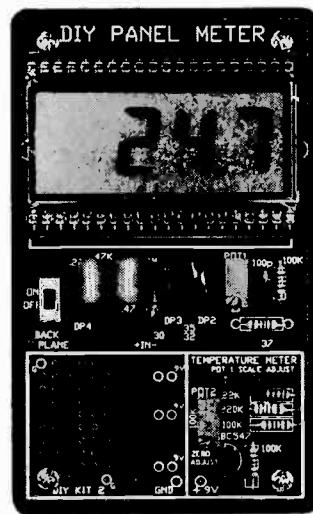


FIG. 4—THE TEMPERATURE-SENSING transistor can be located on the PC board, but leads must be attached for calibration.

located and powered to perform experiments and make other kinds of measurements.

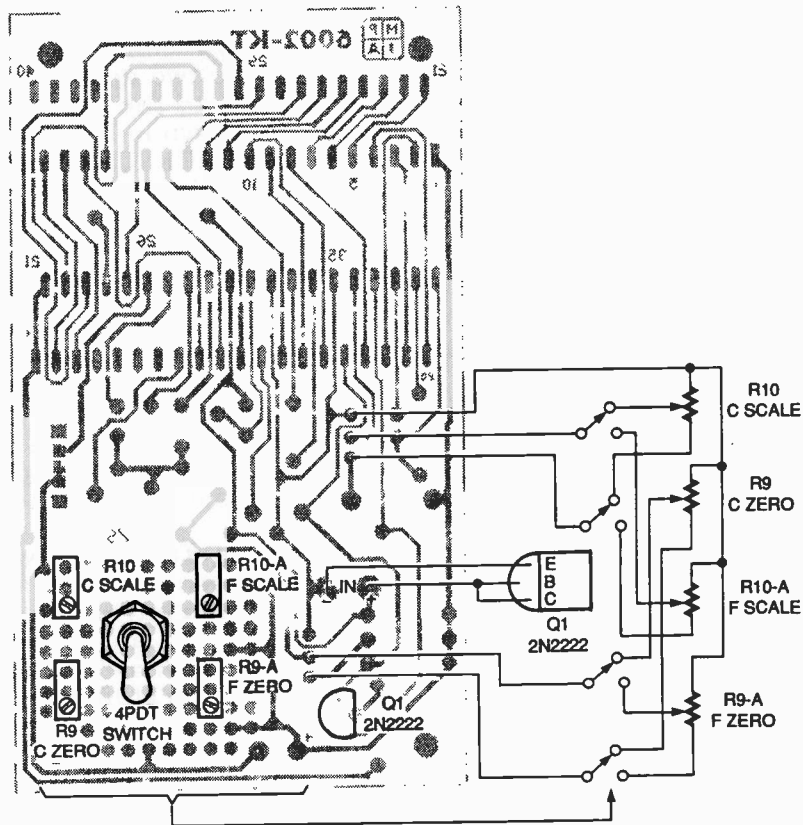


FIG. 5—THE CIRCUIT CAN BE MODIFIED as shown here to display part of the Fahrenheit scale in addition to the Celsius scale. Alternative 2N2222 transistors are installed as shown.

the emitter lead to the negative input wire.

Slip a short length of heat-shrinkable tubing on both leads and pull it over the end of the transistor to form an outer protective jacket, as shown in Fig. 3. Heat the tubing so that it forms a tight shrink fit around both the end of the transistor and the cable.

Standard insulated hookup wire leads are suitable for the temperature probe up to about 6 inches long. However, if the probe is to be mounted on leads longer than 6 inches, use thin shielded cable.

The temperature probe can also be mounted on the PC board directly with leads soldered to the "+" and "-" probe inputs. This arrangement will, however, make thermometer calibration more difficult. If you elect this option, temporarily attach the probe to the board with leads for calibration and mount it permanently to the board afterward. Figure 4 shows the completed digital thermometer.

well as Celsius degrees. Those modifications are shown in Fig. 5. The same figure also gives details for installing the alternative 2N2222 transistors, should you decide to substitute them.

Our tests showed that the meter's response is not perfectly linear for the Fahrenheit scale, and it is impossible to calibrate it at the boiling point of water because 212° cannot be displayed on the 3½-digit display. However, the response was linear enough for the display to give an accurate Fahrenheit reading from about 60 to 80°, the range in which most temperature readings are likely to be taken.

Calibrating the meter

Carefully inspect the circuit board for soldering errors and correct them before proceeding. If the board passes visual inspection, connect a 9-volt battery to it and switch on power. The display will either indicate a "1" or some other reading. If the display shows a "1," adjust potentiometers R9 and R10 to obtain a reading other than a "1."

Fill a container with ice cubes and add a small amount of water. Turn on the digital thermometer and submerge its temperature probe in the ice water, holding it in close contact with an ice cube. Wait until the display stabilizes and then adjust ZERO control potentiometer R9 until the display reads 00.0.

Boil water in a kettle and carefully hold the probe over the kettle spout in the steam with tongs to prevent accidentally scalding yourself. When the display reading stabilizes, adjust SCALE control potentiometer R10 until the display reads 100. If you have access to a digital multimeter with a temperature probe that is known to be calibrated, compare readings and adjust trimmers R9 and R10 more precisely.

If you added the Fahrenheit potentiometers, as shown in Fig. 5, calibrate the Fahrenheit scale next, bearing in mind the limitations discussed earlier. It is recommended that the tem-

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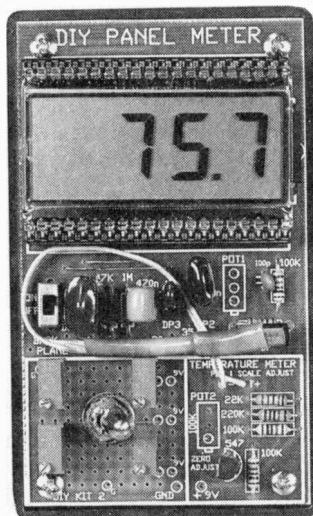
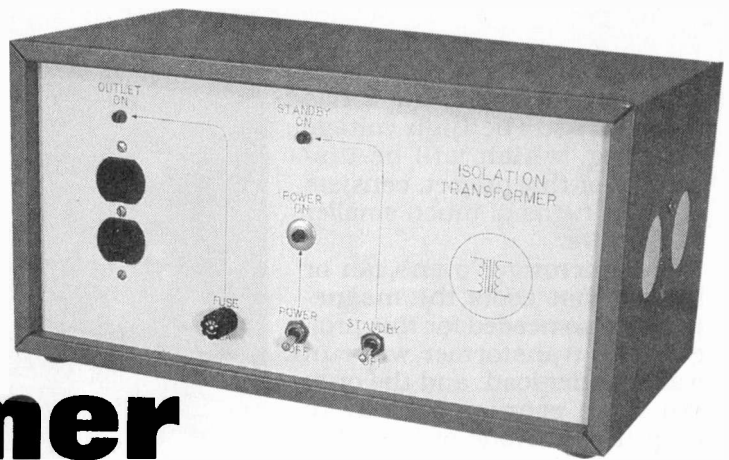


FIG. 6—MODIFIED THERMOMETER can display the full Celsius range and Fahrenheit from about 60° to about 80°.

Modifying the meter

As mentioned earlier, a small area on the PC board is set aside to accommodate components for experiments. We added two more potentiometers and a 4PDT switch to the circuit so the digital thermometer could be calibrated in Fahrenheit as

Home-brew Isolation Transformer



Buils this inexpensive transformer to protect yourself—and your test equipment—while you service and repair electronic appliances.

DOYLE WHISENANT

EVERYONE WHO REGULARLY SERVES television sets really should have an isolation transformer. One side of the chassis of most line-powered TV receivers and tube-type radios is connected directly to the AC line. Therefore, servicing this electronic equipment can be very dangerous because the chassis can be "hot." An isolation transformer isolates the chassis of the equipment being serviced from the AC line. This article explains how to build an isolation transformer for a fraction of the price of a commercial product. It will even supply more current than most commercial units.

The heart of this project is the transformer. The author obtained the two transformers required from two discarded microwave ovens. Buying a new transformer for this project will not save you much money over buying a commercial isolation transformer because the transformer required can cost more than \$150. For example, B&K Precision sells an isolation transformer for \$189.00. Although electronics distributor Mouser Electronics sells one for \$63.50, it will supply only 2.17 amperes, or about 250 watts. Even this modest price is almost three times what our complete project will cost!

Operation

Figure 1 is the schematic for the isolation transformer. Fuse-protected AC line power is first applied to power switch S1. When S1 is closed, neon power indicator NE1 lights up, and power is applied to a cooling fan and to standby switch S2. This arrangement allows transformer power to be turned off, while permitting the fan to continue cooling the transformer.

Neon standby indicator NE2 is wired across switch S2 so that it lights when S2 is open. When S2 is closed, power is applied to the primary side of 1:1 isolation transformer T1. The secondary side of T1 supplies isolated AC power to receptacle SO1. Neon indicator NE3 lights when power is applied to the receptacle SO1.

The isolation transformer will supply 1000 watts for short pe-

riods of time, and 500 watts or less continuously. However, it will run too hot if 500 watts is exceeded for more than about half an hour.

The transformer for this project was made from the windings of two microwave-oven transformers. Microwave ovens have heavy-duty transformers (see Fig. 2) that consist of three windings: a 120-volt AC input coil, a 2000- to 3000-volt AC output coil, and a 3- to 5-volt AC coil that serves as the filament winding for the oven's magnetron. The magnetron is the vacuum tube that produces the microwave energy for the oven.

The filament winding is easily identified; it consists of three to five single turns of 12- or 13-gauge enamel-covered wire. This winding is usually wound directly over the 120-volt AC winding which is wound from

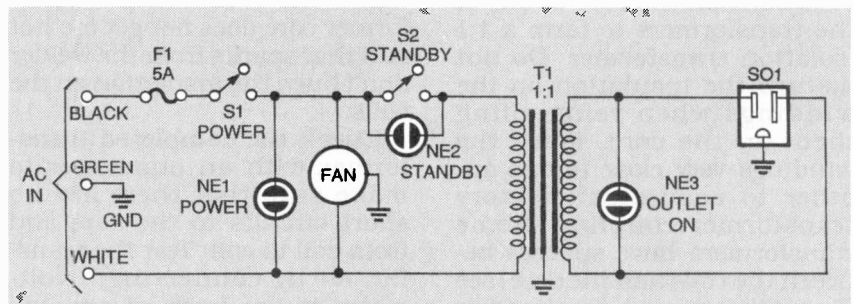


FIG. 1—ISOLATION TRANSFORMER SCHEMATIC. Switch S2 allows power to the transformer to be turned off while the fan continues to cool the transformer.

approximately the same size wire as the filament, but it has more turns. The high-voltage winding, which will be discarded for this project, consists of many turns of much smaller gauge wire.

The microwave oven's fan or blower that cools the magnetron is also needed for this project. The transformer will run warm under load, and the oven fan is an economical way to keep it cool. None of the other parts (see the Parts List), while commonly available, will be found in a microwave oven.

Modifying the transformer

Locate two surplus or discarded microwave ovens that are identical, or as similar as possible. As stated earlier, the transformers from two ovens are needed to build the isolation transformer. These transformers usually remain in good working condition. As an alternative, two surplus transformers might be easier for you to obtain than two scrap microwave ovens.

The pencil in Fig. 2 points to one of the welds that must be removed from the microwave-oven transformer. With a hand-held grinder, very carefully grind away the welds on both sides of the transformer and separate the top core from the base. Figure 3 shows a transformer that has been disassembled. Remove the windings from the core, being careful not to disturb the insulation on the windings. Discard the high-voltage windings.

The 120-volt AC input coils from the two transformers will be used to make the isolation transformer. Place both 120-volt coils back on the core of one of the transformers to form a 1:1 isolation transformer. Do not disturb the insulation on the windings when reinstalling them on the core. Place the windings very close to one another to ensure satisfactory transformer coupling. Some transformers have spacers between the coils and the core (see Fig. 4) that must be replaced in the correct locations.

Once the windings are cor-

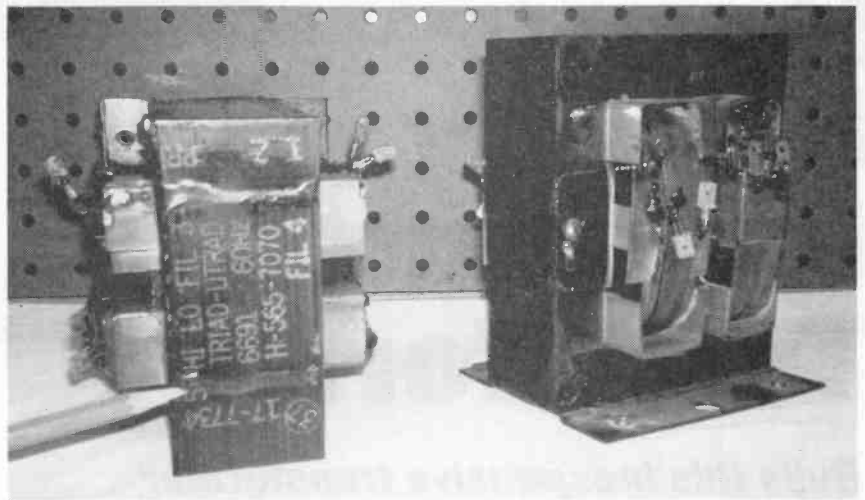


FIG. 2—THE TRANSFORMER for this project was made from two discarded microwave-oven transformers.

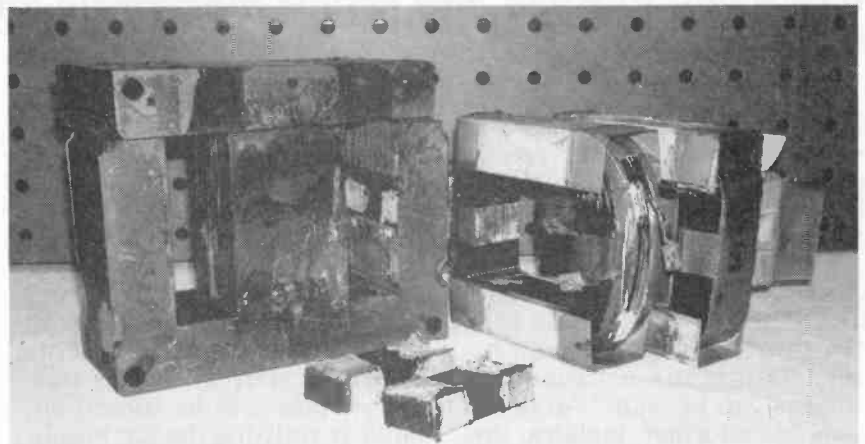


FIG. 3—DISASSEMBLED TRANSFORMER. Remove the windings from the transformer core, being careful not to disturb the insulation on the windings. Discard the high-voltage windings.

rectly positioned back on the core, reinstall the base of the transformer. To do this, weld the base back onto the transformer. If you have access to an electric welder and know how to use it, do this yourself. Otherwise, take the transformer to a welding shop and let a skilled welder do the job for you. Regardless of who does the welding, make sure that the transformer core does not get too hot and that sparks from the welder don't burn the insulation on the coils.

Check the completed transformer with an ohmmeter to make sure that there are no short circuits to the core and from coil to coil. Test the transformer by connecting a voltmeter to the leads of one coil designated as the output coil. Connect the leads from the

other coil to an AC line cord through a 5-ampere fuse. Insulate all exposed connections.

Power up the transformer just long enough to get a reading on the voltmeter. Record the output reading, disconnect the AC power, and reverse the input and output coil connections. Repeat the procedure and check the output voltage again. Determine which output coil voltage measures closest to 120-volts AC; it will be the output side. The prototype transformer had a lower voltage reading in one direction than in the other.

Construction

This project requires a sturdy metal case that measures approximately 14- × 7- × 9-inches to hold both the fan and the transformer, and still have room for all connections.

This project consists of only a few parts, so point-to-point wiring can be used throughout. Figure 5 shows the inside of the prototype unit. Test fit the fan and the transformer before drilling any holes in the case. The fan should be mounted so that its air stream is directed at the transformer. Once the correct positions are determined for the

fan and transformer, mark the locations and drill the mounting holes, but don't mount anything yet.

If you purchase the case specified in the Parts List, you will find that many of the necessary holes are already punched out. Otherwise, prepare the enclosure by drilling a hole and mounting the line cord to the

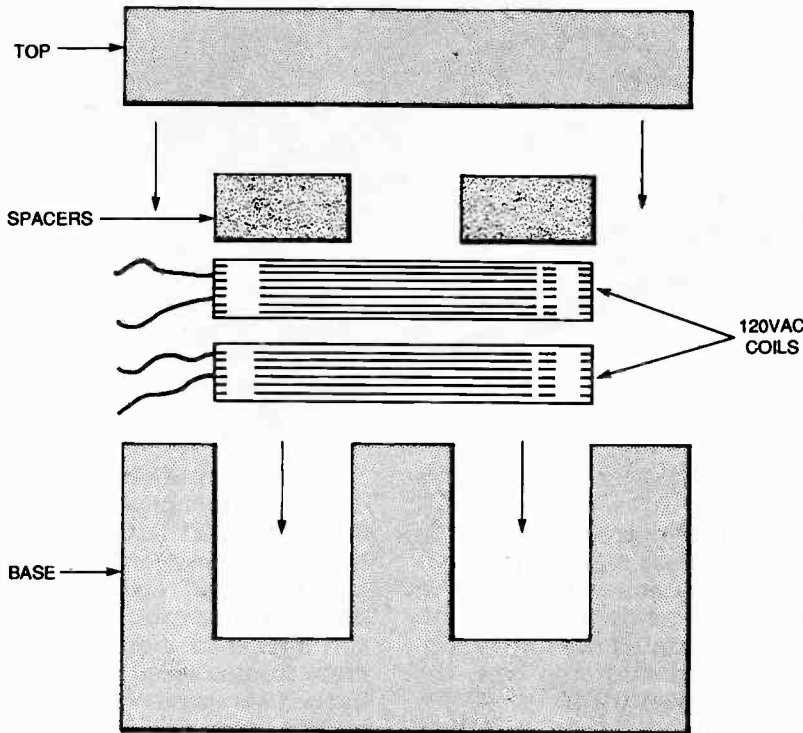


FIG. 4—SOME TRANSFORMERS have spacers between their coils and the core.

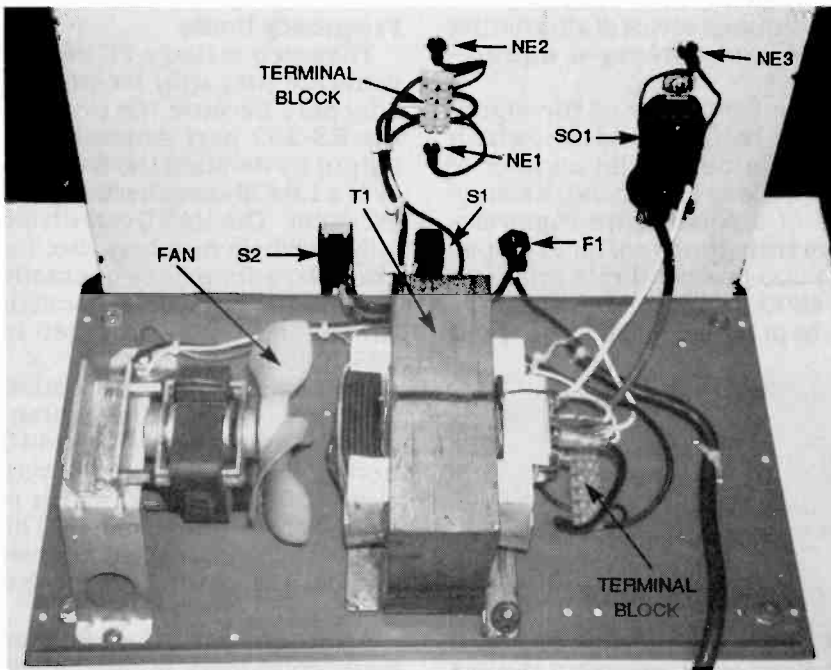


FIG. 5—POINT-TO-POINT WIRING is used throughout this project.

PARTS LIST

- T1—Modified microwave oven transformer (see text)
- F1—5-ampere fuse and panel-mount fuse holder
- S1, S2—SPST 15-ampere toggle switch
- NE1—NE3—120-volt AC neon indicator lamp
- SO1—Standard duplex AC receptacle
- Metal case (Mendleson Electronics, 1-800-344-4465, Part No. 160-1782F or other suitable enclosure), grounded AC line cord, cooling fan from old microwave oven (see text), 14- to 16-gauge wire, terminal blocks, solderless connectors, wire ties, hardware

back of the enclosure. Prepare the front of the enclosure by drilling holes to mount the neon indicators, NE1, NE2, and NE3. Then drill holes for switches S1 and S2. The prototype unit has two large holes punched in each end to allow the fan to draw in cool air and exhaust hot air. Place a screen over those holes to prevent debris from being drawn inside the unit. Prepare an opening for the duplex receptacle on the front panel with a nibbling tool.

Once all the metal working on the enclosure is complete, it can be painted. Next label the enclosure; the labels can be protected with clear spray enamel.

When the enclosure is completely dry, the transformer and fan can be mounted. Start with the transformer, mounting it to the base of the enclosure with rubber washers to reduce vibration. Mount the fan in the direction so that the cooling air flow will be blowing over the transformer. Next install the fuse holder, the line cord, the three neon indicators, switches S1 and S2, and the duplex receptacle SO1.

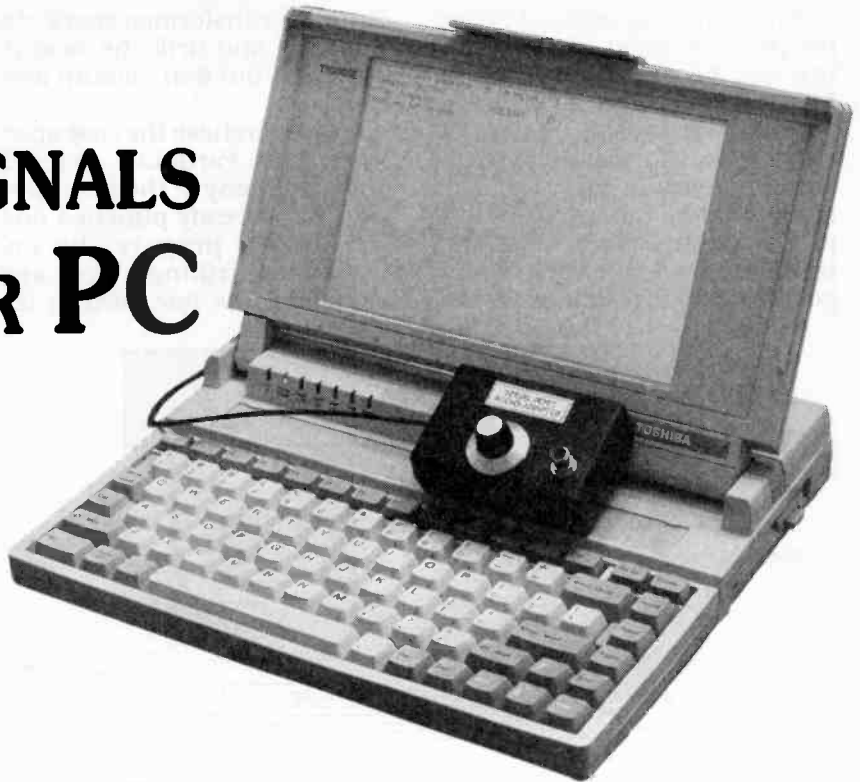
The isolation transformer can produce several amperes of current, so use 14- to 16-gauge wire for all connections to and from the transformer. However, smaller gauge wire can be used for connecting the fan and neon indicators.

Refer to the schematic diagram (Continued on page 110)

PRECISION AUDIO SIGNALS FROM YOUR PC

**Build this
computer-controlled
audio generator—
for under ten bucks.**

MICHAEL A. COVINGTON



DO YOU NEED A PRECISION SQUARE-wave generator for audio testing? If so, look no further than your computer's serial port, a handful of passive components, and a very simple 30-line BASIC program.

That combination can deliver signals with frequencies as high as 4800 hertz, and with crystal-controlled accuracy of 0.1% or better. The software was developed on an IBM-compatible PC, but it should run on just about any computer.

How it works

The trick is U, the ASCII character "U," that is. The hexadecimal value of "U" is 55, which in binary is 01010101 (with eight data bits and no parity, or seven data bits and even parity).

The RS-232 protocol specifies that the bits of an ASCII character are transmitted from least to most significant, preceded by a start bit (always 0) and followed by a stop bit (always 1). So, after adding the requisite start and stop bits, the result is 1010101010.

Now suppose a string of U's is generated at the serial port at some steady rate. The result is a continuous series of alternating ones and zeroes—a square-wave.

The frequency of the signal will be half the baud rate, which by definition is the number of transitions per second. Each cycle of a squarewave comprises two transitions so, for example, a 9600-bps baud rate produces a 4800-hertz squarewave.

In practical terms, just about

any computer should be able to deliver frequencies of 55, 150, 300, 600, 1200, 2400, and 4800 hertz, corresponding to the standard baud rates from 110 to 9600. In addition, the signal can appear at many other discrete frequencies, limited only by the CPU speed of the computer. But there is a catch to this scheme.

Frequency limits

The catch is that a PC cannot generate just any frequency. Why not? Because the UART in the RS-232 port generates its output by dividing the frequency of a 1.8432-megahertz crystal oscillator. The UART can divide only by whole numbers. So, for example, a frequency of exactly 1000 hertz can't be generated; the nearest you can get is 993.1035 hertz.

If you want to tune a guitar, you can't quite produce a standard concert-pitch "A" (440 hertz), but you can get a very close 439.6947 hertz, which is off by only $\frac{1}{80}$ of a semitone. The software will display the nearest standard value to any requested frequency.

Another limitation is that some computers might not be able to deliver high frequencies,

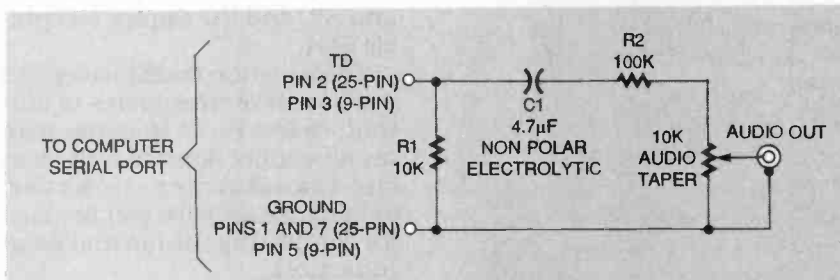


FIG. 1—COMPLETE CIRCUIT of the precision audio generator requires just a handful of passive components.

because they can't output U's fast enough. In that case, squarewave bursts, with silence in between, is generated. If you could hear that, it might sound like buzzing, flapping, or clicking superimposed on the high-pitched tone. The best way to detect this kind of problem is with an oscilloscope or frequency counter.

Even if the computer is fast, there can be breaks in the squarewave. That can happen if the computer is doing task-switching (e.g., under Windows), or if it is heavily loaded with terminate and stay resident programs (TSRs). But under DOS, the author had good results up to 4800 hertz with an old Toshiba laptop.

Hardware and software

There's not much to the circuit, which is shown in Fig. 1. The output of a serial port is nominally 24 volts peak-to-peak, which is much too high a voltage to feed to the input of an audio amplifier. The circuit attenuates the signal to a more useful level, a variable 2-volts peak-to-peak. The circuit also protects the computer from static electricity and voltage surges. Capacitor C1, a non-polarized unit, blocks DC because the serial port, when idling, outputs approximately -12 volts.

The attenuator consists of only four components, so it does not need a PC board. The circuit was built in a small plastic case by mounting the resistors and capacitors directly to the potentiometer and output jack, as shown in Fig. 2. Figure 3 shows the assembled unit.

PARTS LIST

- R1—10,000 ohms, 1/8-watt
- R2—100,000 ohms, 1/8-watt
- R3—10,000 ohms, audio-taper potentiometer
- C1—4.7 μ F, 50-volts, non-polarized electrolytic capacitor (Radio Shack 272-998 or equivalent)
- Enclosure, cables, and connectors to suit your equipment and needs.

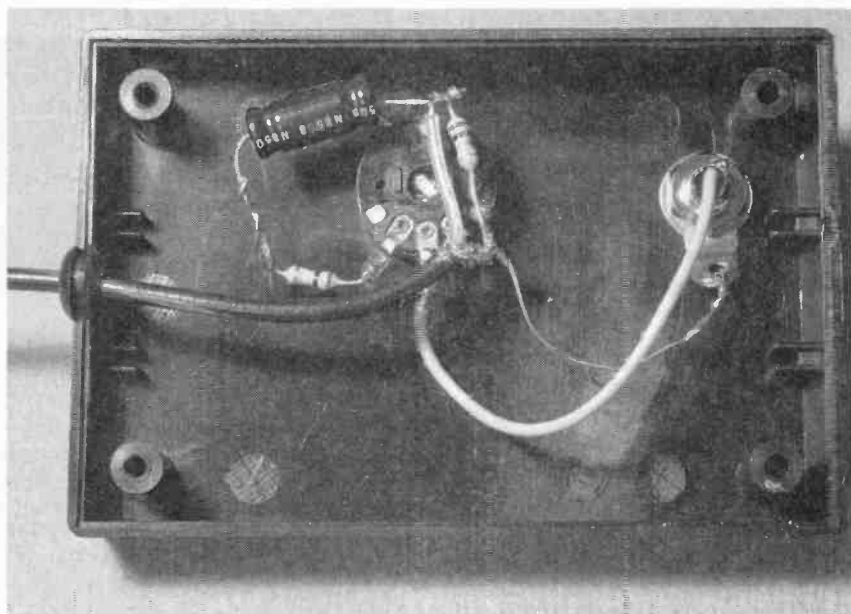


FIG. 2—MOUNT ALL COMPONENTS directly on the potentiometer, as shown here. This eliminates the need for any kind of circuit board.

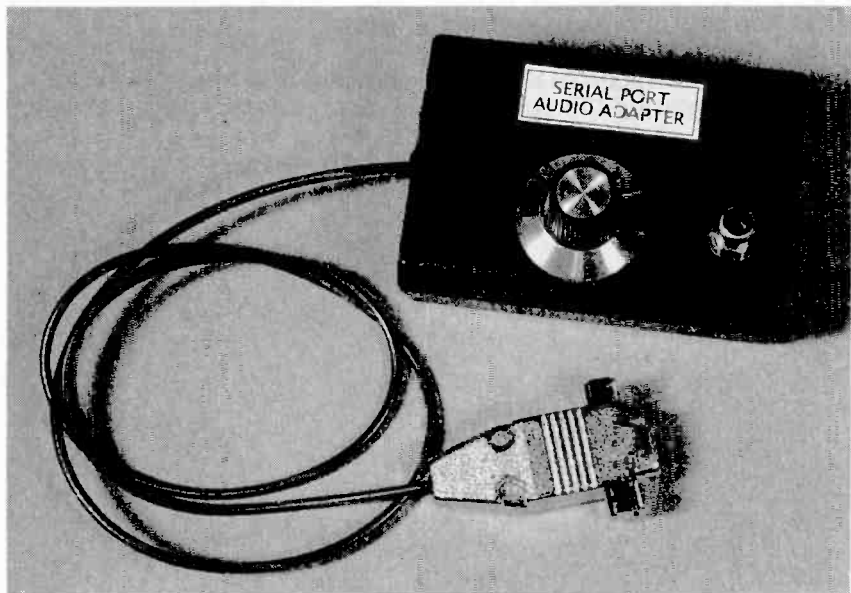


FIG. 3—THE ASSEMBLED UNIT is compact and attractive. An even smaller case than the one shown here could also be used.

If you want the circuit to deliver signals for testing, just run an appropriate cable from J1 to your equipment. For audio output, say for tuning musical instruments or playing audible tones, the circuit can drive a speaker directly, as shown in Fig. 4.

A word of caution before discussing applications: RS-232 ports are supposed to be tolerant of static charges, short circuits, and extraneous voltages, but be aware that some ports are not. Use extra care if your

port is part of a multifunction card that also includes a disk controller.

Many of these cards include both the serial port and the disk controller in a single, fragile VLSI device. If part of the circuit fails, you're likely to lose the whole thing—including access to your disk drives. Generally speaking, when experimenting with accessories connected to a serial port, it's safer to use a card with discrete RS-232 transmitter and receiver ICs.

As for the software, Listing 1

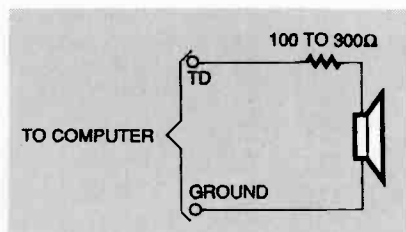


FIG. 4—TO DRIVE A SPEAKER from the generator, use this circuit.

shows the complete program. After setting up several constants, the program requests an output frequency, displays the nearest attainable value, and then starts pumping U's from the serial port. That continues until the user presses a key and then it stops.

The constants defined in lines 120 and 130 specify values for the PC's standard COM1 serial port. To use a different port, make the appropriate modifications. Also note line 190, which specifies the dividend in the frequency calculation. To run the

program on another computer, that value might have to be adjusted.

Putting it to use

A precision squarewave gen-

erator has many applications. For example, you can use it to test the frequency response of an amplifier, as shown in Fig. 5. The input signal to the amplifier appears in Fig. 5-a; note the signal's sharp corners and flat tops. If the amplifier circuit has poor bass response, the tops of the waveform won't be flat (Fig. 5-b); if the treble is weak, the corners of the waveform won't be square (Fig. 5-c).

In general, a clean looking squarewave at the output of an amplifier indicates a good frequency response over a 100-to-1 range. For example, an amplifier that cleanly reproduces a 1-kilohertz squarewave should provide good performance from 100 hertz to 10 kilohertz. Be aware, however, that a squarewave test won't detect clipping in the amplifier.

I have already mentioned tuning musical instruments. Another application is testing wow and flutter in tape recorders. Generate a constant frequency and record it; then play it back while comparing it to the same frequency coming directly from the computer. You can do the comparison by ear, but it's better to use an oscilloscope, with one squarewave going to the external sync input and the other to the vertical input. Then look closely to see how much the waveform jiggles from side to side.

LISTING 1—BASIC PROGRAM

```

100 PRINT "PC Square Wave Generator - M. Covington 1994"
110 INPUT "Frequency (Hz)? ", FREQ
120 ADDR% = &H3F8 ' 2F8 for COM2
130 PARM$ = "COM1:4800,N,8,1,cs0,ds0" ' or "COM2..." etc.
140 '
150 ' Open the serial port
160 OPEN PARM$ FOR OUTPUT AS #1
170 '
180 ' Choose customized baud rate
190 DIVIDEND = 115200 ' 111850 on PCjr
200 DIVISOR% = INT(.5 + DIVIDEND / (FREQ * 2))
210 FREQ = DIVIDEND / (DIVISOR% * 2)
220 PRINT "Actual frequency: "; FREQ; " Hz"
230 '
240 ' Set serial port to new baud rate
250 WAIT ADDR% + 5, &H20
260 OUT ADDR% + 3, INP(ADDR% + 3) OR &H80
270 OUT ADDR%, DIVISOR% MOD 256
280 OUT ADDR% + 1, DIVISOR% / 256
290 OUT ADDR% + 3, INP(ADDR% + 3) AND &H7F
300 '
310 ' Transmit square wave until told to stop
320 PRINT "Press any key to stop."
330 WHILE INKEY$ <> "": WEND ' clear kbd buffer
340 WHILE INKEY$ = ""
350 PRINT #1, "UUUU";
360 WEND
370 PRINT "Emptying buffer..."
380 CLOSE #1
390 PRINT "All done."
400 END

```

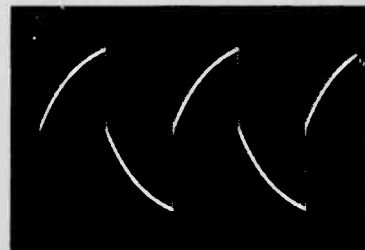
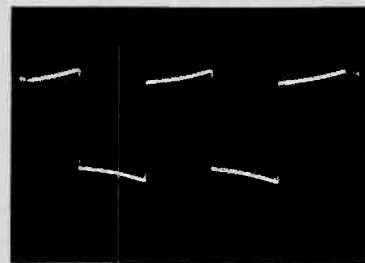
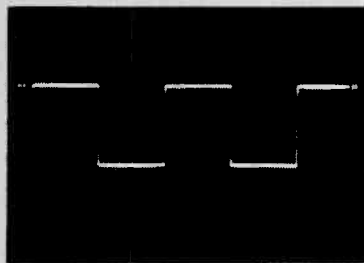


FIG. 5—TEST FREQUENCY RESPONSE as shown here. The input signal (a) is completely clean. Poor bass response affects the tops (b); poor treble response affects the corners (c).

THE PROJECT ANTHOLOGY

*A collection of eighteen projects that will add
spice to your project building pleasure!*

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5	LIGHT ALARM	14	HELIX
6	SIG-TRACER	15	INVERTED V ANTENNA
7	CW FILTER	16	AUDIBLE TIMER
8	VOL-EXPANDER	17	LONG INTERVAL TIMER
9	COMPUTER VOICE	18	TWANGY DISTORTION UNIT

INTRODUCTION

Building projects is fun! Exactly where the most fun is can be debated. Is it in the actual assembly of the gadget? What about designing added features or molding it to particular needs? How about watching friends and family “pop eyes” as you exhibit its operation? Who knows? Never examine a pleasure, just enjoy it! With that admonition, inspect the plans of the seventeen projects presented in this Project Anthology while you heat up your soldering iron.

The experience level required of the project builder is minimal. Of course you require some level of project building experience but every effort has been made to keep the level of difficulty down. In some projects the illustrations go beyond the schematic diagram to include mechanical layout information. Although your electronic theory understanding may be scant, you will require higher levels should you indulge in designing additional functions and features into the projects presented herein. Here are general notes about the parts used in projects.

Resistors. Fixed-valued resistors are rated at either 1/4-watt or 1/2-watt, within 5 percent of their designated value. One-half watt is the preferred rating for resistors because of their physical size and ease of handling on circuit boards. Hobbyists with construction experience should select the wattage size that they deem suitable for the project. Resistors that are specified with wattage ratings may be substituted for other resistors of higher wattage rating. For example: you could replace a 1-watt resistor with a 3-watt resistor provided that the replacement is not of wire-wound construction. Wire-wound resistors have a measure of inductance in them and they may upset the operation of the circuit, especially high-frequency audio and radio circuits. The physical size of the resistor increases significantly with its power rating so common sense directs that you do not use outlandish substitutions. Only composition resistors are used in the following projects. Do not substitute different ohmic values unless the text discusses the possibility, or you are thoroughly qualified to make ohmic value changes by adequate academic knowledge and/or experience.

Capacitors. The voltage ratings of capacitors in the projects should be equal to or above that specified in the Parts List. Electrolytic capacitors should be reasonably close to the specified value in microFarads. The working-voltage-DC (WVDC) rating must never be less than specified, and as a rule never more than twice the specified rating. Two capacitors connected in parallel add their values. Two capacitors, say .10- μ F and .25- μ F in rating, when connected in parallel will be equal to a single capacitor rated at .35 μ F. When paralleling capacitors to obtain useable values, be sure that the WVDC ratings of both capacitors are at least equal to the specified value.

Semiconductors. Solid-state parts such as transistors, integrated circuit chips, diodes, LEDs, etc., cause the most problems for new project builders. It is recommended that they obtain catalogs from retail and mail-order outlets. Radio Shack is an excellent retail source—there's one in every town in North America that has more than two traffic lights, or so it seems. There are a host of parts advertisers who offer free 800 telephone numbers so you can do your shopping at home. Some readers resort to substitution listings for what appears to be hard-to-get parts. This could be risky for beginners because pin connections vary with so-called identical units. If you are calling an 800 telephone number parts outlet, insist upon the exact part. There are enough 800 electronic parts suppliers in North America to call and get the parts you want.

Light-emitting diodes (LEDs) usually have their cathodes identified by the shorter lead which is closest to the flat edge of the circular rim at the base of the part. There are variances, and for bi-color LEDs, this is true for one of the colors only. If you have any doubts, do not hard solder the LED into the circuit at first. Run a power-on test and if the LED does not light, or the wrong color comes up, reverse the leads and try again. The LED should light or the correct color appear. Now you can solder the LED into the circuit. Solderless circuit boards can be used for testing mockups.

Not every construction or parts problem can be forecasted, however, experience is a great teacher and you will learn much by jumping into the construction of a simple project. Experience grows with practice. The fantasies of the Project Anthology are now all yours to enjoy. Have fun!

THE PROJECTS

1 Twinkle Tree

Twinkle Tree is an easy project for beginners to build, and its basic circuit has a number of useful applications. The circuit's visible action appears as a string of ten LEDs (light-emitting diodes) flashing on one at a time in sequence, this being repeated so long as the circuit is powered.

be incorporated in other decorations or models. The LED light display provides an interesting and novel twinkling effect.

The same circuit can be used with the LEDs placed round a small display, so that they flash on in turn with a revolving or racing effect.

How It Works. Figure 1 is the schematic diagram of the circuit for Twinkle Tree which includes a small power supply for operation from AC lines. If the circuit is to be powered from an existing supply, or batteries, omit circuit components ZD1, D1, R6, C4 and T1. The external power supply negative line goes to the "E" line in Fig. 1, and the positive line to the junction of resistors R1 through R5. The voltage supplied should be approximately 5-volts DC. You may want to connect an AC wall-plug power pack rated at 5-volts DC as the power source. Do not use 6-volt DC from dry cells or else the ICs

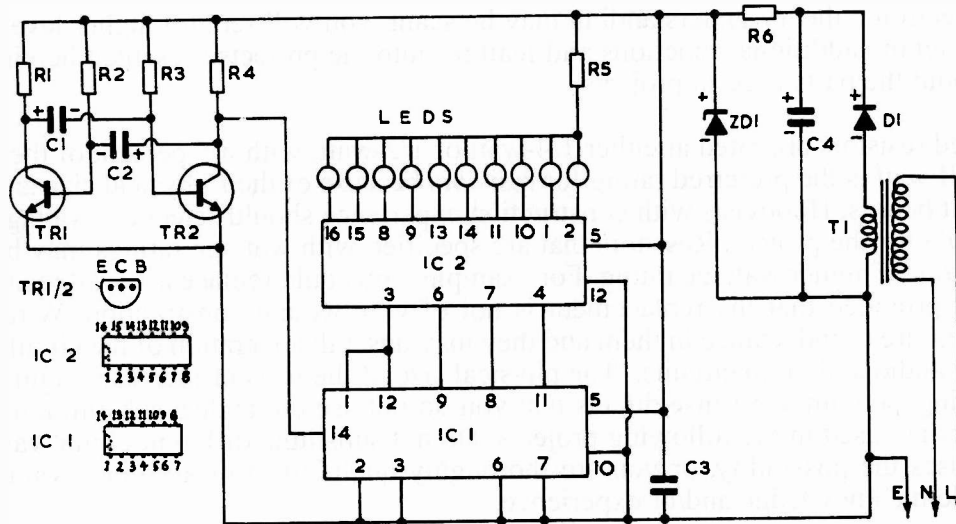


Fig. 1— Circuit diagram for the Twinkle Tree project.

The LEDs can be used on a small table decoration, in the form of a Christmas tree (we call it Twinkle Tree), or around a picture frame; or they may be placed at various points on a hanging decoration, such as a bunch of mistletoe, or can

will be damaged. 4.5-volt DC from three 1.5-volt dry cells may be used, however the LEDs will appear to be a bit dimmer.

The multivibrator circuit consists of transistors Tr1 and Tr2 which produces pulses that form

PARTS LIST FOR TWINKLE TREE

Semiconductors

D1—1N4001 rectifier
 IC1—7490, decade counter (divide by 2 and 5)
 IC2—7441, 1BCD-to-decimal decoder
 LED1-LED10—Light-emitting diode, color optional
 Tr1, Tr2—2N3706, PNP
 ZD1—5.1-volt, 400- μ A Zener diode

Resistors

R1—2,200-ohm
 R2, R3—33,000-ohm
 R4—1,000-ohm
 R5—220-ohm
 R6—33-ohm, 1/2-watt

Capacitors

C1, C2—2- μ F, 6-WVDC, electrolytic
 C3—47-nF or .05- μ F, metallized polyester
 C4—1,000- μ F, 12-WVDC, electrolytic

Miscellaneous

T1—Filament transformer: 117-volt AC primary winding, 6.3-volt AC secondary winding (obtain smallest, lowest power unit available)
 On/Off switch optional, 14-pin and 16-pin IC sockets, perf-board, wire, battery clip (optional), solder.

the input to the binary-coded, decimal-decade counter IC1, at pin 14. This IC counts the pulses and provides a binary output at 1-12, 9, 8 and 11 pins. Pin 5 is its positive line, and 10 is its negative line.

With counters having two or more numerals, as shown later, the IC can pass on a pulse to the "tens" section. Here, it is used alone and repeats the same series of outputs over and over so long as the multivibrator pulses are applied to pin 14.

Chip IC2 is a decoder-driver. Its purpose is to receive the various inputs at 3, 6, 7 and 4, and decode them into outputs at 16, 15, 8, 9 and so on, along to 1 and 2. Thus each of these ten points provides a circuit to the appropriate LED in turn. The outputs connected to LEDs are located at the top of IC2 when Fig. 1 is held right-reading.

All the LEDs are returned through the common limiting resistor R5, to operate from the same 5-volt DC line. The effect is, that each LED is illuminated in turn, along the line, and when the last is reached, this is followed by the first, and the sequence is repeated. Check the LED polarity, and mark this with red sleeving material, or other means, if the LEDs have no means of identification (long lead or flat side).

For the Twinkle Tree the ten LEDs are scattered at random, and any LED could be connected to any of the outputs 16 to 2.

Only one LED is on at a time, so current drain is only some 50 mA or so, and this small current load makes battery operation feasible and long lasting.

Transformer T1 (6.3-volt AC secondary) provides about 9-volt peak across C4, and R6 drops

this for the 5.1-volt DC Zener diode ZD1. A meter placed across this diode should read about this voltage.

AC line current is drawn from a 3-pin power-plug line cord with a 2A built-in fuse. The green lead ground circuit in the power cord provides safe grounding of the secondary and low-voltage circuit. A double-insulated transformer specified as requiring no grounding may be operated without grounding through the AC power cord's green lead. Nevertheless, always play safe by using a ground circuit whenever using the AC line. Naturally construction and wiring must assure that no AC voltages can reach the transformed secondary output or the low-voltage circuit.

Construction. This is where the fun in electronics begins. Design your own Twinkle Tree. Maybe you would want to add a few fixed (always-on) LEDs or build two circuit boards and have twice as many twinkling lights. It's up to you!

2 One-Second Flasher

When making a long exposure using a camera with the shutter set to "B" or "T", some sort of timer is needed in order to obtain accurate results. Unless very long exposures are required, a simple one-second indicator such as the One-Second Flasher is probably the ideal solution. The unit pulses on a LED (light-emitting diode) indicator at one second intervals. The shutter is opened as the LED flashes, and then closed after the appropriate number of flashes have been counted off. There are almost certainly a great many other uses for a simple timer of this type, and it could be used as a simple enlarger timer for example.

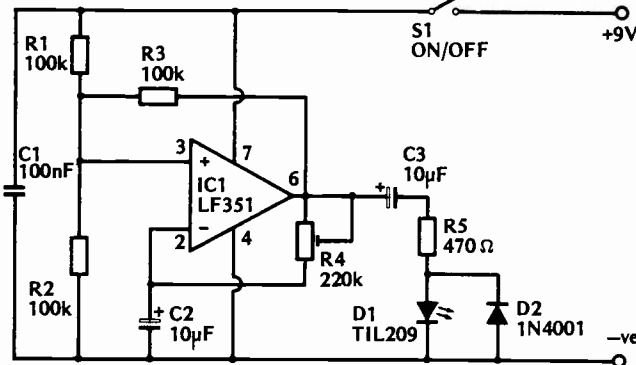


Fig. 2—Circuit diagram for the One-Second Flasher.

How It Works. The circuit diagram for the One-Second Flasher appears in Fig. 2, and is based on an operational amplifier that is biased by R1, R2 and R3 to act as a form of Schmitt trig-

PARTS LIST FOR ONE-SECOND FLASHER

- Semiconductors**
 D1—Light-emitting diode, red
 D2—1N4001 rectifier
 IC1—LF351 operational amplifier
- Resistors**
 R1-R3—100,000-ohm
 R4—220,000-ohm trimmer
 R5—470-ohm
- Capacitors**
 C1—100-nF, metallized polyester
 C2-C3—10- μ F, electrolytic
- Additional Parts & Materials**
 S1—S.p.s.t. slide switch
 Plastic cassette holder, 9-volt transistor-radio battery, wire, perfboard, solder, etc.

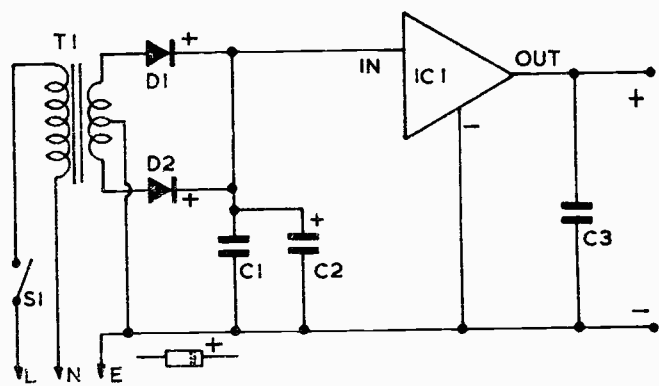


Fig. 3— Circuit diagram for the 5-Volt Power Supply.

needing up to 500 mA. By constructing the 5-Volt Power Supply as a separate unit, any circuit to be operated can be plugged in, and this allows it to provide power for various projects. It may also be used where a 5-volt DC, 500 mA supply is suitable, so it can in some cases be pressed into service where a 4.5-volt or 6-volt battery would otherwise be fitted.

The Circuit. Figure 3 shows the schematic diagram for the circuit. Transformer T1 provides isolation from the AC power line, and has a 9-0-9-volt, 500-mA secondary winding. After rectification, the DC input voltage for IC1 is something over 9-volts. A filament transformer rated at 12-0-12-volts AC may be substituted.

Diode rectifiers D1 and D2 are rated at 50 volts at 1 A: These diodes are readily available. Capacitor C1 helps suppress transients arising from the AC line, and C2 is the main smoothing

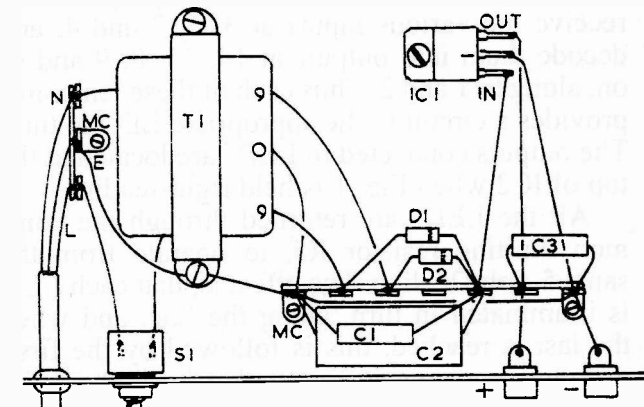


Fig. 4— Parts layout for the 5-Volt Power Supply. Observe markings on the diodes (D1 and D2) when soldering to the terminal strip

(filtering) capacitor. Here, a value of 1500- μ F to 3500- μ F may be used. Higher capacitances provide better voltage-ripple smoothing.

Chip IC1 is the LM341, a 5-volt, 500-mA positive regulator. Actual maximum current depends to some extent on other factors. Here, heat sinking is to a small metal chassis.

Figure 4 shows layout inside a small metal-

ger. The output goes to the low state if the inverting input is taken about $2/3V+$, and high if it is taken below $1/3V+$. The output therefore goes high initially, but C2 soon charges to $2/3V+$ via R4, and then the output goes low. Capacitor C2 then discharges to $1/3V+$ via R4, sending the output high again, and producing continuous oscillation.

Resistor R4 is adjusted to give an operating frequency of one Hertz. The One-Second Flasher can be calibrated against a watch or clock with a seconds hand by empirical means. The output of IC1 is coupled to the LED indicator, D1, by way of DC blocking capacitor C3 and current limiting resistor R5, and the LED is briefly pulsed on as the output voltage swings positive. Diode D2 ensures that there is both a charge and discharge path for C3 so that the output signal is properly coupled to D1.

The current consumption of the unit is about 2 mA.

As You Like It. Assembly and packaging of the unit is left to the builder. The circuit can be housed in a plastic cassette holder. The LED need not protrude because the case is clear. The circuit uses very little current so that a 9-volt transistor-radio battery can be used. The battery can be disconnected by unsnapping the clip connector or adding a single-pole, single-throw slide switch.

3 5-Volt Power Supply

The series of 7400 TTL integrated circuits are intended to operate from a 5-volt DC supply as are many other modern chips, and integrated circuit voltage regulators for this purpose are available.

The 5-Volt Power Supply shown here will provide voltage-regulated power for digital ICs

PARTS LIST FOR 5-VOLT POWER SUPPLY

Semiconductors

IC1—LM341 voltage regulator chip

D1, D2—1N4001 rectifier

Capacitors

C1—0.1- μ F, 50-WVDC, electrolytic

C2—3500- μ F, 16-WVDC, electrolytic

C3—0.1- μ F, 50-WVDC, polyester

Additional Parts & Materials

S1—S.p.s.t., toggle switch

T1—120-volt/9-0-9-volt, 500-mA power transformer

Aluminum chassis box, 3-conductor power cord with molded plug and built-in fuse holder, 2 A fuse, 1 terminal strip with a minimum of 4 insulated ties and 2 grounded ties, 1 terminal strip with a minimum of 2 insulated ties and 1 grounded tie, wire, solder, 2 output connectors, red and black (binding posts preferred), etc.

box chassis. This can be a 4 X 6-in. chassis with enough height to clear the top of the transformer, T1. Follow the layout in the diagram when assembling the project to avoid errors.

Safety. The AC line power cord has three leads, green for ground or earth (E), white for neutral (N), and black for live (L) conductors. A thin power cord (#18 gauge) is adequate. Use a 3-pin fused plug, and place a low-rating fuse of 2A or 3A in this.

The cord passes through a rubber grommet, and its conductors are anchored on the 3-way terminal strip. Note that the switch S1 is placed in the live conductor (L) lead. The earth (E) lead (usually green in color) is connected to the chassis. This is also connected to the transformer core, and to the output negative line. If this lead is omitted and the negative return provided by the chassis is to be relied upon, be sure the attaching screws are very tight, and will not become loose.

The grounding is for safety. If a short circuit should arise in T1 or elsewhere, which could carry AC line voltages to the chassis and low-voltage output circuit, the low-rating fuse in the plug will blow.

The unit needs to be enclosed in an aluminum chassis box or case, so that no hot AC leads can be touched.

Safety, with this unit and similar AC line-operated power supplies, depends upon sound

construction, correct wiring, fusing and grounding, and shielding of high-voltage points against accidental contact by the user. No high voltage must ever be able to arise on the low-voltage output sockets, or low-voltage wiring as equipment connected to the unit will no longer be safe to touch.

Testing. A DC voltmeter should show approximately 5-volts at the output terminals. Due to tolerances in IC1, and lack of exact accuracy of the meter, the reading might be very slightly above or below 5-volts.

To check for regulation, connect a load taking up to about 500 mA. A 6.3-volt, 0.3 A or 3-watt light bulb is suitable. The reading at the output sockets should remain virtually unchanged.

4 Sound-Switch

The Sound-Switch circuit of Fig. 5 is suitable for use in a sound-activated tape recorder and similar voice-activated applications. Provided a reasonably sensitive crystal microphone is used, the unit will operate from speech of normal volume at a range of several feet. To go beyond that range will invite the rustling of paper, coughs, heel clicks, crowd and traffic noises, air conditioner noise, and many other room and out-of-door noises that will obviate the need of Sound-Switch. A too sensitive sound activated

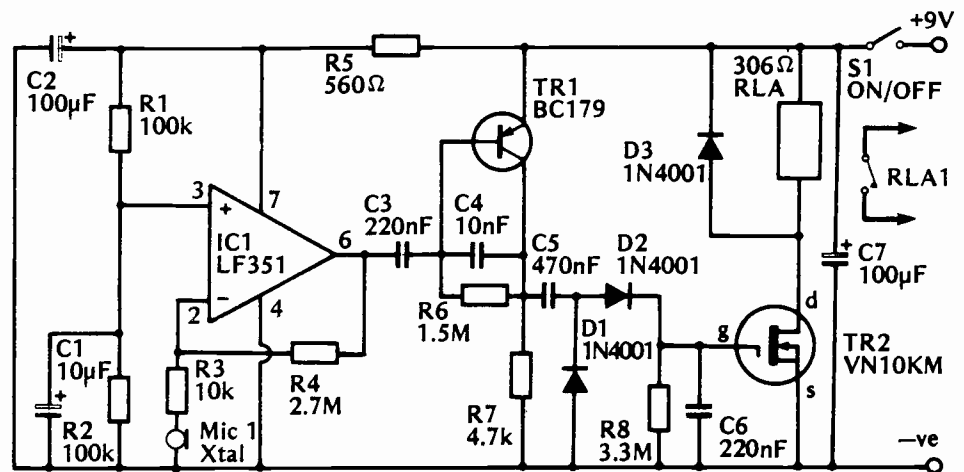


Fig. 5—The circuit diagram for the Sound Switch project.

switch would be on most of the time when placed in a noisy environment and a super sensitive microphone used to increase range would be worthless.

How It Works. The circuit uses IC1 as a low-noise preamplifier having a voltage gain of 270 times, and this is followed by a second stage of

PARTS LIST FOR SOUND-SWITCH

Semiconductors

D1, D2—1N4001 rectifier
 IC1—LF351 operational amplifier
 Tr1—BC179 or 2N3965, silicon PNP transistor
 Tr2—VN10KM

Resistors

R1, R2—100,000-ohm
 R3—10,000-ohm
 R4—2.7-Megohm
 R5—560-ohm
 R6—1.5-Megohm
 R7—4,700-ohm
 R8—3.3-Megohm

Capacitors

C1—10- μ F, electrolytic
 C2, C7—100- μ F, electrolytic
 C3—220-nF, metallized polyester
 C4—10-nF, metallized polyester
 C5—470-nF, metallized polyester
 C6—220-nF, metallized polyester

Additional Parts & Materials

Mic1—Crystal microphone
 RLA—Relay with DC coil resistance of 306-ohms
 Plastic or aluminum case, 9-volt battery (see text), wire, solder, etc.

amplification which gives a similar voltage gain. The second stage uses Tr1 in the common-emitter mode and this is a conventional arrangement except for the inclusion of C4. This capacitor provides a considerable amount of high-frequency attenuation, and this is necessary in order to prevent instability. Capacitor C5 couples the greatly amplified output of Tr1 to a rectifier and smoothing circuit which gives a positive DC output signal which is roughly proportional to the input signal level. If the input signal is sufficiently strong, the bias voltage at the gate of VMOS device Tr2 will be adequate to bias this transistor into conduction, and the relay which forms its drain load is then activated.

A pair of normally open relay contacts are used to control whatever item of equipment is operated by the unit. Of course, the voltage at the gate of Tr2 soon decays as C6 discharges through R8 if the input signal ceases, and the relay is then switched off. The decay time is roughly one second, which is about the optimum time for most applications. The attack time of the circuit is only a fraction of a second, and the unit responds almost immediately when a sound is initially picked up by the microphone.

Using It. You may want to record your voice giving instructions or reports, such as announcing the disassembly of a complicated component. As you speak, imitate the police and military who use such equipment. Begin each sentence with the word, "Kay." For example, "Kay. Removing the pawl from the gimbals." On playback, all

your important words are not clipped and you have an accurate disassembly procedure that can be reversed for assembly purposes.

As the circuit has a fairly high level of gain the component layout must be designed with reasonable care, although the very limited bandwidth of the circuit greatly reduces the risk of instability. The current consumption of the unit is about 3 mA under quiescent conditions, but this increases considerably when the relay is activated. The circuit may be operated from a 9-volt transistor-radio battery, but you may want to use six C cells in series or a wall-plug power pack.

5 LIGHT ALARM

The Light Alarm unit produces a noticeable audio tone when the unit's photocell is subjected to a reasonably high level of light; normal daylight and artificial room lighting are sufficient to operate the circuit. The Light Alarm could be used as a simple burglar deterrent, and it would then be placed in a cabinet or a drawer, and would produce the alarm signal if the cabinet or drawer was opened by a burglar. The sudden noise would hopefully unnerve him or her sufficiently to make them leave the premises immediately. In the case of diet cheaters, the Light Alarm should be refrigerated. It could also be used in a medicine cabinet to sound a warning if a small child should somehow manage to open the cabinet. In this application the on/off switch should be fitted somewhere on the outside of the cabinet

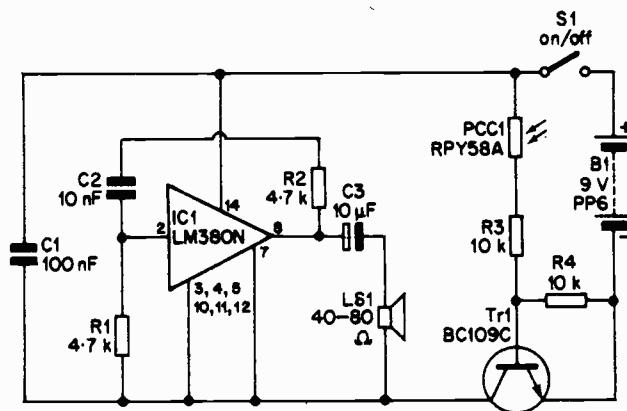


Fig. 6—The circuit diagram of the Light Alarm.

(preferably out of sight on top of the cabinet where a small child would be unable to reach it and probably be unaware of its existence) so that you could switch the alarm off before opening the cabinet, and switch on again after it has been closed.

How It Works. The circuit is activated if Tr1 is switched on by a suitable base current and voltage. Refer to Fig. 6. The voltage and current available at the base of Tr1 is dependent on two main factors, the resistance provided by R4, and the setting of control VR1. If VR1 is set at maximum value, photocell PCC1 needs to have a resistance of about 10,000 ohms to bias Tr1 into conduction and activate the audio alarm circuit of which IC1 is a primary part. Fixed resistor R4 has been used across the base-emitter terminals of the switching transistor so that the sensitivity of the circuit is preset. However, R4 can be raised somewhat in value if increased sensitivity is required. Alternatively, it can be replaced with a 100,000-ohm linear potentiometer if a variable in sensitivity is required from time to time.

The audio-alarm generator uses an LM380N (IC1) in a simple audio-oscillator circuit, and drives high-impedance loudspeaker LS1 via coupling capacitor C3. It is a simple matter to get a non-inverting amplifier having a fairly high gain to oscillate, and it is merely necessary to provide AC coupling from the output to the input. Provided the losses through this coupling are less than the voltage gain provided by the amplifier this will give sufficient positive feedback to sustain oscillation.

The values for R1, R2, and C2 shown in the circuit diagram (Fig. 6) give considerably more feedback than is needed to just sustain oscillations and the circuit oscillates strongly producing a squarewave output at a frequency in the region of 1 kHz (1000 Hz).

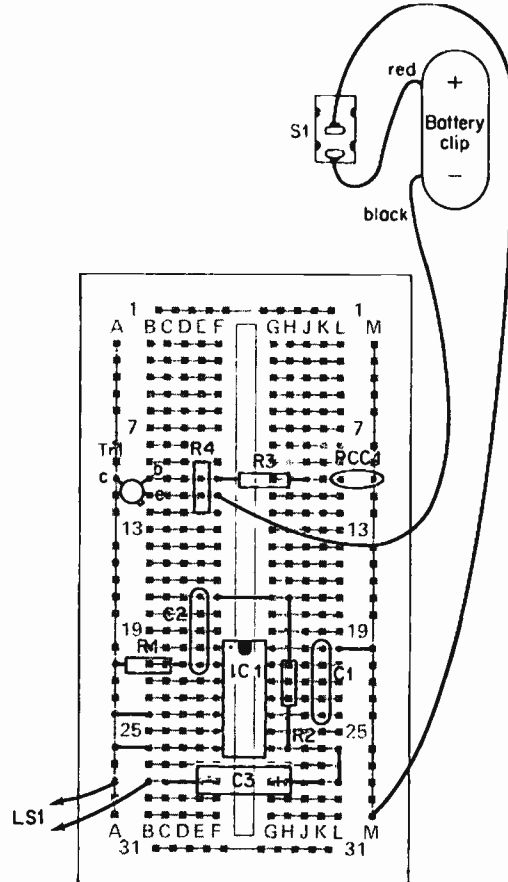


Fig. 7— Construction details of the Light alarm.

Dark Alarm. With a minor circuit change (compare Fig. 6 with Fig. 8) the Dark Alarm circuit is similar to the Light Alarm just described, but it operates an audible alarm if the light intensity received by the photocell falls below a certain threshold level, rather than if it exceeds the threshold level. A possible application for the unit is as a headlights-on reminder for the driver of a car. The circuit will operate properly from a

PARTS LIST FOR LIGHT ALARM

Semiconductors

- IC1—LM380N, audio power amplifier
- PCC1—Photo cell, type RPY58A or common silicon photo cells found in the hobbyist marketplace
- Tr1—BC109C, ECG123A or 2N930, silicon NPN transistor

Resistors

- R1, R2—4,700-ohm
- R3, R4—10,000-ohm

Capacitors

- C1—.1- μ F, metallized polyester
- C2—10-nF, metallized polyester
- C3—10- μ F, 25-WVDC, electrolytic

Additional Parts & Materials

- B1—9-volt transistor-radio battery and connector to match
 - S1—S.p.s.t. miniature toggle
 - LS1—Loudspeaker, miniature, impedance in the range 40 to 80 ohms
- Verobloc or similar solderless breadboard or mating/matching printed-circuit board, solder, wire, etc.

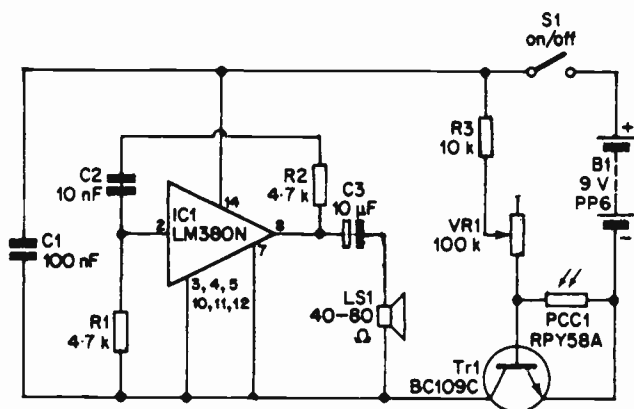


Fig. 8— The circuit diagram of the Dark Alarm.

The breadboard component layout for the Light Alarm is shown in Fig. 7.

Incidentally, it is possible to alter the sound tone produced by the circuit; an increase in the value of R1, R2, or C2 (or more than one of these) produces a reduction in pitch, and vice versa.

12-volt car battery instead of a 9-volt transistor-radio battery provided nose filtering is provided in the battery line.

Control VR1 is used to set the light threshold.

6 SIG-TRACER

The purpose of a Sig-Tracer is much the same as that of a signal injector. However, a signal tracer is, in a way, used in the opposite manner to a signal injector. Instead of injecting a signal at the output of the equipment under investigation and then working towards the input, a signal tracer is used to first verify that an input signal is present, and further tests are then made at strategic points working stage-by-stage towards the output of the equipment. When the signal can no longer be traced (or is obviously at too low a level, seriously distorted, or in some other way incorrect) the approximate area of the fault has been located. Normal voltage testing and similar checks are then used to precisely locate the fault.

A signal tracer for use on audio equipment simply consists of an audio amplifier driving a loudspeaker or an earphone, so that the traced signal, if present and correct, will give the appropriate audio output from the signal tracer. For RF or IF signal tracing the signal tracer must additionally have a suitable demodulator built-in so that an audio signal is produced from the tracer, provided a suitable input signal is present, of course.

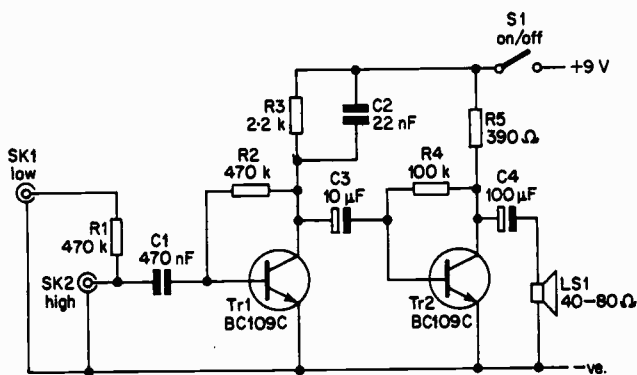


Fig. 9—The circuit diagram for Sig-Tracer.

The Sig-Tracer has good sensitivity so that it can be used for any normal type of audio signal tracing. The circuit provides AM demodulation, and the Sig-Tracer can therefore be used for IF and RF testing on AM radios provided a suitably strong antenna signal is available. The unit has an integral loudspeaker, and although the maximum output power is only a few tens of milliwatts, the volume level obtained is more than adequate for

this application. If preferred though, the loudspeaker could be replaced by an earpiece or headphones. Low, medium and high impedance headphones are all suitable for use with the unit.

The Circuit. The circuit diagram for the Sig-Tracer (see Fig. 9) is basically just two common-emitter amplifiers with capacitive coupling. Transistor Tr1 is the input stage, and has C1 to provide DC blocking at the input, R2 as the bias resistor, and R3 as the collector-load resistor. An input signal from jack SK2 direct to the input of the amplifier (Tr1) may well be sufficient to overload the amplifier in many cases, and a second input having lower sensitivity is therefore provided (SK1), and the necessary attenuation (of nearly 40 dB) is provided by R1 and the input impedance of the amplifier. The input impedance of the amplifier at the high-sensitivity input

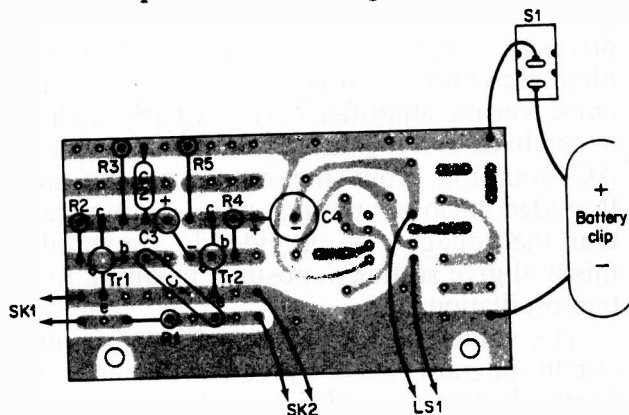


Fig. 10—The components layout for Sig-Tracer.

(SK2) is several thousand ohms, but R1 provides a useful boost in input impedance so that the input impedance at SK1 is approaching 500,000 ohms.

Capacitor C2 is used to roll-off the high-frequency response of the circuit in order to aid stability. It also gives the circuit a simple AM demodulator action by providing RF filtering. The rectification that is also needed in order to produce AM demodulation is provided by transistor Tr1 which, like any amplifier, does not give perfect linearity. It tends to amplify more during positive input half cycles when the collector current increases than it does on negative input half cycles when the collector current decreases. This form of non-linearity is typical of any normal bipolar transistor, and gives the required rectification. There is no need to have any AF/RF switching since the circuit will properly process either type of signal.

The output from the collector of Tr1 is coupled to the input of Tr2 by C3. Tr2 is used as a straightforward common emitter stage, but it is

PARTS LIST FOR SIG-TRACER

Semiconductors

Tr1, Tr2—BC109C, ECG123A or 2N930, silicon NPN transistor

Resistors

R1, R2—470,000-ohm
 R3—2,200-ohm
 R4—100,000-ohm
 R5—390-ohm

Capacitors

C1—.470- μ F, metallized polyester
 C2—.022- μ F, metallized polyester
 C3—10- μ F, 25-WVDC, electrolytic
 C4—100- μ F, 10-WVDC, electrolytic

Additional Parts & Materials

S1—Miniature s.p.s.t., toggle switch
 Aluminum case, printed-circuit board, perf-board or solderless bread board, miniature loudspeaker having an impedance in the range 40 to 80 ohms (LS1), two 3.5-mm jacks (SK1 and SK2) 9-volt transistor-radio battery and battery clip connector, test leads, wire, solder, etc.

7 CW Filter

Although the IF filtering of shortwave receivers has tended to improve somewhat over recent years, few receivers have a very narrow bandwidth available, and this results in more adjacent-channel interference during CW (Morse code) reception than is really necessary. You have heard this interference: voice, music or heterodyne signals (even excessive static) riding over code. A simple way of obtaining improved results with a receiver that does not have a built-in CW filter is to use an add-on audio filter having a narrow bandwidth. If the receiver has a good filter for SSB reception, using an audio filter plus the SSB filter during CW reception should provide excellent results. We have just the unit for you: our CW Filter.

The CW filter is connected between the headphone or loudspeaker socket or terminal strip of your receiver, and either the headphones or an external loudspeaker. The output of the receiver should have an impedance of 8 ohms or more. As the circuit provides unity gain at pass frequencies and a low impedance output, there should be no

run at a fairly high collector current of around 15 mA so that a strong enough output signal to give reasonable volume from a high-impedance loudspeaker can be obtained. C4 couples the output signal to the loudspeaker.

Construction. Before you begin, remember that it is advisable to fit this project into a metal case grounded to the negative terminal of the power supply so that the circuit is screened from stray electrical signals. A suggested component layout on a printed-circuit board for the project is shown in Fig. 10. The project is simple enough to do without a printed-circuit board and may be assembled on a perf-board or some conventional pre-etched, general purpose, circuit board. As the input and output of the unit are in-phase, keep the speaker leads reasonably well separated from the input leads in order to minimize stray feedback and give good stability. It should not be necessary to use shielded leads to connect the board to jacks SK1 and SK2 in order to reduce feedback oscillations, but the external lead which connects to these sockets should be a shielded type.

The current consumption of the Sig-Tracer is about 17 mA, and, a standard 9V transistor-radio battery will not last very long on continuous service. This will not matter in many cases since the unit is likely to be used intermittently during troubleshooting procedures. However, if it is envisaged that the unit will be used quite frequently and for long periods it would be wiser to use a larger battery.

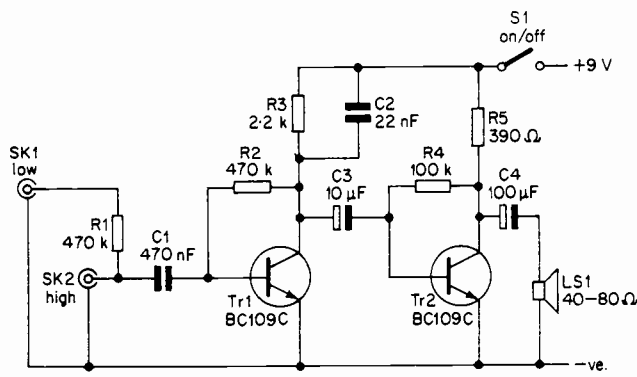


Fig. 11— Circuit diagram for the CW Filter.

problems with a mismatching when the filter is in use.

The frequency response of the circuit peaks at approximately 800 Hertz, and the -6-dB bandwidth is about 300 Hertz or so. The -0 dB points occur at about 350 Hertz and 2 kHz. This is sufficient to normally give a substantial reduction in adjacent channel interference, but the response is not so narrow and peaky that using the receiver with the filter in circuit becomes difficult, with the wanted signal tending to drift out of the pass-band and become lost.

The Circuit. Resistors R1 and R2 (see Fig. 57

11) form a simple attenuator which is needed to counteract the gain of the circuitry that follows, and thus give unity voltage gain overall. The rest of the circuit is a conventional operational amplifier bandpass filter having the circuit values chosen for the desired center frequency and a high Q value (to give the required fairly sharp, peaky response).

An ordinary operational amplifier would not give good results in this circuit due to the limited current drive capability of typically just a few milliamps. A few high-current operational amplifiers are available, but even these can usually only provide a few tens of milliamps, and cannot provide a very high output power. This circuit is based on a TDA2006 device which is primarily intended for use as an audio power amplifier having an output power of up to about 10 watts, and the output overload protection circuitry within the device limits the output current to about 3 amps!

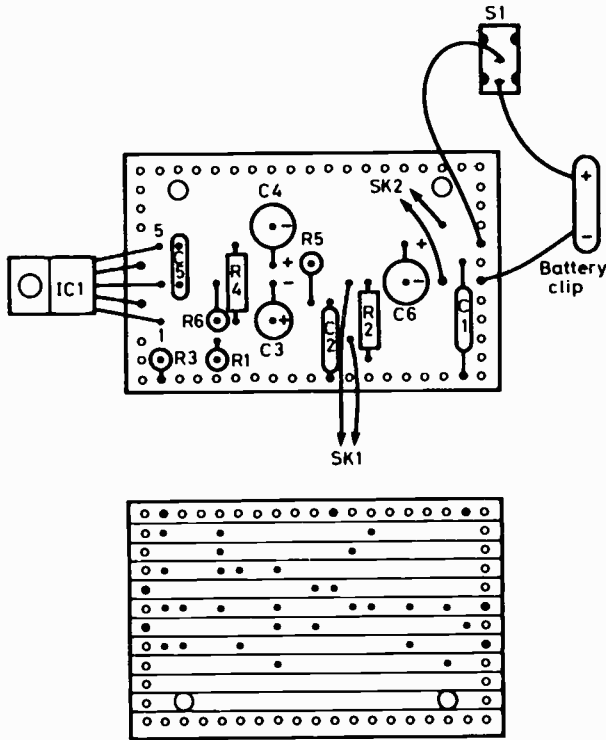


Fig. 12— Suggested parts layout on a stripboard for the CW Filter. Details are provided in text.

Although intended for use as an audio power amplifier, the TDA2006 is a very adaptable device because it can really be regarded as an operational amplifier having a high-power, class B, output stage. The TDA2006 has inverting and non-inverting inputs with a high-input impedance (5 Megohms) at each of these, plus a high open-loop voltage gain over the audio fre-

PARTS LIST FOR CW FILTER

Semiconductor

IC1—TDA2006, power amplifier

Resistors

R1, R3—2,700-ohm

R2—100-ohm

R4, R6—33,000-ohm

R5—180,000-ohm

Capacitors

C1, C2—10-nF, metallized polyester

C3—10- μ F, 25-WVDC, electrolytic

C4-C6—100- μ F, 10-WVDC, electrolytic

Additional Parts & Materials

S1—S.p.s.t. miniature, toggle-type switch

Suitable aluminum case, perfboard or 0.1-in matrix stripboard, 2 RCA phono jacks (SK1 and SK2), DC power supply (see text), wire, solder, etc.

quency range. Unlike many audio ICs which are basically operational amplifiers, the TDA2006 does not have any internal biasing components, and it can therefore be used, as it is here, in standard operational amplifier circuit configurations.

The lowest recommended supply voltage for the TDA2006 is 12 volts, but it seems to operate well using a 9-volt battery as the power source. The current consumption is around 20 mA or so, and this can rise substantially if the circuit is used at high volume with an 8 ohm load. It is therefore advisable to use a fairly large battery pack or suitable 12-volt DC wall plug power pack. A supply voltage of 12 or 15 volts is perfectly acceptable provided C6 working DC voltage (WVDC) has a suitable high, maximum-voltage rating.

Construction. The component layout and wiring of the CW Filter are illustrated in Fig. 12. Construction of the component panel is very straightforward, and there are no breaks needed in the copper strips. IC1 has pre-formed leads and it is necessary to splay the readouts slightly in order to fit them onto a 0.1-in. matrix. IC1 should not need a heat sink if the circuit is battery powered, but this might be necessary if a 12 or 15 volt high-current battery supply or AC-line power supply is used.

If an operating frequency other than 800 Hertz is desired, the center frequency of the filter can be changed by altering the values of C1 and C2. The operating frequency is inversely proportional to the value of these capacitors, but note that reducing the center frequency also reduces the bandwidth of the filter, and increasing the center frequency gives an increase in bandwidth.

When first using the filter it may appear to give a large reduction in gain, and this is simply due to the fact that at most frequencies the filter does give a substantial amount of attenuation. The CW note from the receiver must be fairly accurately tuned to the center of the filter's

response in order to obtain a strong output, and after a little experience with the unit, this tuning will be found to be quite easy.

8 Vol-Expander

Many types of live music, particularly classical music, have a very wide dynamic range. The dynamic range of music is simply the difference between the maximum and minimum sound levels, usually expressed in dBs. This dynamic range can be over 70 dB (although in most cases it is not quite this high).

To record this type of music requires a certain amount of compression being used in one form or another, especially in the case of a cassette recording where the available dynamic range of the recording system (tape and machine) is likely to be limited. Without some form of compression to restrict the dynamic range of the signal either loud passages of music overload the recording or transmission medium, or quiet passages fall into or below the noise level (or a combination of the two).

Music that has undergone even a small amount of carefully applied compression can be rather lacking in musical impact. You hear that kind of flat, background music in elevators and banks. An improvement in the playback can often be obtained by using a certain amount of expansion during playback or reception in order to boost the effective dynamic range of the signal. In order to give the desired effect an expander is required not to affect low-level signals, but produces a small boost in volume at middle dynamic levels, steadily rising to an increase of about 10 or 12 dB at the highest dynamic levels. In this way the lowest volume levels (and the background noise) remain unaltered, but the highest volume levels are substantially boosted. Of course, some noise is also boosted, but this is not noticeable as the wanted signal is strong enough to mask the noise.

Thus the use of a volume expander gives an apparent increase in signal to noise ratio, and can give more impact to music which requires a wide dynamic range. A volume expander cannot be expected to precisely counteract any compression used during the recording process or during transmission, but it can nevertheless produce a substantial subjective improvement when used with many program sources.

This all leads to the Vol-Expander that is our budget version of a practical volume expander hobbyists can build and use with rewarding music enjoyment.

The Circuit. An operational transconductance amplifier makes a good basis for our Vol-Expander since it is essential that the expansion is applied gradually, and is not virtually switched on and off. A voltage-controlled amplifier (VCA) using an operational transconductance amplifier tends to naturally give a suitable control characteristic. The circuit diagram of the Volume Expander is shown in Figure 13, and the operational transconductance amplifier used in the unit is a LM13600N device (IC1). This device has a number of additional features when compared to a basic device such as the CA3080E, the most obvious one being the fact that it is a dual device, and only one section of the device is used.

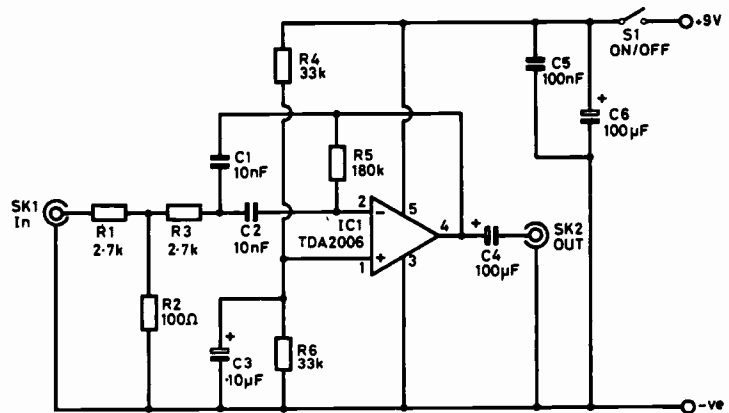


Fig. 13—Circuit diagram for Vol-Expander.

The other additional features of the LM13600N are the inclusion of a Darlington pair-emitter follower stage for use at the output of each section of the device, and linear diodes at the input of each section. The linear diodes can be fed with a small bias current, and this enables the device to handle a significantly higher signal level (about 10 dB in fact) before serious distortion occurs. This enables a higher overload margin and (or) increased signal-to-noise ratio to be achieved.

Resistor R8 is the discrete load resistor for the internal buffer stage of IC1, and R6 provides the bias current for the linear diodes. R7 sets the quiescent voltage gain of the circuit at a little under unity.

Some of the input signal is coupled by C4 to the input of a common-emitter amplifier which utilizes Tr1. The amplified output from Tr1 is cou-

pled by C5 to a rectifier and smoothing circuit which produces a positive bias voltage which is roughly proportional to the input signal level. This signal is applied to the amplifier bias input of IC1 via R12.

If only a low input-signal level is present there will be little or no current flow through R12 and into the amplifier bias input of IC1, and the voltage gain through the circuit will not be significantly changed. At higher signal levels the bias potential produced across C6 becomes large enough to produce a significant current flow

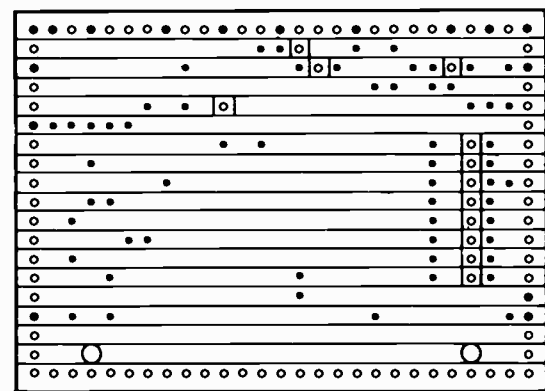
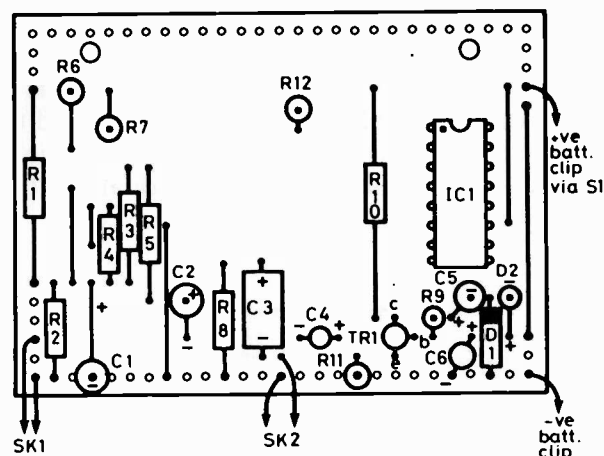


Fig. 14—Construction details of the Vol-Expander.

through R12, and the gain of the circuit is boosted somewhat. At high signal levels of around 500 mV *rms*, the bias voltage becomes high enough to produce a boost in gain of around 12 dB. This is about the maximum expansion that can be used without the signal processing becoming obvious.

Capacitor C6 has been given a fairly low value so that the attack and decay times of the circuit are both fairly short, and the unit responds very rapidly to changes in the input level. However, the attack and decay times are made sufficiently long to prevent significant distortion from being produced.

The current consumption of the circuit is only

PARTS LIST FOR VOL-EXPANDER

Semiconductors

IC1—LM13600N, transconductance linear opamp
Tr1—BC109C, ECG123A or 2N930, silicon NPN transistor

D1-D2—1N4148, silicon signal diode

Resistors (1/2- or 1/4-watt, 5%; 10% over 1 Megohm)

R1, R2—3,900-ohm

R3—220-ohm

R4—15,000-ohm

R5—10,000-ohm

R6—68,000-ohm

R7—39,000-ohm

R8—3,300-ohm

R9—1.8 Megohm

R10—4,700-ohm

R11—120-ohm

R12—10,000-ohm

Capacitors

C1—100- μ F, 10-WVDC, electrolytic

C2—4.7- μ F, 10-WVDC, electrolytic

C3—10- μ F, 25-WVDC, electrolytic

C4—220- μ F, 35-WVDC, tantalum

C5—1- μ F, 10-WVDC, electrolytic

C6—330- μ F, 35-WVDC, tantalum

Additional Parts & Materials

S1, S.p.s.t. miniature, toggle switch

Suitable aluminum cabinet or box, 0.1-in matrix stripboard or perf-board, two RCA phono jacks (SK1 and SK2), 9-volt transistor-radio and battery-clip connector, wire, solder, etc.

about 6 mA, and a small 9-volt transistor-radio battery makes an economic power source.

Construction. An 0.1-in. matrix stripboard panel for the Vol-Expander is detailed in Fig. 14, and a board having 19 copper strips by 27 holes is required. If you cannot obtain this board, a perf-board of the same size with flea clips inserted may be used. Interconnect the flea clips with No. 22 copper wire. Jacks SK1 and SK2 are the popular audio RCA phono types on the prototype.

If a stereo expander is required, it will be necessary to make up two boards, one to process each stereo channel. Alternatively, a longer piece of stripboard or perf-board could be used, and the otherwise unused section of IC1 could then be used as the basis of the additional expander circuit. The power supply center tap provided by R1, R2 and C1 could be used for the additional expander circuit, but all other components (apart from IC1 of course) would need to be duplicated in the extra expander circuit.

The Vol-Expander circuit should give good results if fed with the output of a tuner, cassette or tape deck, or a record deck via a suitable preamplifier. Some items of equipment might be found to have too little output to drive the circuit properly, and it will then be necessary to reduce the value of R11, or to even replace it with a

shorting link. It is just possible that some signal sources will provide too strong a signal so that the expansion commences at a fairly low level, and in such cases R11 can be increased in value. If preferred, R11 could be replaced by a 1000-ohm linear potentiometer which would be adjusted for (subjectively) the best results.

9 COMPUTER VOICE

Need a mechanical-sounding voice, often called a "computer voice"? Well, here's a simple circuit that can be put to good use in amateur dramatic productions, telephone message tapes, etc. It's easy to produce synthetic- or computer-type voice effects from an ordinary voice-signal input. There are several ways to generate this effect, but probably the simplest method that gives good results is to amplitude modulate the ordinary voice signal by using a squarewave as the modulating signal. This is similar to the well-known tremolo effect which is sometimes used with guitars and other electronic instruments, but tremolo units normally use a triangular or sinewave modulation signal to give a smoother form of modulation. In this application a squarewave gives better results, and a sinewave or triangular waveform would be less effective. The unit switches the input signal between being passed straight through to the output, and being attenuated by around 20 dB, or so. A switching rate of a few Hertz is used.

The Circuit. The circuit diagram of the Computer Voice unit is given in Fig. 15. It consists of two sections: an oscillator to provide the modulation signal, and the modulator itself.

The oscillator uses a 555 timer chip in the astable multivibrator mode, and the frequency of operation has been set at about 10 Hertz by the values given to R1, R2 and C1. The mark space ratio (duty cycle) is virtually one to one as the

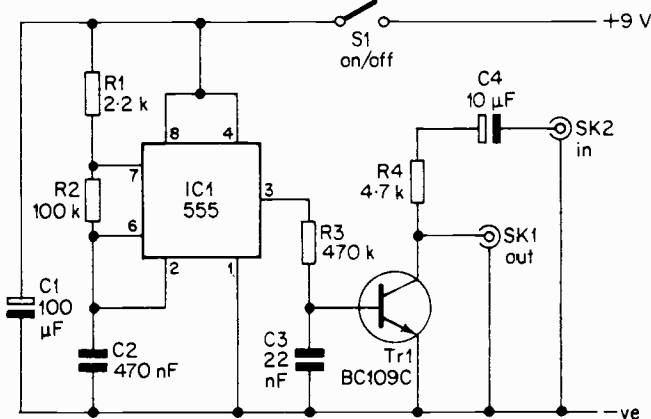


Fig. 15 —The circuit diagram for the Computer Voice unit.

PARTS LIST FOR COMPUTER VOICE

Semiconductors

IC1—555 timer chip

Tr1—BC109C, ECG123A or 2N930, silicon NPN transistor

Resistors

R1—2,200-ohm

R2—100,000-ohm

R3—470,000-ohm

R4—4,700-ohm

Capacitors

C1—100-µF, 10-WVDC electrolytic

C2—.47-µF, metallized polyester

C3—22-nF, metallized polyester

C4—10-µF, 25-WVDC electrolytic

Additional Parts & Materials

S1—S.p.d.t. miniature toggle

Aluminum case, solderless or perf-board circuit board, 9-volt transistor-radio battery and matching battery clip, two 3.5-mm jack sockets (SK1 and SK2) or reasonable substitute, wire, solder, etc.

value of R2 has been made high in value relative to the value of R1.

A very simple modulator is used, but this is quite all right in this application where a small amount of distortion is quite acceptable. Distortion produces new frequencies that help to change the voice signal and make it sound less like the original. A large amount of distortion is obviously not desirable as it would severely impair the intelligibility of the output signal.

Transistor Tr1 is used as a sort of voltage controlled resistor: and, in conjunction with R4, it forms a voltage controlled attenuator. Capacitor C4 is merely a DC blocking capacitor at the input and R3 is used in the base circuit of Tr1 to effectively make Tr1 a voltage-controlled device rather than a current-controlled one. During the periods when IC1's output is high, Tr1 is biased into conduction by the base current it receives via R3, and effectively has a collector-to-emitter resistance of only a few hundred ohms. This gives losses of around 20 dB or so through R4, and attenuates the signal fed to the output by this amount. When IC1's output is low, Tr1 is switched off and the input signal can pass straight through R4 to the output. The only attenuation is due to the potential divider action between R4 and the input impedance of the equipment to which the output signal is fed. This should minimize losses.

Thus the output signal is switched up and down in amplitude, producing the required computer-type voice effect. Capacitor C3 is included in the circuit to slightly slow down the sharpness with which the signal is switched between the two levels of gain, and this helps to avoid "clicks" which can otherwise occur during transi-

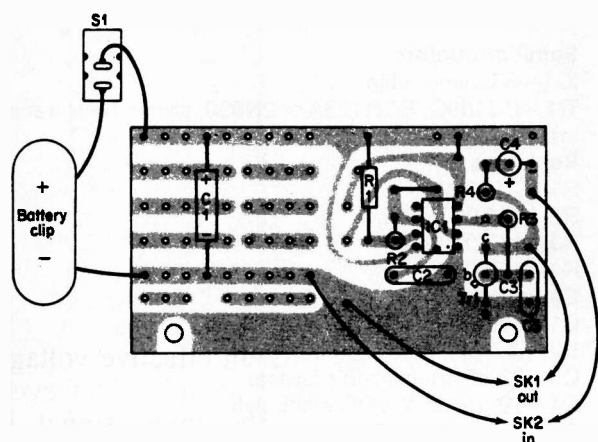


Fig. 16— The Computer Voice unit assembled on a multi-project board. The text advises using a solderless circuit board. Use that which is most comfortable for you.

tions from one gain level to the other. Capacitor C1 is a power-supply decoupling capacitor and this also helps to prevent switching “clicks” from being generated within the unit.

Construction. It is advisable to assemble the project on a solderless circuit board as illustrated in Fig. 16. Assembly is easy and experimental changes in component values will enable you to customize the output voice signals to your taste. Jack sockets (3.5-mm) were used for SK1 and SK2 on the prototype but these can be any two-way audio connectors. It is a good idea to house this project in an aluminum metal case (grounded to the negative supply rail of the circuit) so that the circuitry is screened from power-line hum, radio frequency signals, and other possible sources of electrical interference.

The unit can be used to process a signal directly from a microphone, but this may well cause problems with large losses through the unit even when Tr1 is in the off state. This loss is due to the fact that some microphones are designed to feed into quite a low impedance, and with such a load-impedance mismatch substantial losses occur. Some microphones are designed to feed into high impedance and will not produce this problem. Nevertheless, as microphones of this type have quite a high impedance, the losses provided by the unit when Tr1 is in the on state will be much higher than is really desirable. There is also the problem of the low-output level of a microphone that requires a high level of gain from the unit. This amplification will also boost the noise level to an uncomfortable listening level.

It is better to feed the microphone signal to the unit via a preamplifier, so that a fairly high-signal level is fed to the unit. A mere one stage of isolation with attending load matching is invaluable here.

There should be no problems if the unit is fed from a tape recorder or some piece of equipment which provides a similar signal level (a few hundred millivolts *rms*). It is not advisable to use the unit to process a signal having an amplitude of more than about 1.0 volt *rms* as quite severe distortion could then be produced.

10 Audio Power Booster

Despite the fact that there is a fair amount of noise inside most cars when they are traveling, many car radios and tape players have rather insufficient output powers to play over road noise. One reason for this is probably the fact that it is not possible to obtain a great deal of power using a 12-volt DC supply and a modern transformerless output stage into a 4- or 8-ohm loudspeaker. The maximum possible output swing is nominally 12 volts peak-to-peak. No output stage gives an output voltage swing equal to the supply voltage as there are inevitably voltage drops through the output transistors. On the other hand these are counteracted to some extent by the fact that a car battery usually has an actual voltage which is somewhat more than its nominal level. In terms of *rms* voltage this limits the maximum output to only about 4.25 volts, which gives only about 2.25-watts *rms* into an 8-ohm speaker, or 4.5-watts *rms* into a 4-ohm type.

There are ways of obtaining increased output, and the method used in the Audio Power Booster is to use a bridge-amplifier circuit. The Audio Power Booster is connected between the car radio or tape player and the loudspeaker, and it gives an output power boost of about 9-watts *rms* into an 8-ohm load or 18-watts *rms* into a 4-ohm load.

A Bridge Does It. A bridge-amplifier circuit consists of two power amplifiers with the loudspeaker being driven from the two outputs; neither speaker lead being connected to the car's chassis ground. The two amplifiers are arranged so that under quiescent conditions their outputs are at the usual level of about half the supply voltage, and there is no significant voltage present across the loudspeaker. The amplifiers are arranged to have output signals that are in anti-phase, so that a positive change in the output potential of one is matched by a similar but negative change in the output voltage of the other. Thus when one amplifier has its output fully positive, the output of the other one is fully negative. This gives about 12 volts across the loudspeaker. On signal peaks of the opposite polarity the two output states are reversed so that 12 volts is again

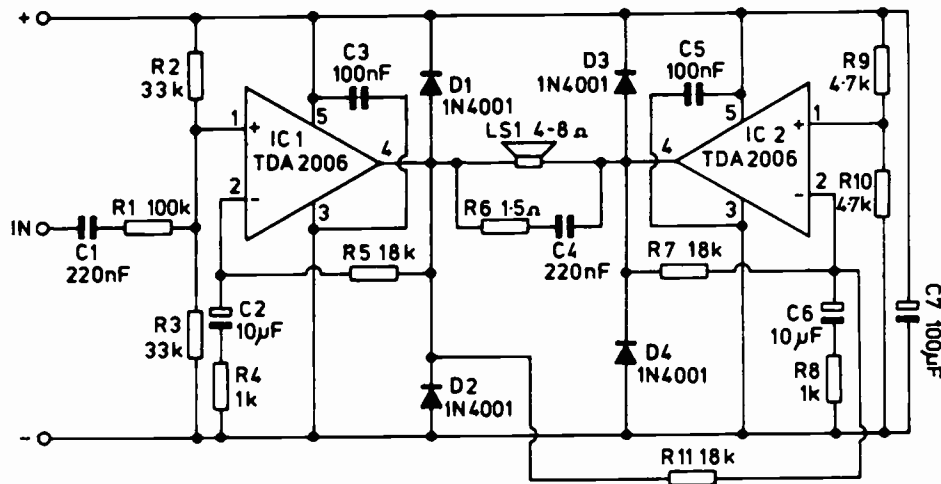


Fig. 17—The circuit diagram of the Audio Power Booster. Notice the almost mirror image of the circuit components surrounding the ICs.

developed across the loudspeaker, but the polarity of the output signal has changed. Thus the amplifier can give up to ± 12 volts across the loudspeaker, or a peak-to-peak voltage swing of 24 volts. This is double that obtained with a normal amplifier, and gives a maximum output current that is also doubled; thus the output power for a given speaker impedance is boosted by a factor of four when compared to an ordinary audio power amplifier.

The Circuit. The Audio Power Booster is based on two TDA2006 audio IC power amplifiers, as can be seen from the circuit diagram of Fig. 17.

Power amplifier IC1 is used as what is virtually a non-inverting amplifier, with the non-inverting input of the device being biased to half the supply voltage by R2 and R3. R5 provides 100-percent negative feedback from the output to the inverting input of IC1 at DC so that the circuit has unity voltage gain and the output is biased to the required level of half the supply voltage. C2 and R4 remove some of the feedback at audio frequencies and this gives a voltage gain of about 18 times at these frequencies. This is far more than is actually needed, and a voltage gain of little more than unity is in fact sufficient. It is necessary to remove a substantial amount of feedback though as instability is otherwise likely to occur. R1 is used at the input of the amplifier to reduce the sensitivity to a more suitable level, and C1 simply provides DC blocking at the input.

IC2 is used in virtually the same configuration, but its non-inverting input is not fed with an audio signal, and only receives the DC bias signal from R9 and R10. Resistors R2, R3, R9 and R10 are all close tolerance components so as to ensure a reasonably small voltage difference

across the outputs of the two amplifier stages under quiescent conditions; and, consequently, a small and insignificant quiescent current through the loudspeaker. Resistor R11 couples the output signal of IC1 to the inverting input of IC2, and the value of R11 is chosen to give IC2 an effective voltage gain of unity. However, as the input signal is coupled to IC2's inverting input there is a phase inversion through this section of the amplifier,

giving the required anti-phase relationship at the two outputs.

Diodes D1 to D4 are protection diodes for the two ICs, while R6 plus C4 form a *Zobel* network which helps to prevent instability. Components C3, C5 and C7 are all supply decoupling capacitors.

Construction. A 0.1-in. matrix stripboard having 18 copper strips by 17 holes is used to accommodate most of the components, and the component layout of this board is given in Fig. 18. There are no breaks in any of the copper strips. The audio power ICs are modern types which physically resemble plastic power transistors, but they have five rather than three leads. These must be carefully bent apart slightly in order to fit these devices into this stripboard.

PARTS LIST FOR AUDIO POWER BOOSTER

Semiconductors

IC1, IC2—TDA2006 audio power amplifier chip

D1-D4, 1N4001 rectifier

Resistors

R1—100,000-ohm

R2, R3—33,000-ohm, 2%

R4, R7—100-ohm

R5, R11—18,000-ohm

R6—1.5-ohm

R8—1,000-ohm

R9, R10—4,700-ohm, 2%

Capacitors

C1, C4—.22- μ F, Mylar

C2, C6—10- μ F, 25-WVDC, electrolytic

C3, C5—.1- μ F, metallized polyester

C7—100- μ F, 25-WVDC, electrolytic

Additional Parts & Materials

Suitable aluminum chassis box, 0.1-in matrix stripboard or perf-board, transistor heat sinks (see text), s.p.s.t. switch (optional), sockets, wire, solder, etc.

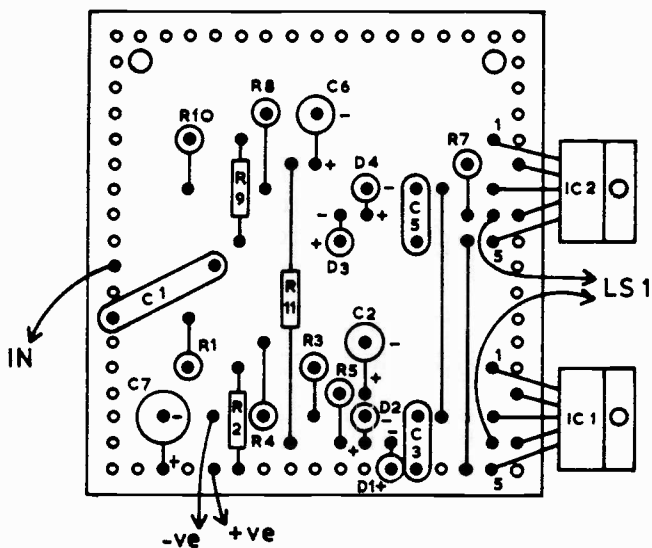


Fig. 18—Component layout for the Audio Power Booster as placed on a 0.1-in. matrix stripboard. The copper strips (on the reverse side of the board) run horizontally from left to right. If perfboard is used, interconnect all leads on the common horizontal row of holes for each strip.

Ensure that you do not omit the two jumper (link) wires. Be very careful to connect the polarized components with the correct polarity, especially the four rectifiers as these could be damaged or cause damage if connected incorrectly. Use the same care with electrolytic capacitors.

The two ICs should be bolted to a substantial heatsink. If the unit is used in a negative ground vehicle it can be fitted into a metal case which can be used as the heatsink, but it will probably be necessary to use an aluminum bracket to provide a thermal path from the ICs to the case. A suitable bracket can easily be produced from #18 swg aluminum that is commonly used in manufactured chassis boxes.

In positive ground cars this is not really advisable since the heat-tabs of the ICs connect internally to their negative supply readouts. This would result in the case connecting to the negative supply, and the likelihood of a short circuit between the case of the booster and the positive chassis of the car. Insulation sets supplied with the semiconductors can be used to insulate the heat-tabs from the case. Do a careful job since vibrations may shake the parts apart.

Components R6 and C4 are not mounted on the component panel, but are wired across the output socket or terminals of the Audio Power Booster.

When installing the booster remember that neither output lead should be allowed to come into contact with the chassis of the vehicle. The TDA2006 incorporates output short-circuit protection circuitry and thermal overload shutdown circuitry, and accidental contacts between the output leads and the chassis (or each other)

should not damage the unit.

Power. The power supply voltage for the unit should be taken from the supply line of the radio or tape player with which the booster is employed, as it will then be switched on and off with the main item of equipment. However, the unit can have its own on/off switch added into whichever supply lead is not grounded. The input for the booster is taken from whichever output lead of the radio or tape player is not grounded, and the correct lead can be found simply by connecting the two leads, in turn, to the input of the unit to see which one provides the desired result.

If the unit is used with a radio or tape player that has only a very limited output power it may be necessary to reduce R1 in value somewhat in order to fully drive the booster.

11 Pit-Stop—The Indy of Electronics

Pit-Stop is a motor-racing game that can be played with up to four competitors, the winner being the first driver past the checkered flag after a pre-arranged number of laps. The rules are simple and to the point. A driver can move away from the starting grid only when he has tanked up. Fueling and moves (distance round the track) are determined by an electronic indicator, the number of moves depending on skill in selecting the numbered LEDs that flash in sequence. Each move results in fuel being used up and the state of each fuel tank is monitored by a FUEL GAUGE. Lack of fuel is shown by the TANK EMPTY indicator light; drivers must then stop to TANK SELECT and refuel before any further movement. In addition to the DRIVE and REFUEL operations, there are hazards and advantages along the track dictated by game cards.

Pit stops can be enforced by game-card selection and, in a more realistic version of the game where refueling is confined to the pits, also made at a driver's discretion. If this rule applies, a TANK EMPTY light on when the car is out on the track puts the driver out of the race.

The Circuit. The circuit diagram for the Pit Stop game can be considered to consist of four basic blocks:

- counter;
- the decade counter and ten-LED flashing display that can be stopped momentarily to indicate either REFUEL or DRIVE distance outputs, selected by the players;
- four tank capacitors, chargeable when tank-up switches are pressed;

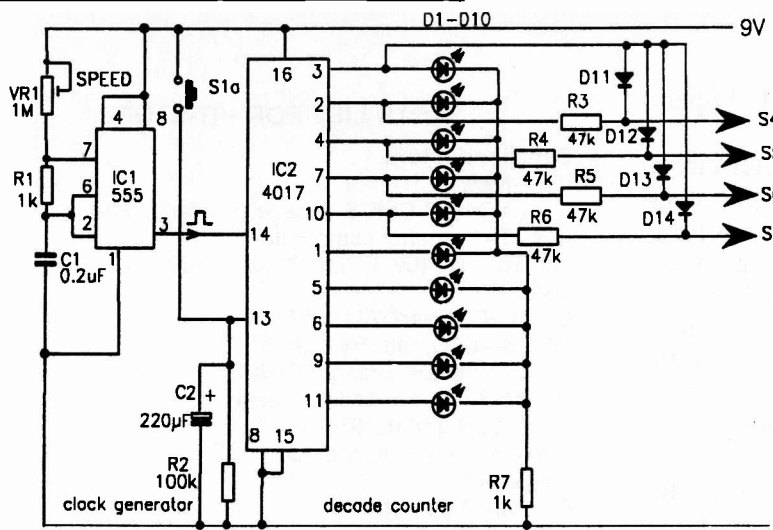


Fig. 19—Circuit diagram for the Pit-Stop counter circuit.

- the comparator, controlling the TANK EMPTY light, and a meter that monitors fuel levels.

In Fig. 19 the clock generator, which provides the timing pulses for controlling the decade, the clock generator, IC1, is the popular CMOS 555 timer used in the astable multivibrator mode. The frequency of oscillation is controlled by the fixed capacitor C1, and the variable resistor VR1 (SPEED). Output pulses are available at pin 3.

The 555 output of IC1 is directly coupled to the clock input of integrated circuit IC2, a 4017 decade divider/counter. With the reset output (pin 15) connected to the 0V line, the ten LEDs (D1-

D10) connected in the divider outputs flash sequentially at a speed determined by the setting of VR1. Normally, VR1 is set so that the counter output LEDs flash at several times per second. During a turn by a player, when S1 is pressed, contact S1a freezes the display on one LED for a few seconds before flashing resumes. The rate of flashing should be fast enough so that some skill is required to anticipate the selection of a particular LED. However, for younger players, it may help to select a slower speed with VR1.

As shown in Fig. 20, each player has a tank (electrolytic capacitors C3-C6) that can be charged via a TANK-UP switch (S4-S7). Four of the outputs of the counter are coupled via resistors (R3-R6 on Fig. 19) to the TANK-UP switches. During refueling, when a selected output is frozen for a few seconds, if the relevant TANK-UP switch is pressed, the positive voltage on the output pin is connected via the 47,000-ohm resistor (R9) and switched to charge the driver's tank capacitor. If by misjudgment another driver's LED is selected, then the other driver can press his or her TANK-UP button and take on some fuel.

Before pressing the GO switch S1, the TANK SELECT switch S2 must be set to the player's position. Diodes D15-D18 isolate the tank capacitors and prevent any short-circuiting of charges if the rotary contacts of S2 should make-before-break. Switch S2 connects the comparator (IC3) and fuel meter (M1) to monitor the state of the player's fuel tank capacitor. It also connects the tank capacitor to a discharge circuit, when S1 is pressed, formed by R10 and C8 connected in parallel. On each turn, a player's tank is discharged slightly by this circuit, i.e. fuel is used up on the drive, especially if short distances are selected. Switch S3, DRAIN TANK, serves two purposes: it can be used with a Hazard Card to simulate a loss of fuel situation, or (at all positions of the TANK SELECT switch) to drain tanks for the next game.

Diodes D11 to D14 enable tank capacitors to be charged via the TANK-UP pushbuttons if the ALL refuel light is on.

The comparator is a 741 operational amplifier, IC3, which monitors the voltage in a tank capacitor and compares it with a reference voltage set by potentiometer VR2. When the voltage level in the connected tank capacitor falls below the reference voltage, output pin 6 of the comparator goes high; this switches on transistor Tr2 and the

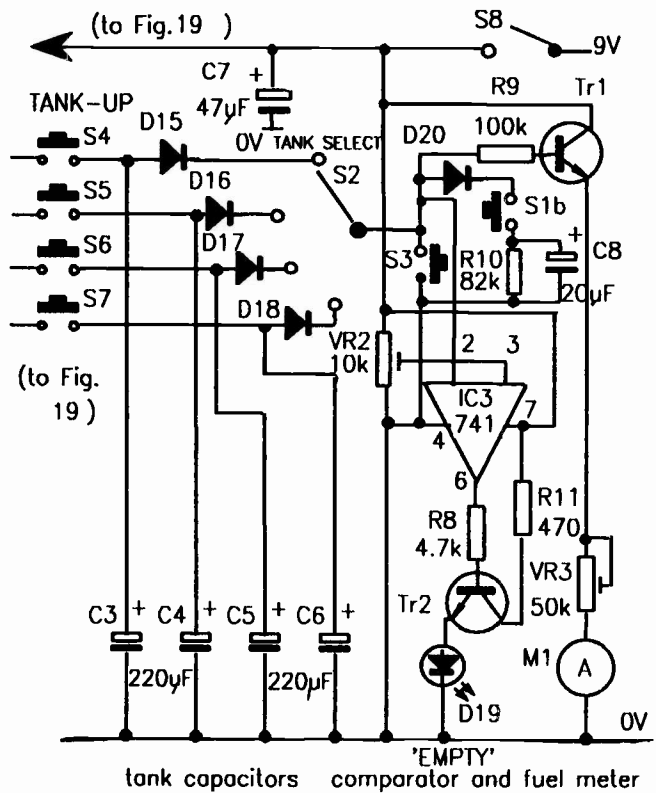


Fig. 20—Circuit diagram for the Pit-Stop fuel-tank and comparator circuit.

TANK EMPTY LED lights. A TANK-UP operation is then required.

Switch S2 also connects the fuel meter circuit to a driver's tank circuit for monitoring purposes. Transistor Tr1 is connected as an emitter-follower, the high-input impedance preventing excessive drain on the tank capacitor. The fuel reading on the micro-ammeter (M1) in the emitter circuit is set by the series preset resistor VR3. Leave the setting for VR3 in the maximum resistance position. This will prevent the meter from being damaged when the game is first turned on.

Construction. The prototype was constructed on a 15-in. square, 3-ply board, layout as shown in Fig. 21, with four 2-in. xxX 1/4-in strips for the sides. The clock generator and decade counter were mounted on a separate piece of 0.1-

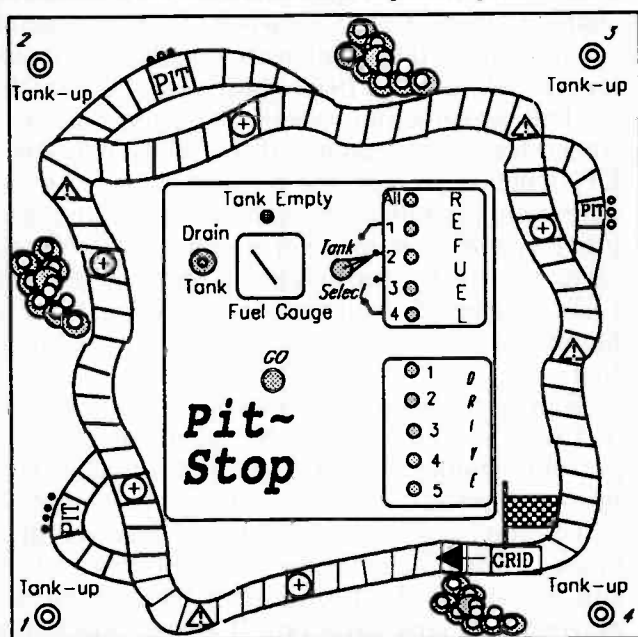


Fig. 21—Suggested Pit-Stop game board layout. The final layout is limited only by your imagination.

in stripboard or perf-board. A perf-board with flea clips may be used or a solderless breadboard and later converted to a matching pre-etched circuit board with components soldered in place. The wiring is not critical, but neatness is important should troubleshooting be required.

The track layout can be an enlarged replica of the one shown in Fig. 21, or can be modified to incorporate other ideas, especially if the constructor is a motor-racing enthusiast.

Playing. If you drive a car, a quick briefing on the play philosophy is all you will need to understand the game.

1. Before starting, set the battery switch S8 on and make sure that the four fuel tanks are discharged by pressing the DRAIN TANK switch S3 while rotating the TANK SELECT switch S2.

PARTS LIST FOR PIT-STOP

Semiconductors

- IC1—NE555CP timer
- IC2—CD4017 CMOS decade counter/divider
- IC3—741 op-amp comparator
- Tr1, Tr2—BC109, ECG123A or 2N929, silicon NPN transistor
- D1—LED, green (ALL REFUEL)
- D2-D5—LED, red (REFUEL)
- D6-D10—LEDs, orange (DRIVE)
- D11-D18—1N4148 silicon diode
- D19—LED, red (EMPTY)
- D20—1N4148 silicon diode

Resistors

- R1, R7—1,000-ohm
- R2—100,000-ohm
- R3-R6—47,000-ohm
- R8—4,700-ohm
- R9—100,000-ohm
- R10—82,000-ohm
- R11—470-ohm
- VR1—1,000,000-ohm potentiometer
- VR2—10,000-ohm trimmer
- VR3—50,000-ohm trimmer

Capacitors

- C1—0.2- μ F, metallized polyester
- C2-C6—220- μ F, 10-WVDC, electrolytic
- C7—47- μ F, 10-WVDC, electrolytic
- C8—20- μ F, 10-WVDC, electrolytic

Additional Parts Materials

- M1—Microammeter, 50 or 100 microamperes
- S1—2-pole, non-locking, push-button switch
- S2—Single-pole, 4-way rotary switch
- S3-S7—Non-locking, push-button switch
- S8—S.p.s.t., toggle or slide (on/off) switch

2. Set the SPEED potentiometer VR1 to an agreed speed.
3. Select in turn to decide order of play by highest drive positions, and which two cars will be in pole (front) positions.

NOTE: Only two cars can be abreast at any time during a race, so a third car coming up fast behind two cars on the same patch of track will have to tuck in behind and forfeit any extra distance selected for the move.

4. The driver in pole position starts by switching the TANK SELECT switch to his position (RED, BLUE, YELLOW or GREEN). For instance, when the RED switch position is selected as shown, the red driver tries to anticipate when the LED for the red output is on and presses GO momentarily to select it. If successful, he then presses his TANK-UP switch to charge up his tank only while the LED remains on. Successful fueling is indicated if the TANK EMPTY lamp goes off, and a driver can select a drive distance when the next turn comes round, or elect to tank-up further.

5. The next driver in pole position, switches the TANK SELECT switch to his position and tanks-up in the same way.
6. The two drivers on the back row of the starting grid follow suit, but cannot drive off until at least one driver in pole position has moved (the no-passing two rule).

NOTE: Holding down the TANK-UP switch after flashing resumes will result in some loss of fuel.

7. At the beginning of a turn, on TANK SELECT, if the TANK EMPTY light is on, a driver must tank-up. Any DRIVE moves selected inadvertently are forfeited.
8. If the ALL position is selected, all drivers can press their TANK-UP button to take on fuel.

Game Cards. Game cards are of two types—hazard and advantage. When a car lands on a hazard square (indicated by a triangle) the player draws a Hazard Card and obeys the instructions on the card. Likewise, an Advantage Card is selected whenever a car lands on an advantage square (indicated by a circle). Cut a number of cards to the size of business cards. Leave one side blank and on the other side type or write the following:

Hazard Cards

- Oil spill-lose a turn.
- Spin off track-lose a turn!
- Slow-down for chicane-reduce drive by 1.
- Tank holed-press DRAIN TANK.
- Aqua-planing-compulsory pit stop to fit wet tires. Lose a turn.
- Engine overheating-compulsory pit stop. Lose one turn.
- Flat tire-reduce drives by one and one compulsory pit stop.

Advantage Cards

- Super-fuel!-add 2 to drive score.
- Engine finely tuned-up-add 1 to drive score.
- Following wind-double drive score.
- Reserve tank-perform TANK-UP.
- Double accelerate-hold card until needed.
- Close gap-tuck in behind car immediately in front.
- Good road-holding-hold card and add 1 to drive score on next bend.

If you wish, let your imagination add additional hazards and advantages to the game cards you make.

The playing pieces for the board game may be pawns from a discarded chess set or some other easily gripped object. Coins are too difficult to

manipulate. Paint the playing pieces appropriate colors to reduce confusion. Now then, drivers, man your cars!

12 Minefields

You are the captain of two ships that must navigate through magnetic minefields, racing against other ships in order to enter your safe port first. The game can be played by up to four players, each with two ships. In turn, under electronic control, the ships are steered past minefields in the direction of the home port. Refer to Fig. 22 for the board layout. The eight minefields normally flash sequentially (free-run) to warn ships of danger, until a mine is detonated (glows steadily) by a player.

Depending on the players' temperament or the state of the race, some players may take the longer safe channels (unless under other orders), while other captains may risk a winning dash for the home harbor via the minefields.

Movement. Players move in turn by pressing their DETONATE pushbuttons, which freeze the flashing minefield display for a few seconds. This results in one of two situations, as follows:

1. On detonate, one of the eight mines will glow for a few seconds together with one of the navigation lights. The player will observe which of the navigation lights is on, and also check if there is a ship lying on one of the eight shaded squares that surround the glowing mine. After the player has made his move, any victim in the minefield must either return his ship to base in the case of a direct hit (dark square) or take a NEAR MISS game card (gray square) and act upon instructions.

With regard to the direction of play, Fig. 23 shows the four moves. These are made in relation to a player's starting direction shown next to the DETONATE button:

- A green (starboard) light indicates a forward diagonal turn to the right.
- A red (port) light indicates a forward diagonal turn to the left.
- AHEAD indicates a forward move directly towards the harbor.
- ASTERN indicates a backwards move directly towards the base.
- A ship is only moved one square at a time, unless a game card instructs otherwise.
- Ships cannot be moved sideways.

2. If a mine does not remain on after a DETONATE, then one of the two center LEDs ACTION STATIONS or NEAR MISS will glow. 67

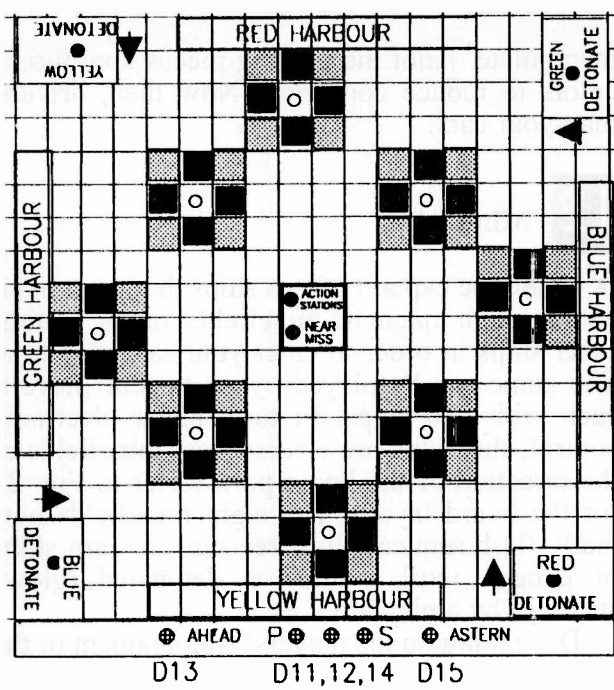


Fig. 22— Minefields game board layout.

PARTS LIST FOR MINEFIELDS

Semiconductors
 IC1—NE555CP timer chip
 IC2—CD4017 CMOS decade counter/divider
 D1-D8, D10—Red light-emitting diode
 D9, D15—Orange light-emitting diode
 D11, D12, D14—Tricolor (green/red) light-emitting diode³
 D13—Yellow light-emitting diode

Resistors
 R1—2,200-ohm
 R2—5,600-ohm
 R3—100,000-ohm
 R4—1,000-ohm
 VR1—500,000-ohm potentiometer

Capacitors
 C1—0.5- μ F, metallized polyester
 C2—220- μ F, 10-WVDC, electrolytic
 C3—4.7- μ F, 10-WVDC, electrolytic

Switches
 S1—S.p.s.t. slide or toggle (on/off)
 S2-S5—Push-button, non-locking (DETONATE)

Additional Parts & Materials
 Shallow box (can be made from plywood), 9V transistor radio battery, plastic shapes for ships, stripboard or perf-board, wire, etc.

If it is a NEAR MISS light, then the player will take a NEAR MISS game card and act on it. However, in the event of ACTION STATIONS, all players are at liberty to press their DETONATE button as soon as the display returns to free-run, primarily to ward off any danger or to create havoc. The player will then take a game card from the ACTION STATIONS pile and act on the instructions. Game cards can sometimes be held for future use if not valid. In this case, they will take the place of a turn. After use they will be returned to the bottom of their respective piles.

The SPEED control (VR1) can be panel-mounted if desired and marked for half-speed and full-speed settings to cater for younger children, and for special instructions, e.g. on

ACTION STATION game cards. Depending on the agreed speed and a certain amount of anticipation, the display can easily be frozen on a desired mine, or navigation direction to shorten a game.

If a move cannot be made for any reason, e.g. obstacles such as coast lines, other ships, mines, then the move is forfeited. A move can be made by either of a player's two ships when thought advantageous, e.g. to hold direction or to avoid a minefield.

Hazards. One of the eight mines can be detonated (permanently lit): by a player's DETONATE switch as a normal turn, by detonating after the ACTION STATION light comes on, or if an ACTION STATION game card says DETONATE.

Any ships in a minefield when it is detonated (one mine permanently on) either take instructions from the top NEAR MISS game card if in the light-shaded square or if a DIRECT HIT is registered (on a dark square) go back to base for repairs.

The HALF SPEED and DETONATE game card introduces an element of skill. It allows more time for a player to anticipate which mine shall be detonated. The player operates the HALF SPEED button to slow down the display before detonating. This gives a chance to inflict a direct hit or a near miss on any rival ships already in a minefield.

The SPEED control can be reduced for the first few games, or to assist younger players; alternatively, younger players could use the

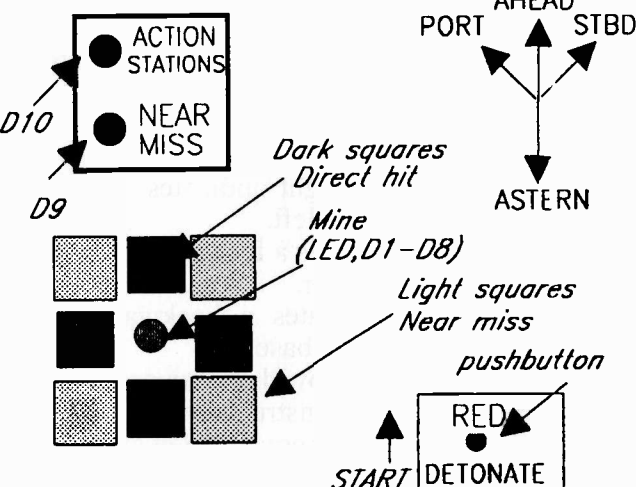


Fig. 23— Details of one minefield and related DETONATE switch and LEDs.

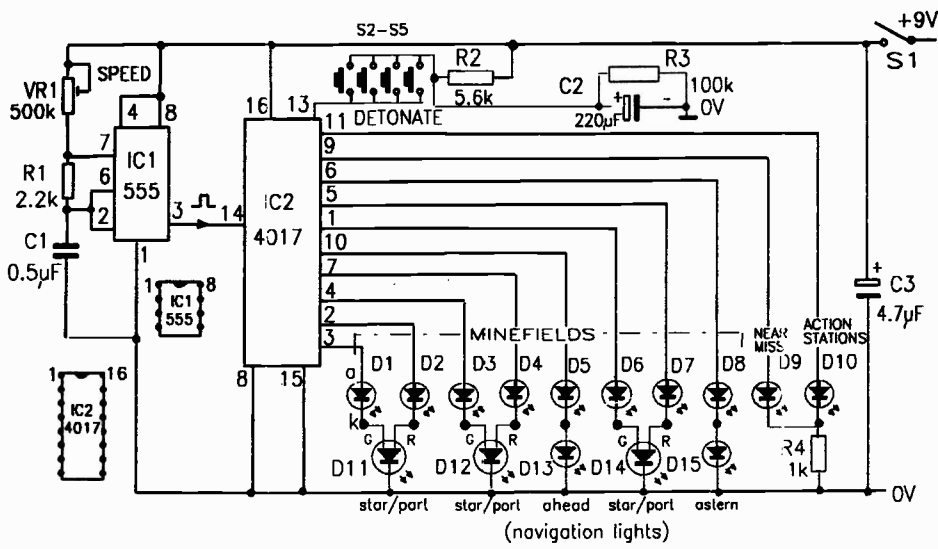


Fig. 24— Circuit diagram of the Minefields circuit.

straight cut per tile. The exception is the top tile over the speaker which because of its different angle must be narrower, 7 × 3.5 inches.

Triangular wood blocks are used to support the tiles. These are made by first cutting four 3-inch squares, then sawing diagonally to give eight triangles. The two wood blocks for the over-speaker tile are made by halving a 30- × 2-inch rectangle along the diagonal.

HALF SPEED control for each move.

Ships may not enter an opponent's HARBOR.

Circuit. The 555 timer can be varied by VR1 to give a suitable speed for the free-run display for the mine and navigational LEDs. Refer to Fig. 24. The inclusion of three tricolor LEDs in series with the minefield LEDs gives green (starboard) and red (port) navigation signals. Also, the electrolytic capacitor C2 together with resistor R3 provides a time constant to hold the detonate and navigation information for a few seconds for scrutiny after a DETONATE push-button is released. This time can be lengthened or shortened as desired by altering the value of capacitor C2 (reduce capacitor value to shorten time and vice versa).

Layout is not critical, but requires a minimum of woodworking skill. The circuit elements can be soldered rats-nest style or assembled on pre-etched circuit boards and solderless boards. Neatness will make troubleshooting easier.

A standard 3 × 1 mix of sand and Portland cement (we will call it concrete) is used to fill the space behind the tiles. The concrete is applied between the blocks and the tile bedded on to it.

In all cases screw two or three stout wood flat-head screws at random angles into the wood where the cement is to be laid leaving about an inch out of the wood, so that the protruding head of the screw will be buried in the concrete. These screws will then secure the concrete block in place when it is dry. Thoroughly wet the back of the tile before applying it to the concrete. In some cases the front of the tile may need to be held in place while the concrete sets, with wood panel nails knocked into the wooden sides. It does no harm to leave them there afterward.

All jointing is done by a strong wood glue. Elmer's wood glue was used for the prototypes which is very strong and convenient to apply; however there are many suitable wood glue alternatives on the market. The glue also fills any small gaps where the saw might have made a slight rough cut. Construction must proceed in numerous stages to allow the glue and concrete to set before continuing with the next stage, so some patience must be exercised. Make both speakers at the same time so that each stage can be completed on both and thus save time.

First Stage. Refer to the diagram of wood panels (Fig. 25), and buy sufficient plywood for all pieces. Remember that these pieces are for one speaker, so each unit will have to be duplicated. As so many are just 3-in. strips, it is likely that much can be obtained as scrap cuts. Most large lumber yards sell these at a reduced rate, and the color or grade doesn't matter as all are concealed except the top and bottom cheeks. The thickness should be as specified, 3/8 inch for the sides, baffles and back, 1/2 inch for the front, and

13 Building the Kapellmeisters

Most transmission-line loudspeaker enclosures involve a lot of tricky woodwork so that many speaker builders with only modest woodworking skills are deterred from building one. With the Kapellmeisters, although quite a lot of woodworking is needed, none of it is difficult, mostly it consists of cutting straight edges. These edges must be straight though, so if your saw cuts tend to wander, get the lumber yard to cut them for you. The measurements are uniform with many pieces being identical.

Preparation. Ceramic tiles used in the construction of the Kapellmeisters are standard 8- × 4-inch, cut down to 7 × 4 inches. That is just one

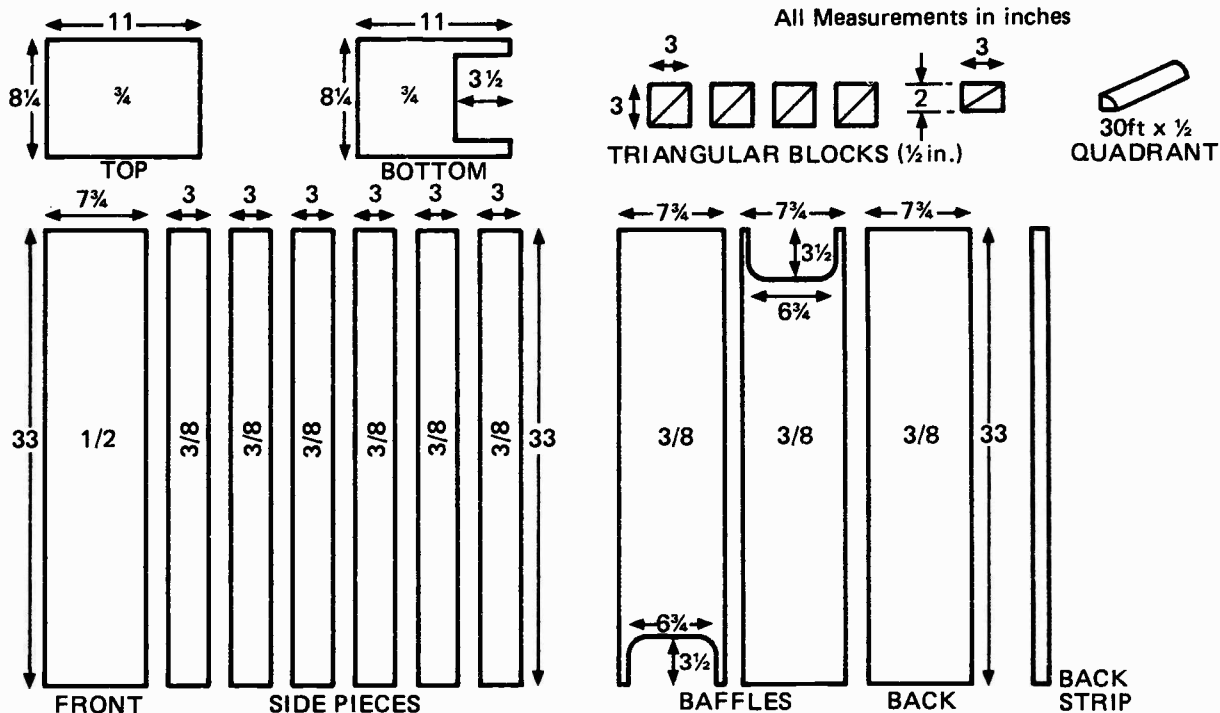


Fig 25 —View of all the wooden parts for one speaker cabinet including dimensions. Each side of the cabinet is made of three parts requiring a total of six side pieces for one speaker. All pieces should be plywood. See text for addition details on materials.

3/4 inch for the cheeks. It really will save a lot of time and energy if you get the lumberyard to cut the pieces with his machine saw. They usually charge slightly for each cut.

The lumber yard probably will not do the shaped ports at one end of the baffles and bottom cheek, but this can be managed with a fret or coping saw. A 7-1/2 x 4-1/4-in. elliptical speaker hole should be cut in the front panel starting 21 inches from the top. Before you cut the hole, check the physical size of the loudspeaker. It may be slightly different. It is desirable though not essential for the hole to be beveled outward.

Loudspeaker. A word about the loudspeaker that you should select. An oval speaker was selected for the original unit and it was rated at 8 watts with pretty good specifications at a low price. You should do the same; however, that would take away the fun of redesigning all project builders get involved with. Keep in mind that as the price goes up, the increase in performance lags behind so that dollars are wasted. Keep in mind that the Kapellmeister is designed to bring the best out of inexpensive loudspeakers.

Second Stage. Start with the front panel; lay it face down supported on some scrap quarter-inch ply or hardboard. Glue the top and bottom edges and fit the top and bottom boards. The front edges of the top and bottom cheeks should *not* rest on the ply supports but directly on the work surface; they will thus protrude a quarter of an

inch beyond the panel. Refer to Fig. 26(a). The top and bottom cheeks should also be positioned to give an equal overlap at either side. The idea is for the top and bottom cheeks to overhang the front, sides and back 1/4-in. from all sides.

Weights should be applied to the free sides of the cheeks to hold them against the panel while drying. Measure the distance between the rear edges of the top and bottom cheeks to ensure that it is exactly 33 inches and therefore the top and bottom are parallel. Wait for glue to set and harden.

Third Stage. Fit the first pair of side pieces, gluing the ends and the edge contacting the back of the front panel; ensure the pieces are flush with the edge of the front panel. Measure across the upper edges to make sure they are 7-3/4 inches and so are true. Now glue the triangular blocks in place at the bottom and top as shown in (a) of Fig. 26, the top ones being the special sized ones. Glue the edges as well as the face that contacts the sides, but be careful in pressing them into place that you do not move the sides. Wait for the glue to set.

Fourth Stage. Now fit the speaker, screwing it in place over the aperture, and connect by soldering a pair of wires which are run down the panel to a hole drilled in the bottom. Leave a few inches of free wire outside the cabinet, and make sure both speakers are connected the same way to the color-coded wire. After the wires are

installed, fill the drilled hole for the wires with a mixture of saw dust and wood glue to seal the hole airtight and secure the wire in place.

It is prudent to cover the front of the speaker with a piece of stiff cardboard secured by masking tape or staples to protect the cone from accidental damage.

Fit several screws to the bottom and top cheeks between the triangular blocks, leaving about an inch protruding at different angles. These will be embedded in the concrete when it is applied and so will hold the resulting concrete wedge in place. Next fill the space between the bottom blocks with cement (not too wet) and bed the trimmed tile onto it. Place the top narrow tile

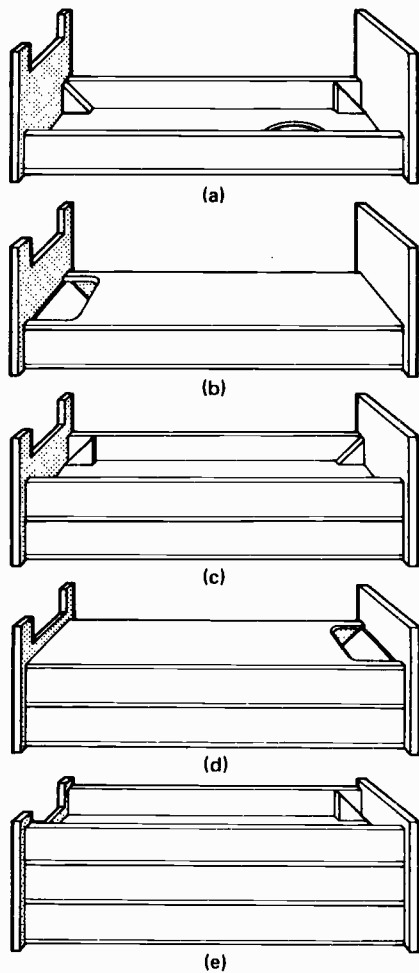


Fig. 26 — The views a through e show the assembly procedure for the Kapellmeister. (a) First stage in construction. The front is glued to the top and bottom cheeks, using 1/4-in. supports to lift front panel to correct position. First pair of side pieces fitted and triangular blocks (small ones at the top) in position. Then apply concrete, fit tiles and lay wadding. (b) Fix in place first baffle, gluing down to insure close fit. (c) Fit second pair of side pieces and four triangular blocks (all blocks installed hereafter are regular size). Install tiles, concrete and wadding. Tuck extra lengths of wadding through aperture into first channel. (d) Fit second baffle in place. Aperture goes at the top. (e) Glue in third pair of sides and last pair of triangular blocks. Fit tile and concrete and install wadding with extra length going into the aperture. Install the back panel (not shown). Refer to text for complete details.

on the blocks and fill in behind it with cement.

Fifth Stage. Saw suitable lengths of 1-2-inch round molding (quadrant) and glue into the corners between the front panel and the sides. If they are warped they should be held in place with panel nails. Glue two additional strips of 1-2-inch round molding at the top inside edge of the sides and nail in place.

Cut three lengths of 1-inch thick acoustical wadding to size and lay them in the cabinet so that two start at the bottom of the speaker, and the third lies over it to the top of the case. (You can substitute roof/wall glass-foam 3-1/2-in. insulation for the acoustical wadding. Remove the insulation from its paper backing.) Fill the space above the speaker with a rolled up piece of wadding. Do not compress the wadding. Make

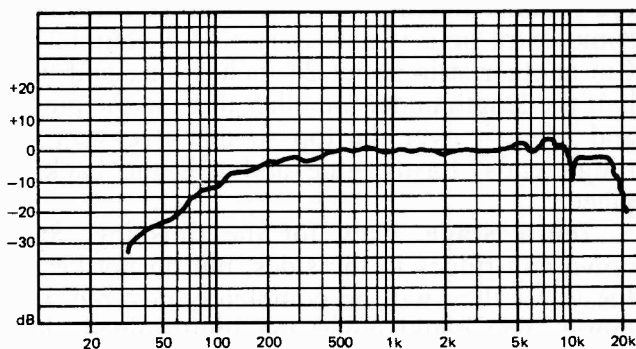


Fig. 27—Curve of the Kapellmeister speaker system frequency response. Some bass boost by the amplifier will straighten the curve at the low end.

the lengths a few inches longer so that they bend up at the bottom over the tile. Drops of wood glue or any quick-drying cement will hold the wadding in place.

Now fit the first baffle with the cut-out at the bottom, gluing to the top edge of both the sides and the upper 1/2-inch round molding surface. Also glue to the top and bottom cheeks. Secure with wood panel nails to ensure a close fit as (b) in Fig. 26. Next, fit the second pair of side pieces and two pairs of blocks top and bottom, (see c). Fit 1/2-inch round molding to corners as with the first channel, also to top edges of the sides; wait for all the glue to dry.

Sixth Stage. Fit the tiles and cement as with the first pair, not forgetting to use concrete-securing screws to top and bottom cheeks in the area to be filled with concrete. This time the top one will be bedded and the bottom one rear-filled. Wait for the concrete to set.

Seventh Stage. Cut two pieces of acoustical wadding about 18-inches long and push half the length of each up the lower channel through the cut-out, and lay the other half length back along the top channel. Now lay three full length strips

over these along the complete upper channel. This gives the extra density at the first bend needed to dampen the third-harmonic antinode.

Next comes the second baffle which is glued and nailed as the first but with its cut-out at the top as shown at (d). Fit the third and final pair of sides, also the last pair of blocks plus the 1/2-inch round molding in the corners and top edges, see (e). Allow glue to harden,

Eighth Stage. Now for the last tile, again not forgetting the screws in the top to secure the concrete wedge. Mount the tile on the blocks using wood-panel nails to keep it in place; this will be easier if the enclosure is stood vertically upside down. Return to the assembly to the horizontal, and fill in rear with cement. Wait until set.

Ninth Stage. Lay three strips of wadding in the channel making sure the bend is filled. Put some extra here if necessary to fill completely. Cut another strip about 24-inches long and tuck half the length under the other three at the outlet, and bring it over the top so that it covers the rough ends. Lastly glue and nail the back in place.

Tenth Stage. Now for the finishing. Sand down any ridges in the sides, but do not be too fussy, for they will be completely covered with fabric. You could cover the multi-joined sides with a wood veneer, but it is not mandatory.

Check carefully for any cracks or crevices in the jointing and fill with the wood glue. Sand, then stain or varnish the top cheek and the edges of the bottom one; there is no need to do underneath unless you are fussy. Paint the body with flat black paint including the inside rim of the loudspeaker aperture, but be very careful not to get any paint on the loudspeaker cone as this would affect its flexibility. The painting ensures that the bare wood does not show through the grille fabric with which the whole body excluding the cheeks is covered.

The two back strips (one for each speaker) should now be cut to fit exactly between the top and bottom cheek rear overhangs. These strips conceal the join in the fabric covering so should be about one-inch wide preferably beveled at both edges to give a good finish. They should be stained or varnished the same color as the cheeks.

Eleventh Stage. Obtain sufficient black speaker grille fabric to cover both speakers. Any other color can of course be used if preferred and is obtainable.

Cut the fabric to the exact size to cover the body between the cheek overhangs, but leave a flap 4 inches longer and 8-inches wide, at the start. Secure the vertical starting edge at one edge of the back of the enclosure with tacks so that the

flap hangs over the bottom. Then pull it around, keeping it taut, overlapping the start and securing it with one of the wooden strips down the middle of the back. This can be done with brass counter-sunk screws with cupped washers which give a professional-looking effect.

Next trim the flap to fit between the prongs of the bottom and fix it across the exit port with staples.

Twelfth Stage. Make or purchase two sets of 2-inch high, wood legs. A single rear one should be made to incline backward under the rear exit vent to give greater stability. They can be stained or varnished to match the rest. The Kapellmeisters are now complete and ready to go into action.

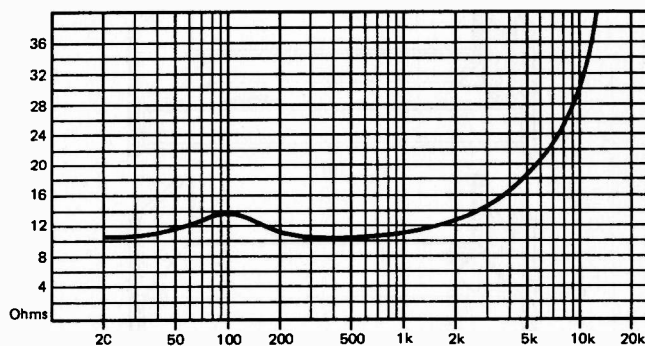


Fig. 28 — The Kapellmeister's impedance curve which is typical of projects using quality loudspeakers.

Performance. As an anechoic room was not available to test the Kapellmeisters, frequency response tests were made with the multiple-microphone-position technique. The test was repeated on the second speaker, and the results were very close, so the plot in Fig. 27 can be considered fairly accurate.

Surprisingly, the treble response is sustained beyond 16 kHz and actually continues up to 20 kHz, a remarkable achievement for a single-driver speaker with no tweeter. This is a tribute to the controlled flexure of the cone and the effectiveness of the high-frequency folded horn inside the cabinet. The undulations are fairly smooth, and some of the vicious peaks and dips encountered with certain multi-driver speakers are notably absent. The response is within 5 dB from 16 kHz to 200 Hz, apart from small deviations at 7 kHz and 10 kHz. There are no phase problems over any part of the range.

Of course the performance varies from loudspeaker type to speaker type, but when you start with a known-good loudspeaker the results will be good.

As expected, the bass is not sustained with a flat response to as low a frequency as would be obtained from a large infinite baffle or reflex

enclosure. The response crosses the -5 dB level at 200 Hz and from there a very gentle descent, but audible output is maintained down to around 36 Hz. Actually, there is a 3-dB drop in the octave 500 to 250 Hz, a 6-dB drop from 250 to 125 Hz, and a 12-dB drop from 125 to 62 Hz and below. This gentle and gradually increasing slope results in a more natural and musical bass than when the roll-off is lower, but steeper. A further advantage is that this curve is ideal for applying a little bass boost at the amplifier. All bass boost controls hinge the response curve upward from a pivotal point at 1000 Hz. Frequencies just below 1000 Hz are hardly affected, but the amount of boost increases as the frequency drops. If bass is boosted with speakers having a steep roll-off, the frequencies just above the roll-off point are lifted to produce a hump, so resulting in a boomy effect. Here, bass boost will lift the curve to give a flatter response without boom.

Thus with a little boost in the bass, the single-driver loudspeaker in an enclosure only 8-inches wide can be made to give a response equivalent to that of a much larger multi-driver speaker, but without the phasing problems and distortions they and the crossover network produce.

The impedance curve is also of interest and is here shown (Fig. 28). There is no large peak in the bass, just a small rise at 100 Hz, which is at the third harmonic of the transmission line resonant frequency.

Bass peaks indicate a high back *emf* generated by a large cone movement at the resonant frequency, even though the acoustic output may be damped by the cabinet design. Often these excursions may be large enough to enter the non-linear region or even strain the cone suspension. In such cases bass boost should be applied cautiously and moderately if at all to avoid speaker damage, quite apart from causing a hump in the response as noted above. Here, having no impedance peak, there is no excessive cone excursion at any frequency and no such restraint is necessary. Bass boost can thus be applied to obtain a satisfactory balance without fear of damage, providing the speaker's power rating is not exceeded.

At the high-frequency end, the impedance curve gradually rises to 60 ohms at 20 kHz. This is not due to increasing cone movement but the increase of the coil reactance with frequency. This means that less power is being taken from the amplifier at these frequencies. As amplifier distortion often decreases with an increase of load impedance, this should present a very easy load for any amplifier, and there should be none of the unexpected problems often encountered when an amplifier takes a dislike to a particular

speaker. Nowhere does the impedance fall below 10 ohms.

An amplifier of just a few watts may be used for full listening impact in a listening room. Five watts per channel should be sufficient and well within the, speaker's 8-watts rating. You can go the full power rating for a larger listening room. The efficiency afforded by the Kapellmeisters allows the opportunity to use a class A amplifier which can easily be designed for low powers such as these.

14 Window Helix Antenna

A low-cost and effective window-mount vertical antenna can be constructed from insulated hook-up wire and PVC (polyvinyl chloride) piping (Fig. 29). A 5- or 6-foot length of 1-inch PVC piping will do well. If you have a tall window you may be able to use a longer length with a secure attachment. A swivel mounting bracket which is attached to the window sill will permit you to tilt the vertical outward away from the window. When you do so be certain to use a guy arrangement at the top of the window (or even a long bracket) to prevent whipping in the wind.

Good performance on the 11- to 19-meter bands is obtained using a helical-wire length of approximately 15.5 feet which is laced through screw eyes turned into the PVC piping. Space the screw eyes to accommodate the overall length of

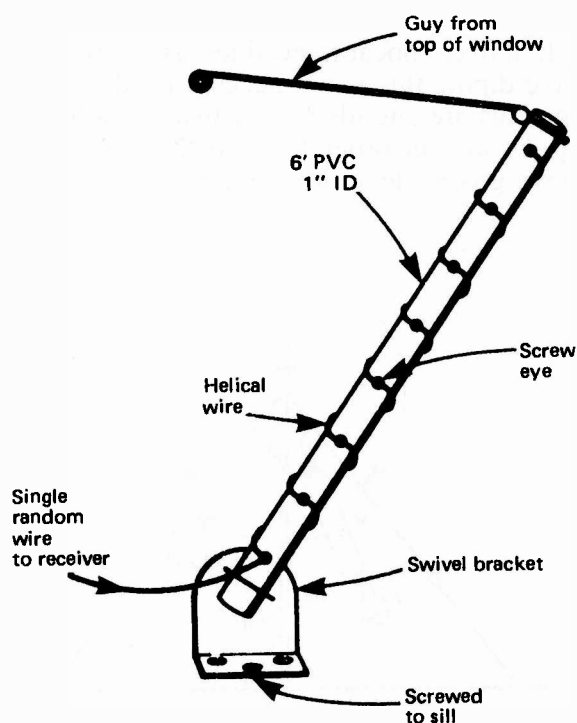


Fig. 29— Construction details for the Window Helix antenna.

wire you plan to use. In place of screw eyes, you may want to cement the wire to the pipe using the glue commonly used to cement PVC pipes together.

A 15.5-foot wire length also resulted in acceptable performance on the 22- to 31-meter bands as well. A random-wire feed was used permitting the position of the helical wire and the wire connecting from the base to the receiver to act as a long-wire so as to improve performance on the lower frequency shortwave bands. A tuner is helpful, though by no means mandatory.

Coaxial feed can also be used. When doing so, connect the outer braid to the swivel bracket.

If you live in an apartment complex where the management objects to window antennas, paint the pipe black so it will be less noticeable and attach a national flag to it. It would be un-American or un-Canadian to ask you to take it down, especially if you first raise the flag on a national holiday.

15 Inverted V Antenna

It may not appear so, but the Inverted V Antenna is really a modified version of the half-wave dipole. Looking at Fig. 30, it should be obvious how the Inverted V name is obtained and its relationship to the dipole antenna.

The Inverted V Antenna configuration has similar characteristics to a half-wave dipole and has the obvious advantage of needing only one mast or other central support. Although at first sight it may appear to need less space than a half-wave dipole this is not necessarily the case. The elements are slightly longer than for a half wave dipole, and in order to keep the elements well above ground level it is either necessary to have

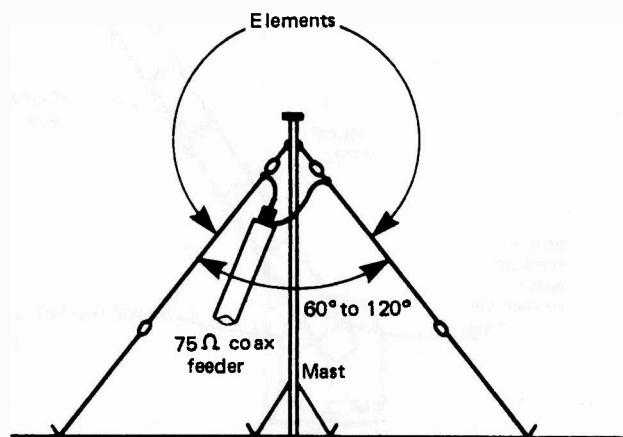


Fig. 30 —The arrangement used for the Inverted V Antenna. The length of one element of the "V" are given in the table.

One-half Length (One Element) of Inverted V Antenna

Amateur Band (Meters)	Antenna Length (Feet)	Amateur Band (Meters)	Antenna Length (Feet)
10	8.40	29.5 (30)	23.98
12	9.74	40	34.45
15	11.45	80	66.50
16.5 (17)	13.39	160	127.79
20	17.13		

Broadcast Band (Meters)	Antenna Length (Feet)	Broadcast Bands (Meters)	Antenna Length (Feet)
11	9.38	41	33.73
13	11.22	49	39.96
16	13.68	60	49.24
19	15.81	75	61.09
22	17.72	90	73.56
25	20.47	120	101.21
31	25.03		

a tall mast (especially for an antennas cut for a low frequency band) or keep the angle between the elements quite large and have very long supporting lines. Angles of the Inverted V are typically 60 to 120 degrees. This type of antenna is probably most suitable for use in situations where suitable supports for the antennas are already available or are easily improvised. For example, antennas of this type are often installed over the pointed roof of a house (but must be kept reasonably well clear of the roof in order to obtain good results).

The length of an Inverted V Antenna in feet is equal to 486 divided by the frequency in megahertz, or in meters it is equal to 148 divided by the frequency in megahertz. This is the total length of the two elements, and must be halved to give the length of each element.

The lists provided below give the element lengths (not the overall lengths) for Inverted V antennas for use on the shortwave, amateur and broadcast bands.

16 Audible Timer

This easy-to-build-timer circuit can be set for any period of minutes, from 1 minute to 7 minutes. A rotary switch is used to select the timing period.

The position to which the switch is set is indicated by numerals marked on the panel. A push-button resets the circuit and timing begins from the instant the button is released. At the end of the period there is a loud audible signal from the speaker. This is an intermittent note for maximum impact against a noisy background. The note continues for 1 minute. As well as the sound

signal there is a high-intensity LED which comes on during the timing period and flashes when the period ends.

One of the advantages of this timer is that it can be set and run in the dark. This makes it suitable for dark-room timing. It is also ideal as a timer for use by blind or deaf persons.

How It Works. The Audible Timer relies on the principle of obtaining a relatively long timing period by dividing down the frequency of a high-frequency astable multivibrator. The chip used for the multivibrator is the well-known 555 timer in its CMOS form (Fig. 31). The frequency is independent of variations in the level of the supply voltage, so the circuit is ideal for battery operation. The preset resistor VR1 allows the frequency to be set to 273 Hz. This provides the alarm tone. The 273 Hz signal is divided by the 14-stage counter IC2. At pin 8 of the counter we obtain a signal at approximately 1 Hz which is used to make the note intermittent. The timing frequency comes from pin 14 of the IC, at which the astable frequency is divided by 2^{14} , or 16384, giving a frequency of 1/60 Hz, or 1 count per minute.

The output from pin 14 is inverted by transistor TR1 and fed to the clock input of a second counter IC3. This is a decade counter with decod-

ed outputs. The outputs of this counter are normally at logical high, except that just one of the outputs is low at each stage of counting. When the counter is reset, output 0 goes high. On the next positive-going clock input, output 0 goes low and output 1 goes high. At each successive high-going clock input the outputs go high in turn from 0 to 7, repeating. The rotary switch S3 selects which of the outputs is to be used to indicate the termination of the timing period.

The circuit is reset by pressing button S2, which resets both counters and also the flip-flop formed by gates IC4a and IC4d. All outputs of IC2 go low. All outputs of IC3 go low, except for output 0, which goes high. Output 0 is not used in the circuit. A low output from one of the other pins of IC3 makes the output of the flip-flop (IC4 pin 3) go high. The output of IC4c goes low. This turns off the npn transistor TR2, which drives the loudspeaker, but turns on the pnp transistor TR3, causing the LED to light.

While the reset button is held, the output from IC2 pin 3 is low, turning off TR1. This means that the input to IC3 pin 14 is high. Counting begins when S2 is released. After 30 seconds, IC2 pin 3 goes high, and the input to IC3 goes low, but this has no effect on IC3. After 1 minute IC2 pin 3 goes low, and the input to IC3 goes high, causing

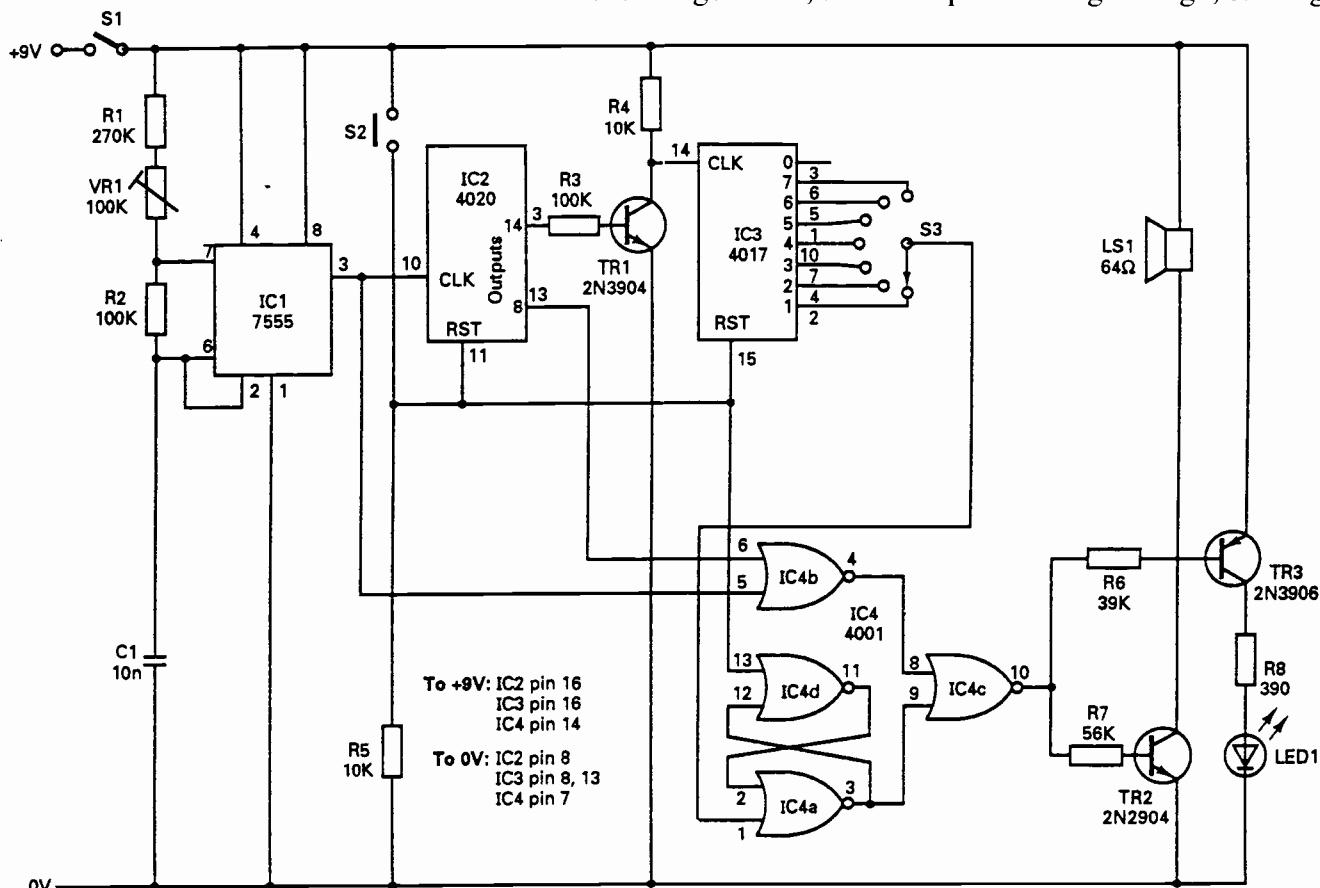


Fig. 31—Circuit diagram for the Audible Timer.

PARTS LIST FOR THE AUDIBLE TIMER

Semiconductors

IC1—7555 timer
 IC2—4020 counter chip
 IC3—4017 counter/divider, 10-line output chip
 IC4—4001 quad 2-input
 LED1—Light-emitting-diode, high-intensity red
 TR1—2N3904 transistor, npn
 TR2—2N2904 transistor, npn
 TR3—2N3906 transistor, pnp

Resistors

R1—270,000-ohm, metal-film
 R2—100,000-ohm, metal-film
 R3—100,000-ohm
 R4, R5—10,000-ohm
 R6—39,000-ohm
 R7—56,000-ohm
 R8—390-ohm
 VR1—100,000-ohm linear-taper potentiometer

Additional Parts & Materials

C1—1-nF, polystyrene capacitor
 LS1—Loudspeaker, sub-miniature, 1.5-in. dia., 64-ohm
 S1—Switch, s.p.s.t. (on/off), toggle or slide
 S2—Switch, push-button, non-locking
 S3—Switch, rotary, 7 positions minimum
 9-volt transistor-radio battery, battery connector, plastic case, wire, perf-board, solder.

this counter to advance one count. Its output 1 goes high. The counter is incremented every minute until the output selected by S3 goes high.

The high level from the selected output sets the flip-flop. IC4 pin 3 goes low. This makes pin 9 low, allowing the signal reaching IC4c from IC4b to pass through to TR2 and TR3. This signal consists of the logical NOR of the astable signal (273 Hz) and the signal from output 8 of IC2 (1 Hz). The result is a note at 273 Hz, pulsing at the rate of 1 Hz. This is heard from the loudspeaker. The LED flashes on at the same time. Since the mark-space ratio of the astable output is high, the LED is turned on at almost full brightness during the on periods.

Construction. This circuit requires only a small current and is powered from a 9-volt transistor radio battery. Assuming that a small (1.5-in. diameter) loudspeaker is used, it can be housed in a small plastic case with the circuit. The parts can be assembled on a perf-board or some other pre-drilled board with holes on a 0.1-in grid. For stability of timing, and minimum effect of temperature, use metal-film resistors for R1 and R2 and a polystyrene capacitor for C1.

Assemble the astable circuit and the first counter (IC1 and IC2). Check that all outputs of IC2 go low when S2 is pressed. When S2 is released, a voltmeter shows that the output at pin 13 is approximately 1 Hz and that pin 3 changes from high to low or low to high every 30 seconds. Adjust VR1 to obtain this timing. While the

remainder of the circuit is being built, it is convenient to use the output from IC2 pin 1 to drive TR1. The signal there runs at 1/15 Hz thus saving prolonged periods of waiting while testing the circuit.

Wire up TR1 and IC3, and test their operation, then complete and test the remainder of the circuit.

17 Long-Interval Alarm Timer

The Long-Interval Alarm Timer is capable of timing intervals of hours or even days. The maximum interval is two weeks. The timer sounds an alarm when the selected interval has elapsed. In addition, it sounds a different alarm if any attempt is made to turn it off before the end of the interval. In this way the unit can convey two messages: "Interval still in progress!", and "Interval finished!". While it is timing, the unit uses very little current (2.5 mA) so it is suitable for battery operation over prolonged periods.

The circuit was intended as a pill-box reminder, though it has other applications. If you have to take pills regularly, it is all too easy to forget exactly when the next dose is due. Conversely, it is easy to forget that a dose has been taken only recently and taking a second dose too soon could have undesirable effects, if nothing less than wasting money on expensive medicine.

The Long-Interval Alarm Timer can not prevent a person taking out too many pills when the pill-box is opened, neither can it make sure that the person actually swallows the pills removed, but, with intelligent use, it is a helpful personal prompter.

Pill Box. The circuit is housed in a small box serving as the pill-box. A micro-switch activated by the lid of the box lets the circuit know when the box is opened. The warnings are given by an audible sounder and by a pair of flashing LEDs. Shutting the box (presumably after having taken a pill) starts the long-period timer; both LEDs are out and there is no alarm sound. If the box is opened before the next time that a dose is due, an urgent high-pitched alarm sounds, bleeping rapidly, and the red LED flashes. This warns the person that it is not yet time for a pill. The person shuts the box, the sounder and LED cease their activity, and timing continues unaffected by the action of opening the box. When a dose is due, a slower, deeper bleeping note is heard and a green LED flashes. This continues until the box is opened.

The LEDs are of different shape, the red one

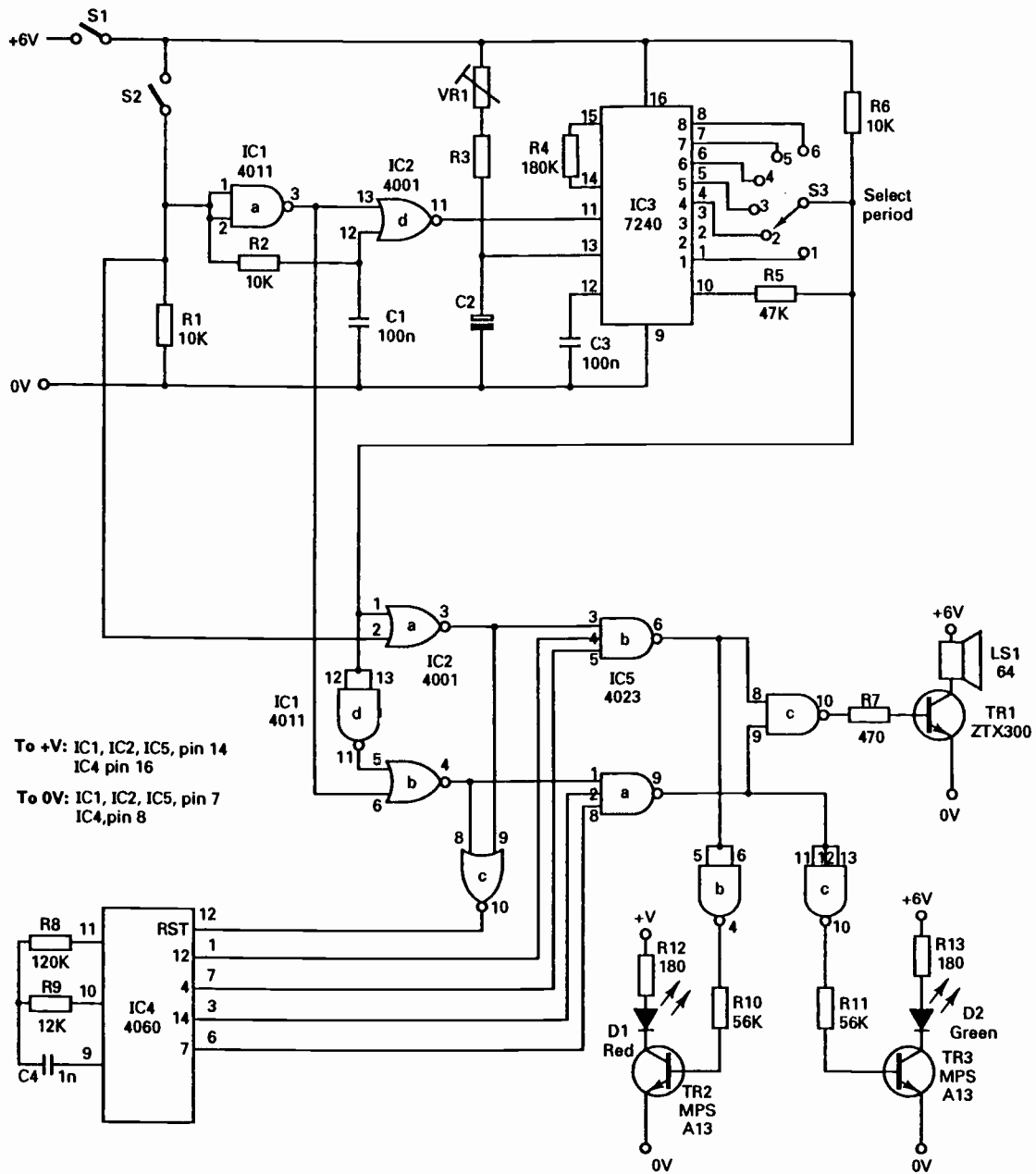


Fig.32—Circuit diagram for the Long-Interval Alarm Timer.

being triangular to reinforce the warning message. The difference of shape avoids the risk of confusion by color-blind persons.

How It Works. This project is based on the 7240 CMOS programmable timer chip (IC3), which has an accuracy of 0.5%. It contains a time-base generator, the frequency of which is decided by a resistor and capacitor (R3/VR1 and C2 in Fig. 32). The basic time period is RC sec-

onds; so, given that the maximum value of R is 10 Megohms and the maximum value of C is 1000 μ F, the maximum time period is 10,000 seconds, or 2.8 hours. IC3 also has an 8-stage binary-divider chain. The total period available is 27 times the above, which is just over 14 days. But, as explained below, there may be practical problems in obtaining the very longest periods.

In Fig. 32, S1 is an optional power switch. S2

PARTS LIST FOR LONG-INTERVAL ALARM TIMER

Semiconductors

D1—Light-emitting diode, red (see text)
 D2—Light-emitting diode, green (see text)
 IC1—4011 2-input NAND chip
 IC2—4001 2-input NOR chip
 IC3—7240 CMOS programmable timer chip
 IC4—4060 14-stage counter with oscillator chip
 IC5—4023 3-input NAND chip
 TR1—ZTX300, SK3854 or ECG123AP,
 TR2, TR3—MPSA13 high-gain Darlington

Resistors

R1, R2, R6—10,000-ohm
 R3—See text to determine value
 R4—180,000-ohm
 R5—47,000-ohm
 R7—470-ohm
 R8—120,000-ohm
 R9—12,000-ohm
 R10, R11—56,000-ohm
 R11—56,000-ohm
 VR1—(See text)

Capacitors

C1, C3—1- μ F
 C2—(See text)
 C4—1-nF

Additional Parts & Materials

B1—Battery consisting of 4 AA alkaline cells and holder
 LS1—Loudspeaker, 1.5-in. dia, 64-ohms (approximately)
 S1—Microswitch, normally-open (See text)
 S2—Rotary switch, miniature, non-shorting, 6 (or more) positions
 Plastic case, 4- x 2.5-in. circuit board builder fabricates, knob, wire, solder, etc.

For a single-period timer, omit S3 and wire the chosen output directly to the junction between R5 and R6.

The first stage of the logic consists of two NOR gates and a NAND gate wired as an inverter (part of IC1, 4001). These gates detect the two alarm states. Gate IC2a goes high (at pin 3) when S2 is open (box open) and the IC3 is timing (output low). This is the state of opening the box while the timing interval is in progress. Gate IC2b goes high (at pin 4) when S2 is closed and the output of IC3 is high. This is the state after the end of the interval if the box remains unopened.

A high output on either pin 8 or pin 9 causes a low output from Gate IC2c (pin 10). This makes the reset input of IC4 low. IC4 is a 14-stage counter with its own oscillator, which begins to oscillate when the reset is made low. The oscillator has a period of about 25 kHz, which is divided down to produce 1.6 kHz at pin 7 (high-pitched note), 200 Hz at pin 6 (low-pitched note), 6 Hz at pin 1 (fast bleeping), and 1.5 Hz at pin 3 (slow bleeping). The remainder of the logic consists of gates producing the fast high-pitched bleep signal, which goes to the red LED (D1) by way of transistor TR2, and the slower low-pitched bleep, which goes to the green LED (D2) by way of TR3. Both signals go to the speaker LS1 by way of TR1.

Putting It Together. The project is built on a board only 4 in. (10 cm) by 2.5 in. (6.5 cm). With a miniature loudspeaker, 1.5 in. (38 mm) in diameter, the unit is housed in a reasonably small plastic box. Since it requires only 2.5 mA, the timer runs for about a month on a set of four AA alkaline cells. There are only 3 logic gate ICs, IC1 (2-input NAND, 4011), IC2 (2-input NOR, 4001) and IC5 (3-input NAND, 4023) and all gates are used. The gates belonging to these three ICs are scattered in ones and twos all over the circuit diagram but can easily be identified by their symbols.

Begin with the trigger circuit IC1a/IC2d and timer IC3, and their associated resistors and capacitors. For use as a pillbox timer, with a maximum interval of 8 hours (IC3, pin 8) values for the timing components are $R3 = 3.3$ Megohm, $VR1 = 2.2$ Megohm and $C3 = 47 \mu F$. Use a tantalum capacitor for C3. The tolerance of these is $\pm 20\%$, but VR1 allows timing to be adjusted to accommodate this.

The main problem with tantalum and aluminum electrolytic capacitors is that they have an appreciable leakage current. The effect of this is that charging times tend to be longer than those calculated by multiplying R and C together. As a

is the switch which is closed to initiate timing. In the pill-box application, this could be a microswitch, mounted so that it is closed when the lid of the pill-box is closed. Closing S2 generates a brief low pulse which goes to pin 11 of the timer IC3 and starts the timing. The output of the timer is normally high, but goes low for the whole of the timing interval. The length of the interval is selected by a rotary switch S3. If you have a dedicated version planned for the timer project, you could hard-wire the switch out of the circuit.

Pins 1 to 8 of IC3 are the outputs from the 8-stage divider chain. When the counter is reset they all go high, while timing they go through an inverted binary sequence. Thus pin 1 goes low after the basic time period, while pin 4, for example, goes low after 8 times the basic period. R5 connects the output to the reset terminal (pin 10) so that the counter is reset at the end of the interval. Figure 32 shows only 6 outputs being used; this is sufficient for the pill-box application, but there is no reason why all 8 outputs or any combination of fewer outputs should not be selected.

rule, tantalum capacitors have lower leakage than aluminum electrolytic capacitors. The most commonly available types have a leakage of $0.02 \mu\text{A}$ per volt per μF , with a minimum leakage of $1 \mu\text{A}$. Low-leakage types are available with half this leakage, though such types are not widely stocked. The leakage quoted above is for a capacitor operating at its maximum working voltage; leakage is markedly reduced when operated at a lower voltage. The voltage across the capacitor in this project ranges from 1.6 to 4.2 volt, but the working voltage is likely to be 16 WVDC or even 20 WVDC for a $47\text{-}\mu\text{F}$ capacitor. This helps to keep leakage to an acceptable level. Using a $47\text{-}\mu\text{F}$ tantalum capacitor with resistances totaling 5 megohms or more is feasible. If really long intervals are required, make the resistor slightly less than the calculated value.

Having settled on a suitable value for R3, adjust VR1 until an interval of 225 seconds is obtained with S3 switched to the calibration position, position 1. This gives intervals of 8 hours, 4 hours, 2 hours, 1 hour and 30 minutes from pins 8 to 4. Other values of R3 and C3 may be substituted for other applications.

Next assemble the oscillator circuit, IC4 with resistors and capacitor. A voltmeter monitoring the output at pin 14 confirms that this works correctly when pin 12 is made low. Assemble the rest of the logic and check that the outputs at IC1 pins 4 and 10 and IC5 pin 10 behave as described earlier. Finally, add the transistor switches. TR2 and TR3 are shown in the schematic diagram as single NPN transistors, but the MPSA13 is a high-gain Darlington transistor. High-intensity LEDs are preferred but a red triangular one of normal intensity may be used for D1.

18 Twangy Distortion Unit

A conventional distortion unit has a major effect on the processed signal. Apart from adding distortion products, it also changes the input signal's envelope. In other words, it alters the way in which the volume of each note varies. Normally the output from a guitar-string pluck has a high initial level, but it rapidly falls away to a much lower level, and then decays at a more gradual rate. The envelope of a signal is the all-important parameter that governs its precise character and sound. In the case of a guitar it is the fast attack and quite rapid initial decay that gives the characteristic "twangy" guitar sound.

Clipping the signal from a guitar tends to give an output signal of uniform amplitude right up to the point where the input signal decays away to

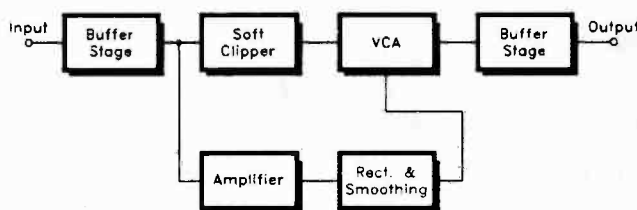


Fig. 33 —Block diagram for the Twangy Distortion Unit.

practically nothing. The fast attack of the input signal is retained, but the rapid fall in amplitude immediately after the attack period is not. This gives a sound which is largely twang free! Even with soft clipping, the amount of compression applied to the input signal is such that the original envelope of the signal is largely lost.

It is possible to produce a distortion unit that retains the original envelope of the input signal, or something close to it. It requires a rather more complex circuit than an ordinary distortion unit, but our Twangy Distortion Unit is reasonably

PARTS LIST FOR TWANGY DISTORTION UNIT

Semiconductors

- IC1—NE5532N, very low-noise, dual-operational amplifier
- IC2—LM13700N or LM13600N, very low-noise, dual-operational amplifier
- IC3—LF351N JFET wide-band operational amplifier
- D1-D8—OA91 diode

Resistors

- R1, R2, R14—100,000-ohm
- R3—1,000-ohm
- R4, R10—10,000-ohm
- R5, R6, R17—3,900-ohm
- R7, R8—470-ohm
- R9, R11, R13—18,000-ohm
- R12—270,000-ohm
- R15—27,000-ohm
- R16—33,000-ohm
- VR1—100,000-ohm, linear-taper, carbon
- VR2—4,700-ohm, miniature, trimmer
- VR3—470,000-ohm, miniature, trimmer

Capacitors

- C1—10-nF ceramic
- C2—1- μF , 50-WVDC, electrolytic
- C3—22- μF , 16-WVDC, electrolytic
- C4—470- μF , 10-WVDC, electrolytic
- C5—10- μF , 25-WVDC, electrolytic
- C6, C7—2.2- μF , 50-WVDC, electrolytic
- C8—1- μF , 50-WVDC, electrolytic
- C9—4.7- μF , 50-WVDC, electrolytic

Additional Parts & Materials

- B1—9-volt, transistor-radio battery and clip connector
- JK1, JK2—Audio jack (select to match audio system cables)
- S1—S.p.s.t., miniature, toggle switch
- S2—S.p.s.t., push-button, locking switch
- 8-pin IC socket (2 required), 16-pin IC socket, control knob, aluminum case, circuit board, wire, solder, etc.

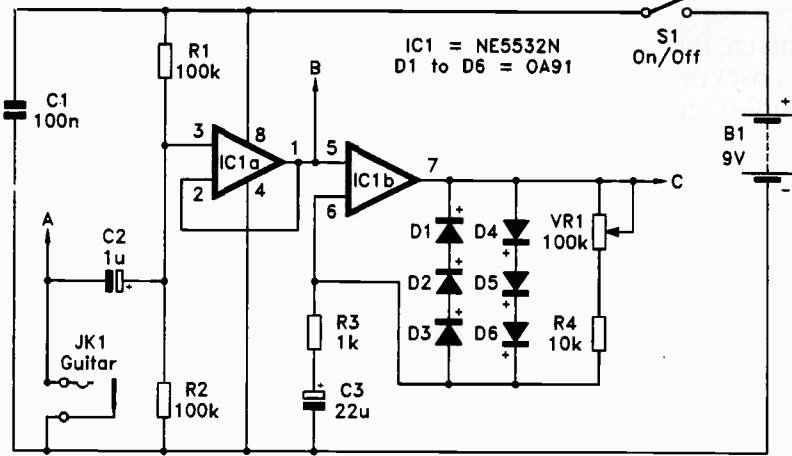


Fig. 34—Circuit diagram for the input buffer and clipping amplifier stages of the Twangy Distortion Unit.

simple and inexpensive to build.

Signal Flow. The block diagram of Fig. 33 shows the arrangement used in the Twangy Distortion Unit. The input signal is applied to a buffer stage, and the signal is then split two ways. The main route is via a soft clipping amplifier, or a hard clipping amplifier can be used here if preferred. The distorted and compressed output signal from the clipping circuit is fed to a voltage-controlled amplifier (VCA), and then to the output via a buffer amplifier. The amplitude of the output signal is governed by the control voltage fed to the VCA. The higher the control voltage to the VCA, the higher the amplitude of the output signal. By feeding the VCA with a suitable control voltage, the output signal can be molded into the required envelope shape.

The control voltage is produced by a side chain which first amplifies the input signal from the buffer stage. The amplified signal is fed to a rectifier and smoothing circuit. This produces a DC output voltage that is roughly proportional to the amplitude of the input signal. Via the VCA, this DC voltage modulates the output signal to give an output envelope shape that is reasonably close to the envelope shape of the input signal. The output envelope is not identical to the input envelope because a few small errors occur in the amplitude control circuits. However, the match is close enough to give the required twangy sound.

The Circuit. Figure 34 shows the circuit for the input buffer and clipping amplifier stages. The circuit for the VCA and other stages is shown in Fig. 35. Taking Fig. 34 first, the clipping amplifier is based on chip IC1b. If hard distortion is required, simply replace D1 to D6 with

a pair of 1N4148 silicon diodes, one diode for each string of three (D1-D3 and D4-D6) connected as in Fig.34; IC1a acts as the input buffer amplifier, and this is a simple non-inverting type which provides an input impedance of 50,000 ohms. IC1 is an NE5532N, which is a very low-noise dual operational amplifier.

A transconductance operational amplifier (IC2) is used as the basis of the VCA. Although this is a form of operational amplifier, apart from differential inputs it has little in common with ordinary operational amplifiers such as the 741C and LF351N. A transconductance amplifier is current rather than voltage operated. The output current is controlled by the differential input current. In practical circuits, including the present one, series resistors at the inputs plus a load resistor at the output effectively convert the device to a form of voltage operation. R10 is the resistor in series with the input signal, and R9 is the output load resistor. C4 plus R5 to R8 are used to provide biasing to the inputs of IC2, and they also provide a center-tap on the supply lines which is

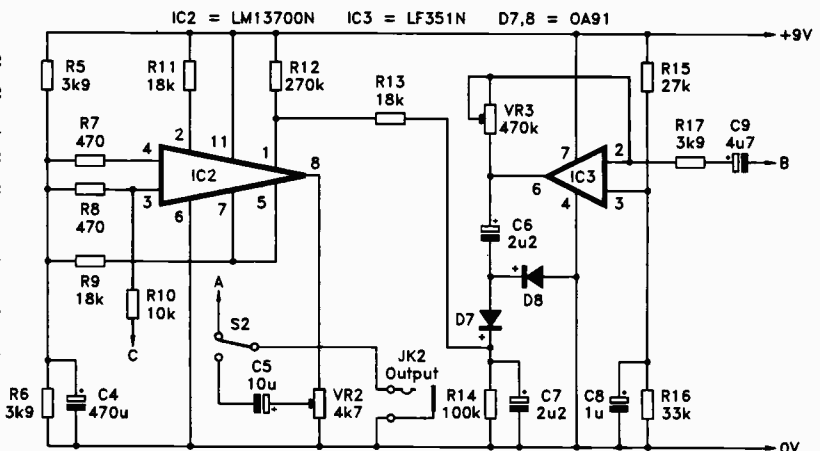


Fig. 35—The circuit for the voltage-controlled amplifier and rectifier stages of the Twangy Distortion Unit.

used as a sort of central ground bus for the output load resistor. Unlike ordinary, operational amplifiers, transconductance amplifiers are often used "open loop". IC2 is certainly used in this manner, and it therefore lacks any form of negative feedback circuit.

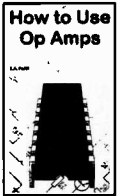
Chip IC2 has a built-in emitter-follower buffer stage which can be connected at the output of the transconductance amplifier. VR2 is the load resistor for this stage, and it also acts as a variable output attenuator. This enables the output level of

Continued on page 107

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MILLIOHM TESTER

Measure low resistances with this super simple circuit that connects to your DMM.

ROBERT A. HEIL

THE MILLIOHM ADAPTER ALLOWS resistances from 1 milliohm to 1 ohm to be measured with a high degree of accuracy on any digital multimeter. The circuit loads the device under test with a current of 100 milliamperes at 5 to 6 volts. The adapter connects to a DMM that is set on its millivolt- or 2-volt scale.

Ohm's law says that resistance equals voltage divided by current, or $R = V/I$. Thus, a DMM reading of 5.7 millivolts would correspond to 0.057 ohms. ($5.7 \text{ mV}/100 \text{ mA} = 57 \text{ milliohms}$ or .057 ohms.)

Circuit description

The milliohm adapter circuit, shown in Fig. 1, is powered from a 9-volt battery. A resistor to be tested (R_x) is connected across banana jacks J1 and J2, and a pair of banana plugs, connected directly to J1 and J2, plugs into the voltage input jacks of a DMM.

Switch S1 applies battery power to 7806 voltage regulator IC1. Capacitor C1 removes voltage transients. Resistors R1 and R2 form a voltage divider for the ground pin of IC1. Potentiometer R2 trims IC1's output voltage to exactly 6-volts DC. Potentiometer R3 sets the output current through R_x to 100 milliamperes. Because R3 is a relatively large resistance compared to R_x , the error introduced by different values of R_x (1 mil-

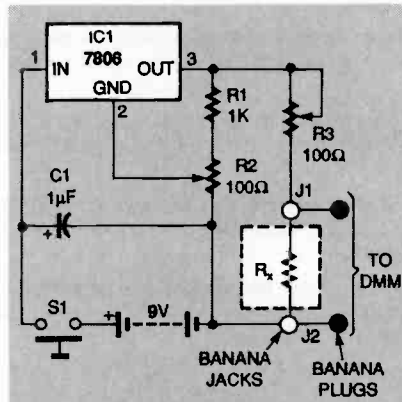


FIG. 1—MILLIOHM ADAPTER CIRCUIT. A resistor to be tested (R_x) is connected across banana jacks J1 and J2, and a pair of banana plugs, connected directly to J1 and J2, plugs into the voltage input jacks of a DMM.

liohm to 1 ohm), or the effect it will have on the 100-milliamperere current source, is below 2%.

Construction

A PC board is available from the source given in the Parts List, but the project is also easy to breadboard. You must select a case for the project before beginning the assembly. The prototype's case measures approximately 2 by 3¼ inches and is about 1 inch deep. The case has an aluminum cover.

A parts-placement diagram is shown in Fig. 2. Stuff the board as indicated, and check your work before continuing. Remove the covers from the ba-

nana plugs and place them into the common and the volt/ohms terminals of your DMM. Dab some petroleum jelly or other similar substance on the ends of the jacks protruding from the DMM. With the lid attached to the project case and facing up, press the upper left back of the plastic case onto the ends of the plugs stuck in the DMM. The petroleum jelly will transfer onto the project case and will mark the hole locations for drilling, allowing the adapter to plug directly into the DMM. Permanently mark those locations before continuing. Then turn the case over and similarly mark

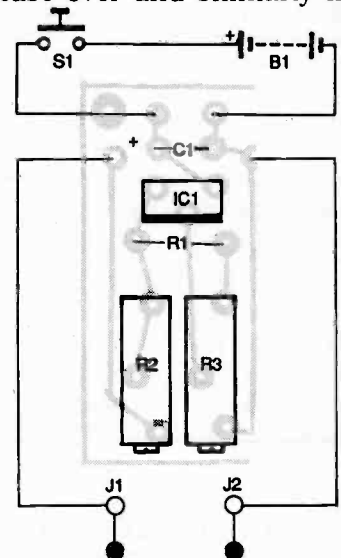


FIG. 2—PARTS-PLACEMENT DIAGRAM. This circuit is simple enough to point-to-point wire.

the locations on the lid of the case for the two banana jacks directly above the holes for the plugs.

Drill appropriately sized holes in the case bottom and lid for the banana plugs and jacks. Be sure to use insulated jacks if your case has an aluminum plug covers. Next install the



THE ADAPTER looks like it was custom made for this meter.

PARTS LIST

- R1—1000 ohms
- R2, R3—100 ohms, 20-turn potentiometer
- C1—1 μ F, disc capacitor
- IC1—7806 6-volt regulator
- B1—9-volt battery
- S1—SPST momentary switch
- J1, J2—banana jack/plug combo
- Project case (Radio Shack No. 270-230 or similar unit), PC board, wire, solder.

Note: the following items are available from RAH Projects, P.O. Box 15904, N.B., CA 92659:

- Etched and drilled PC board—\$3.95 plus return postage
- Parts kit including PC board (no case)—\$10.95 plus \$2.50 S&H

Check or money order, only. California residents please add sales tax. Allow 4 to 6 weeks for delivery. Personal check orders will be shipped after the funds have been cleared.

cover. Solder a 3-inch piece of test lead wire to each banana plug and install them in the bottom of the plastic case with No. 10-32 nuts instead of the origi-

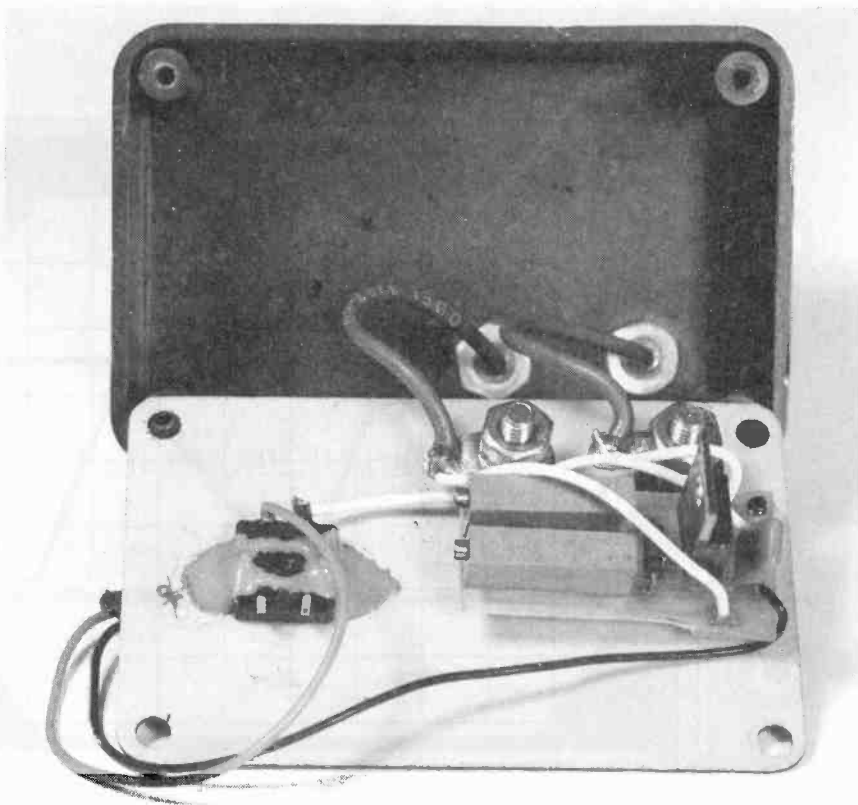
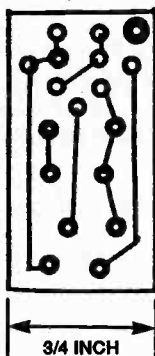


FIG. 3—THE INSIDE of the completed unit. The case is large enough to contain the 9-volt battery.



MILLIOHM ADAPTER FOIL PATTERN.

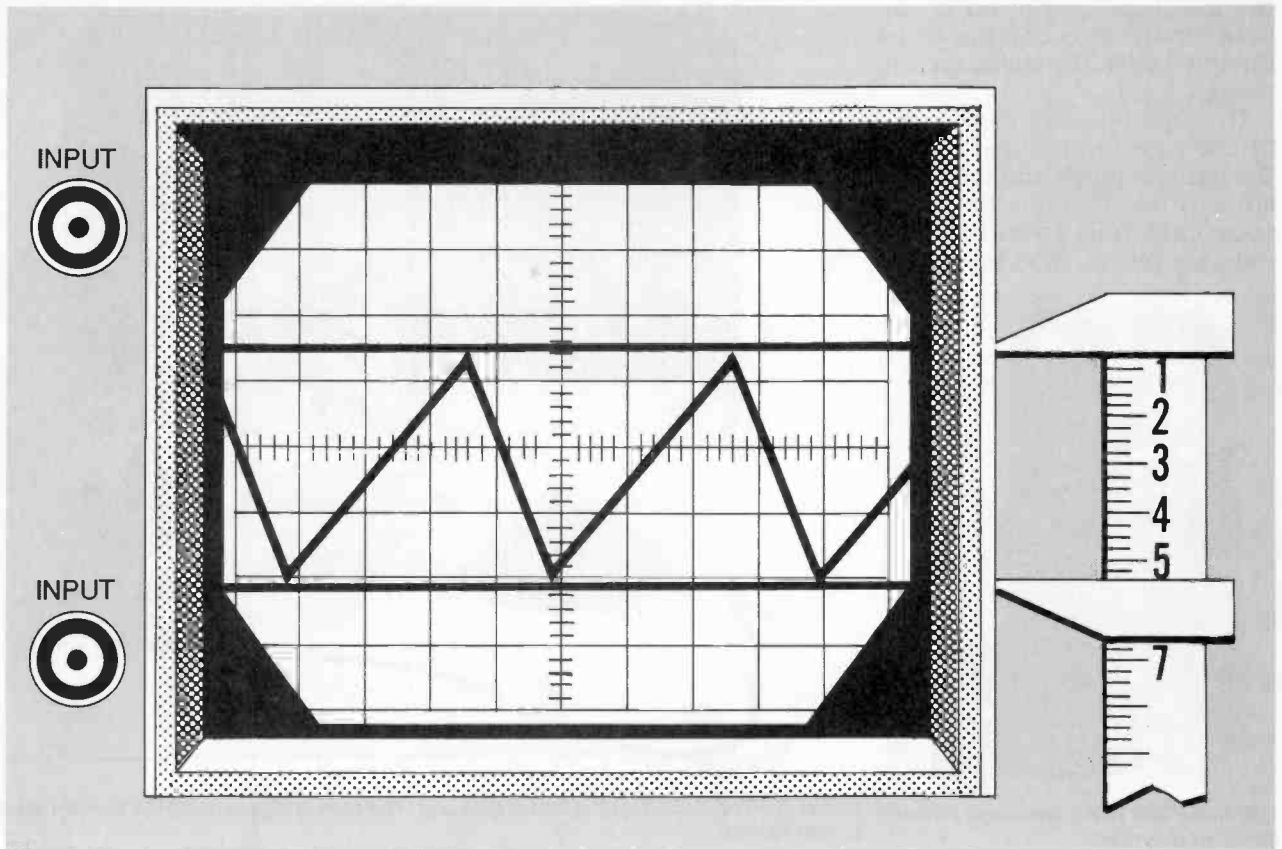
banana jacks in the case cover. Mount the PC board on the cover as close to the jacks as possible. You can secure it with No. 4-40 hardware on one corner with a plastic spacer.

Any momentary switch will work in the circuit, but make sure there's enough room in the case for the 9-volt battery. The battery connector can be made from an old 9-volt battery. Remove the old battery case and cut the leads from the cells to the connector at the top. Solder on new wires, and keep in mind that the small connector is now negative and the large one is positive.

Attach the negative side of the battery to the negative PC board input and the positive side to one side of the momentary switch. Solder another wire from the remaining side of the momentary switch to the positive PC board input. Solder one output from the PC board and one banana plug wire to a spade lug on the back of one banana jack. Do the same for the other jack. Figure 3 shows the inside of the completed unit.

Calibration

With the cover still off, plug the adapter into the DMM and set the range of the meter to 20 volts. Press S1 and adjust R2 for 6 volts DC. Next, place an ammeter across the banana jacks and adjust R3 for a reading of 100 milliamperes. To calibrate the circuit when used in conjunction with test leads, short circuit the leads together and write down the reading; then subtract that reading from any readings you take with the test leads. Now get out that junkbox and start testing those components with unknown values. Ω



VOLTAGE CURSOR ADAPTER

Measure the voltage values of waveforms accurately and easily on your oscilloscope with the Voltage Cursor Adapter.

HAVE YOU EVER HAD TROUBLE MEASURING the voltage value of a waveform on an oscilloscope screen? Are you tired of counting graticule squares and "guesstimating" those values? If so, you need the Voltage Cursor Adapter. It superimposes horizontal cursor lines on the top and bottom of the waveform—a kind of electronic calipers—to permit direct readout of the voltage value. The cursor lines extend across the entire screen.

The lower cursor (think of it as the floor) is the *zero-volt cursor* and the upper cursor (think of it as the ceiling) is the precision DC *reference voltage*. The cursors can be placed on any parts of the waveform that you want to measure, and the volt-

SKIP CAMPISI



THE CURSOR ADAPTER superimposes horizontal cursor lines on the top and bottom of a waveform.

age can be read directly from a turns counter coupled to a precision potentiometer.

Figure 1 is the schematic diagram for the voltage cursor adaptor. The required 15 to 25-volt power to the circuit can be supplied either by batteries or a wall-mounted AC to 15-volt DC adapter. The author's prototype has a jack that will accept a plug from either the adapter or a battery pack consisting of two 9-volt batteries taped together.

The MC78L12 voltage regulator (IC1) supplies regulated 12-volts DC to the rest of the circuit. The ICM7555 timer (IC2), a CMOS version of the industry-standard 555, drives the CD4066B, a CMOS bilateral switch (IC3). This drive frequency can either be a normal

frequency (NORM) of 100 Hz or a low-frequency (LO-F) of 10 kHz, depending on the setting of switch S1. Set S1 to LO-F for inputs below 500 Hz.

The DC reference voltage supplied to pin 3 of IC3 is set by R3, a 10-turn, 5000-ohm precision potentiometer. The voltage can be read directly from a turns counter dial coupled directly to the potentiometer's wiper. The accuracy of this reading can be 1% or better. Trimmer potentiometer R1 permits the voltage to R3 to be calibrated to precisely 10 volts.

The circuit is calibrated by setting the digital reading on the turns counter of R3 to the

full clockwise position and adjusting R1 for a reading of 10 volts at the wiper of R3 with a digital voltmeter.

Bilateral switch IC3 converts the DC reference to a square-wave with exactly the same wiper amplitude. The square-wave output appears on the common pins 4, 9, and 10 of IC3 and coaxial plug PL1.

Building the adapter

The circuitry is simple enough to be built on an approximately 2 x 3-inch stock predrilled perforated board by point-to-point wiring methods. (The prototype circuit was built on a multipurpose board from

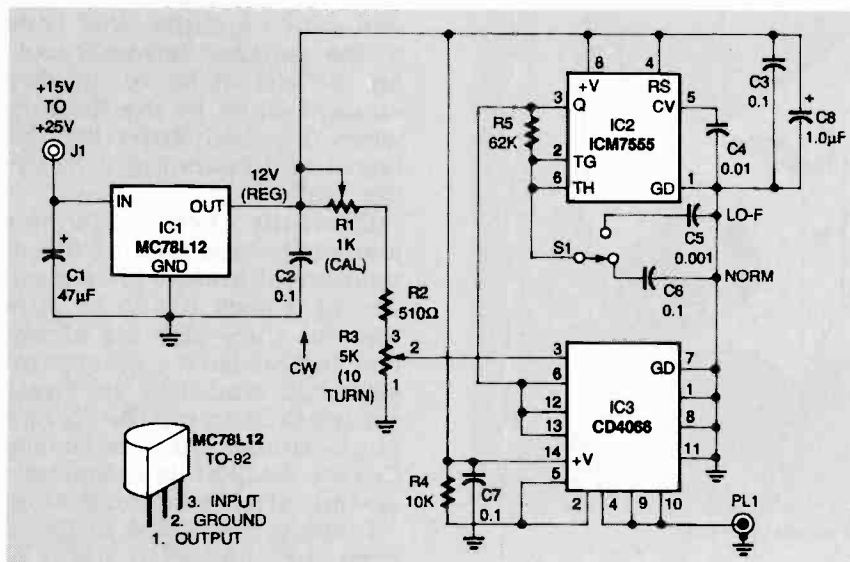


FIG. 1—SCHEMATIC DIAGRAM for the voltage cursor adapter. Power can be supplied by batteries or an AC adapter.

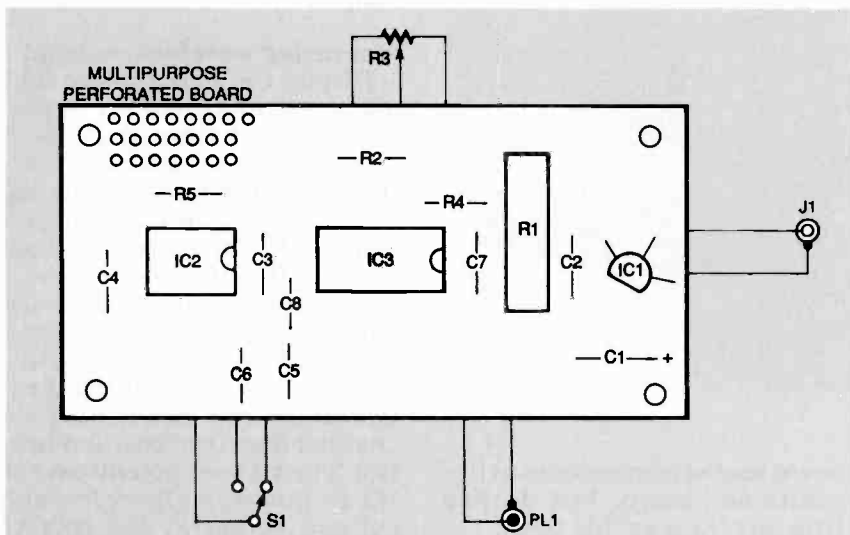


FIG. 2—USE THIS AS A GUIDE for positioning the parts on the perforated construction board.

PARTS LIST

Resistors: all fixed are ¼-watt, 5%

R1—1000-ohm multiturn trimmer potentiometer, Bourns 3005P 101 or equiv.

R2—510 ohms

R3—5000-ohm, 7/8-in. precision potentiometer, ten-turn with matching multiturn dial, Clarostat 73JB with a 15-turn dial or equiv. (See text)

R4—10,000 ohms

R5—62,000 ohms

Capacitors

C1—47µF, aluminum electrolytic, 35 VDC

C2, C3, C6, C7—0.1µF, ceramic

C6—0.1µF, polyester

C4—0.01µF, ceramic

C5—0.001µF, polyester

C8—1.0µF, solid tantalum dipped

Semiconductors

IC1—MC78L12 12-volt voltage regulator, Motorola or equiv.

IC2—ICM7555 CMOS timer, Harris or equiv.

IC3—CD4066B CMOS quad-bilateral switch, Harris or equiv.

Other components

S1—SPDT switch, miniature, panel-mounted, 3A

J1—coaxial jack, panel-mounted (to mate with power plug)

PL1—panel-mounted phone plug 1/8-inch dia.

Miscellaneous: multipurpose perforated board 1²⁷/₃₂ x 2²⁷/₃₂ (Radio Shack 276-150 or equiv.); project case, aluminum, 4 x 2 1/8 x 1 1/2 in. (Radio Shack 270-239 or equiv.); one 8 pin DIP socket and one 14-pin DIP socket; four standoffs with screws, 1/16 inch; two 9-volt batteries with two snap connectors and attached plug or wall-mounted line AC to 15-VDC adapter, 50 mA; insulated hookup wire; solder; screws.

Radio Shack.) There is nothing critical about component selection or placement. Figure 2 is a guide for positioning components on the circuit board.

The prototype was mounted in a two-part aluminum case that measured approximately 4 by 2 by 1 1/8 inches. If you intend to put the circuit in similar project case, use the blank circuit board as a pattern and mark the hole locations on that part of the case with the ends folded up.

It is recommended that both

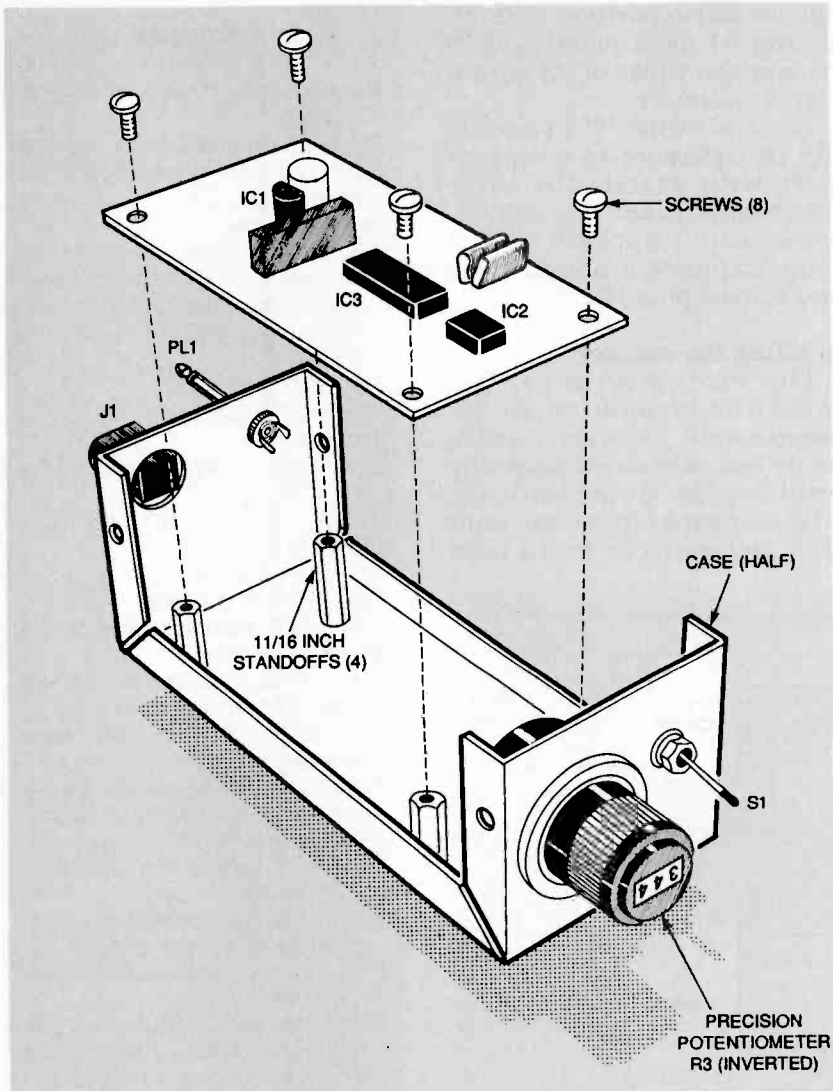


FIG. 3—HERE'S HOW EVERYTHING MOUNTS inside the case.

assembly diagram, and drill the holes that you marked on the case half for mounting the $\frac{3}{4}$ -inch standoffs. Then drill the holes for mounting jacks J1 and J2, precision potentiometer R3 with counter and switch S1 in the case end surfaces.

Mount the jacks, potentiometer and switch on the case half. Cut 3- to 4-inch lengths of No. 22 AWG stranded, insulated, hookup wires for making all connections to the board-mounted components, as shown in Fig. 2. Note: A lower cost counter can be substituted for the digital readout dial used in the author's prototype.

Solder one end of the wires from the jacks, potentiometer and switch and the other ends to the assigned terminal pads on the circuit board, leaving enough slack in the hookup wires to permit inverting the board and fastening it to the case half.

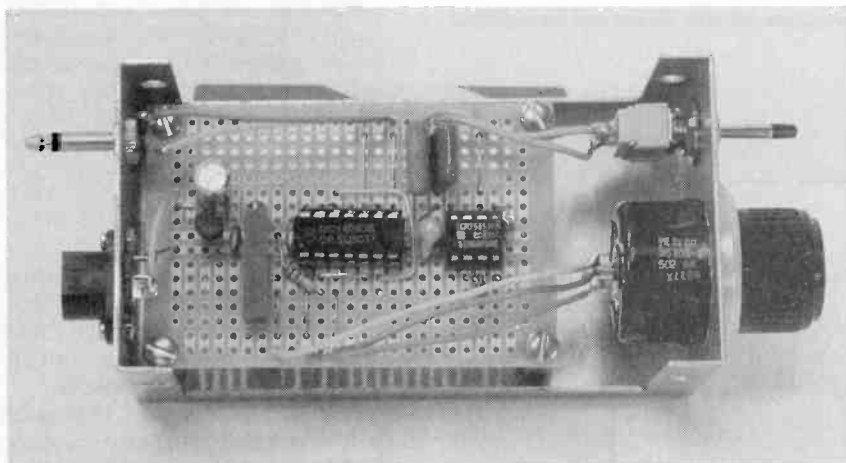
Carefully check all solder joints to be sure they are free of inadvertent bridges or cold soldering. Check IC1 to be sure that the three pins are identified and soldered correctly. Insert IC2 and IC3 in their sockets, observing the correct pin locations. After the Voltage Cursor Adapter is completely assembled it is ready for testing.

Connect the times 10 probe from the channel B input of your oscilloscope to the output plug (PL1) of the Voltage Cursor Adapter.

Measuring waveform voltage

Display the signal whose voltage you want to measure by plugging a lead from the signal source into the channel A vertical amplifier jack of your oscilloscope. Set the triggering on channel A. The output is variable from 0 to 10 volts.

Set your oscilloscope's attenuators to accommodate the 0 to 10-volt range. Using the CHOPPED/ALTERNATE mode, position in the zero cursor with the channel B vertical position control. Then adjust potentiometer R3 to position the *reference voltage cursor* at the correct level on the signal waveform you want to measure. Ω



EVERYTHING FITS EASILY inside the case.

IC2 and IC3 be inserted in sockets. Insert and solder an 8-pin socket for IC2 and a 14-pin socket for IC3, as shown in Fig. 2. Insert and solder all other on-

board leaded components in the positions shown, but do not trim any leads at this time.

Set the circuit board aside. Refer to Fig. 3, the mechanical

MINI LOGIC ANALYZER

AFTER YOU HAVE COMPLETED YOUR latest logic circuit design, you will probably want to build a prototype to test its operation. If the circuit is not complex, a common logic probe is all that's needed to troubleshoot it. However, if the circuit has multiple signals that must be checked for proper time phasing, or if it requires one or more complex driving signals to exercise its operation, then you need a more powerful testing tool.

Professionals use a logic analyzer and function generator to make these tests. Experimenters, hobbyists, and those on a tight budget will want to build the PC Mini Logic Analyzer. It costs only about \$30 to build, but when it is linked to an IBM-compatible computer, it is sufficiently capable for most hobby applications. The PC Mini Logic Analyzer provides up to eight driving signals (outputs) and eight inputs. Each output can be programmed with up to a 64-bit pattern. In addition to its logic analyzer function, the unit can serve double duty as a digital integrated circuit (IC) tester.

The analyzer consists of a hardware interface with applications software. The inter-

This mini analyzer is inexpensive, versatile, and easy to build.

JAMES J. BARBARELLO

face buffers the signals that are sent from the computer's parallel port to the circuit to be tested. It also buffers the signals that are returned from the circuit to the computer, and shifts their voltage levels so that they are compatible with the PC's logic levels. The interface obtains its power from the circuit under test, so it will always recognize the proper logic levels: TTL at 5 volts, or CMOS from 3 to 15 volts. The interface can be connected directly to any parallel port on your PC.

The software displays 64 bits of the eight outputs and eight inputs simultaneously. It allows full on-screen programming of the outputs. Scan time (the time to process the 64 bits) can be adjusted from a high of about 100 bits/second on an average

PC to a low of one bit every 10 seconds. The slower speeds allow you to single step through a circuit and observe how each output bit affects the prototype circuit's operation.

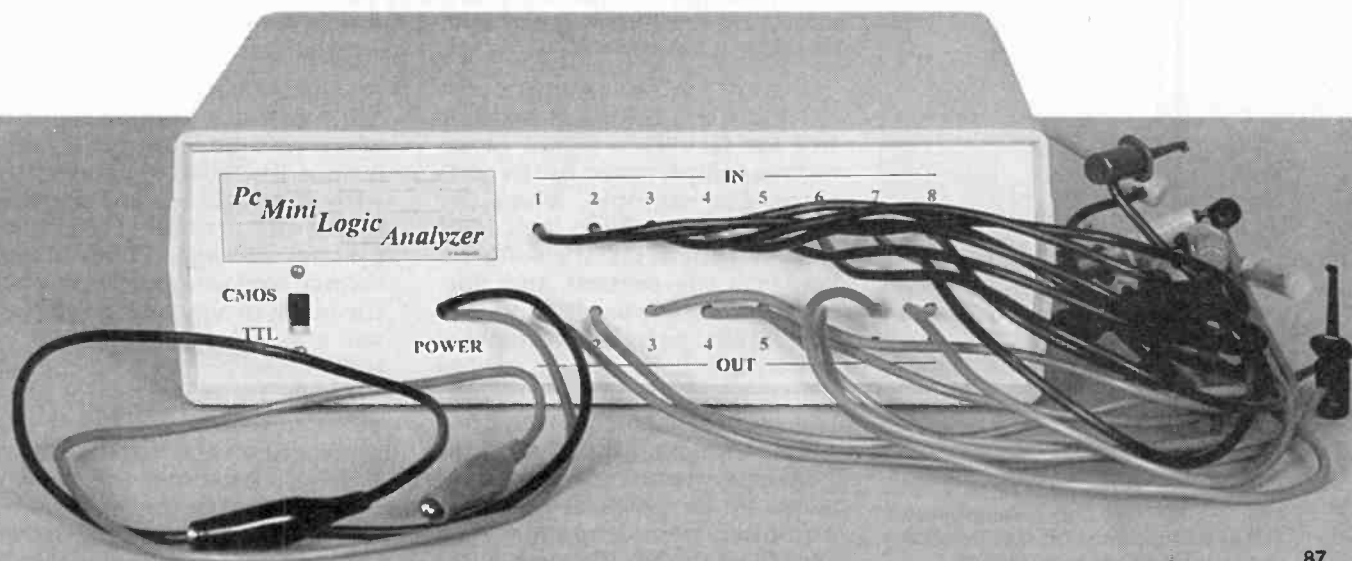
Best of all, the interface circuit is composed of common components, all available from most electronic component suppliers. Although a PC board layout is provided here, it is not essential for proper operation; the circuit can also be constructed on a solderless breadboard.

The hardware interface will be described first, followed by the software. Then, an actual logic analyzer application will be described, followed by an example of how to use the analyzer as a digital IC tester.

Theory of operation

The analyzer incorporates two basic functional blocks; a transistor buffer/inverter section, and an analog switch section that feeds voltage comparators. The transistor buffer/inverter section is shown in the schematic in Fig. 1.

Transistor Q1 in Fig. 1 is configured as a standard inverting switch. A signal greater than



(Q1–Q8) to provide eight outputs.

The second functional block is shown in Fig. 2. Two of the analog switches in a CD4066B CMOS quad-analog switch IC (IC2-a and IC2-b) feed their outputs to the non-inverting input of IC1-d, one of the four voltage comparators in an LM339 quad comparator IC. When the control pin of an analog switch is pulled high, the switch will pass the input signal to its output, also putting from about 50 to 200 ohms in series in the process. When the control pin is brought low, the path between input and output becomes a very high impedance, effectively disconnecting the input from the output.

The signal from pin 1 of the parallel port is inverted twice, once by transistor Q9 and a second time by Q10. Therefore, the control signal for analog switch IC2-b is 180° out of phase with

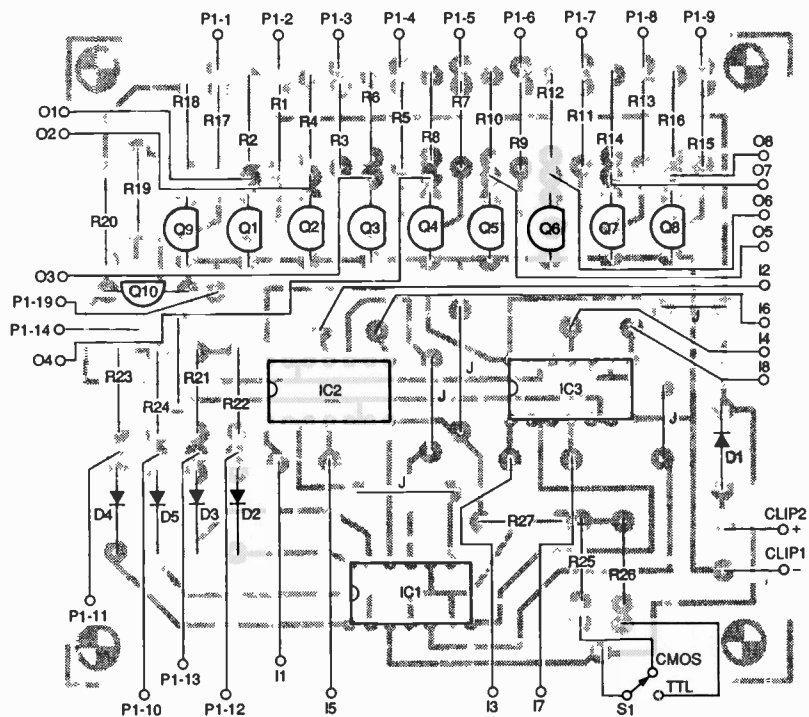


FIG. 4—PARTS-PLACEMENT DIAGRAM. The circuit layout is not critical, so you can use either the PC board or an experimenter's breadboard.

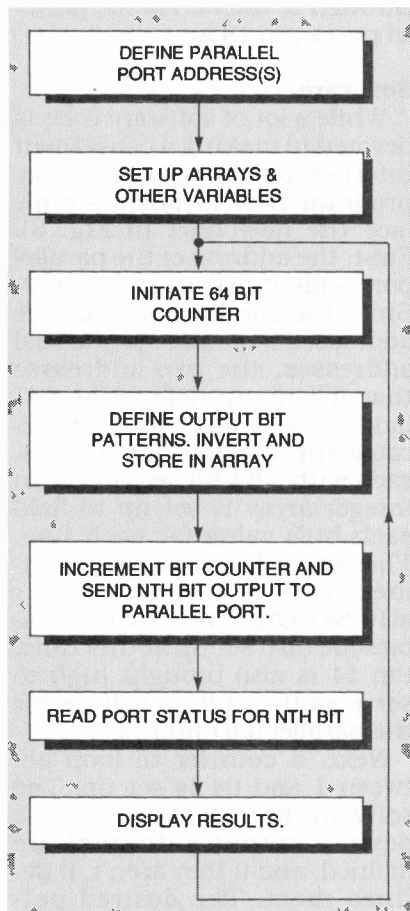


FIG. 3—BASIC PROGRAM FLOW. First, the address of the parallel port that's going to be used is identified and called ad0.

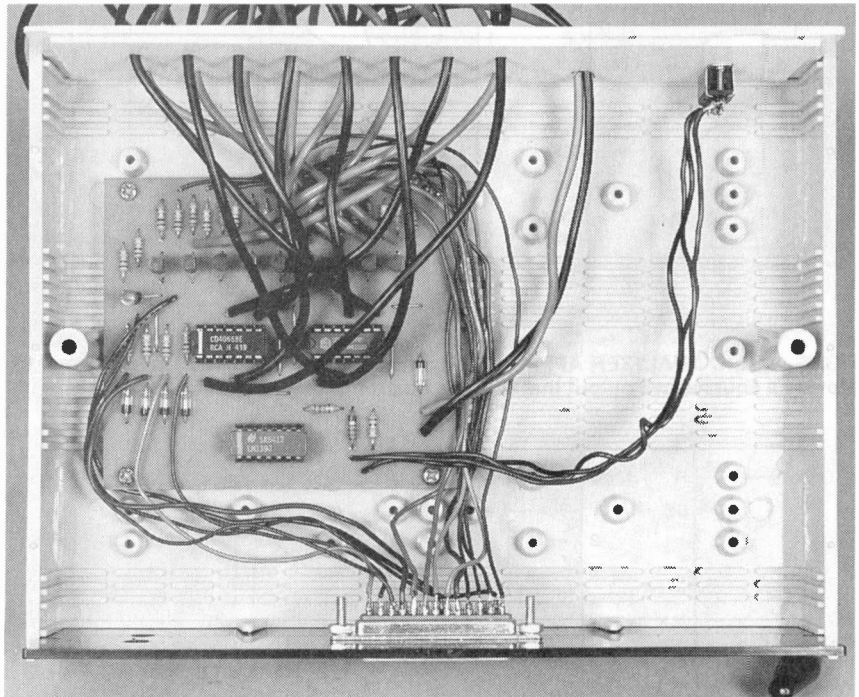


FIG. 5—AUTHOR'S PROTOTYPE. Use micro-clips for the 16 input/output lines, and insulated mini alligator clips for the power and ground leads. Route the wires through holes in the enclosure and attach the connectors.

the signal for IC2-a. With a high signal at pin 1 of P1, switch IC2-a will be on, and IC2-b will be off. Conversely, with a low signal at pin 1 of P1, the switch IC2-a will be off, and IC2-b will be on. This allows the two switch outputs to be connected together (some-

times called a "wired OR"), because only one switch will be on at a time.

Comparator IC1-d compares the signal at its positive input to the reference voltage at its negative input. When the signal is greater than the reference, the

TABLE 1

Connection	Output	Voltage
None	O1	Vbattery-Vdiode
None	O2	Vbattery-Vdiode
None	O3	Vbattery-Vdiode
None	O4	Vbattery-Vdiode
None	O5	Vbattery-Vdiode
None	O6	Vbattery-Vdiode
None	O7	Vbattery-Vdiode
None	O8	Vbattery-Vdiode
O1 to P3	O2	0 to 0.5V (approx)
O1 to P4	O3	0 to 0.5V (approx)
O1 to P5	O4	0 to 0.5V (approx)
O1 to P6	O5	0 to 0.5V (approx)
O1 to P7	O6	0 to 0.5V (approx)
O1 to P8	O7	0 to 0.5V (approx)
O1 to P9	O8	0 to 0.5V (approx)
O2 to P2	O1	0 to 0.5V (approx)

ode. This pulls parallel port pin 13 low when a low signal is provided to the comparator. This arrangement allows signals greater than the 5-volt level of the parallel port to be processed. The analog switch/comparator block is used four times to accept eight inputs and provide them to the four comparators for input into the PC.

The reference voltages for the comparators are created in the voltage divider consisting of R25, R26, and R27. When switch S1 is in its TTL position, the voltage across R27 (provided to the comparators) will be about 2 volts with a 5-volt power supply. With S1 in its CMOS position, the voltage across R27 will be about 70% of the power supply voltage. Those voltage levels correspond to the lower limits of valid high logic levels for those logic families. A common ground reference is provided from the power supply through to the PC via the parallel port's pin 19 and clip 2.

Software

While a lot of software code is devoted to making a convenient interface for the user, the basic program flow is fairly simple (see the flowchart in Fig. 3). First, the address of the parallel port is identified and called ad0. Since the parallel port must be addressed with three sequential addresses, the two addresses that follow are defined as ad1 (ad0 + 1) and ad2 (ad0 + 2). Because the analyzer has 16 lines, each with a 64-bit sequence, an integer array is set up to hold each bit's value for each line. The array has maximum dimensions of 16 by 64, or a(16,64). Other necessary variables are also set up at this time. Pin 14 is also brought high to serve as the pull-up voltage for the parallel port inputs.

Next, a counter to loop between 1 and 64 is set up. The software then makes sure the desired output pattern(s) are defined, and if they aren't, it defines them. The desired patterns are inverted (to compensate for the hardware inversion in the interface transistors) and stored in the integer array. Next,

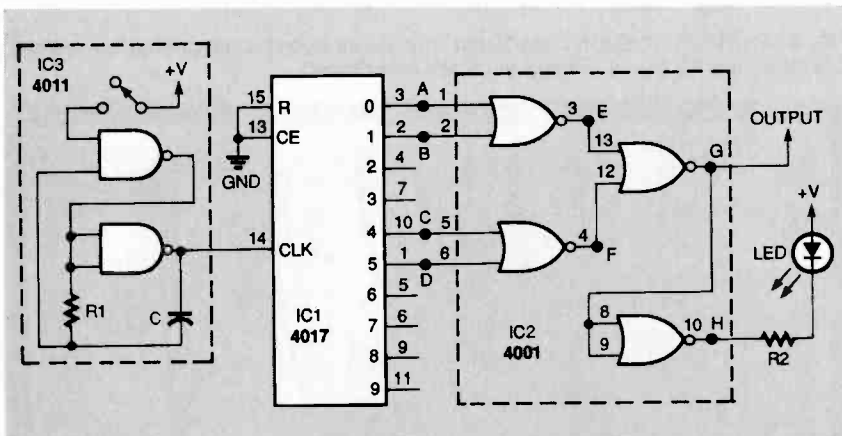


FIG. 6—LOGIC ANALYZER APPLICATION. This self-clocking circuit is supposed to provide a squarewave output that has one quarter of the input frequency.

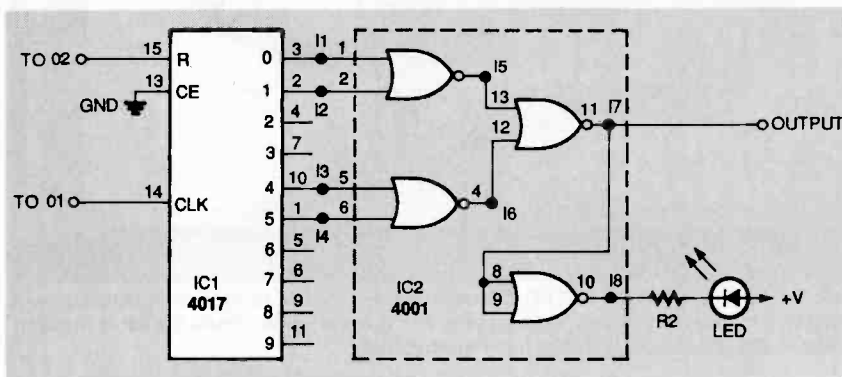


FIG. 7—MONITORING ALL POINTS in the circuit will reveal any problems quickly. Here's the test circuit with the CD4011B replaced by the analyzer.

comparator's output goes high, and blocking diode D2 is reverse-biased. The high output at pin 14 of the parallel port pulls the parallel port pin 13 in-

put high. A low signal from the comparator output allows the parallel port pin to sink voltage from pin 14 into the comparator's output through the di-

LISTING 1

```

REM**** MINITEST.BAS
REM**** QUICK CHECKOUT OF MiniAnal
REM**** V940708 (c) 1994, JJ Barbarello
CLEAR : COLOR 7, 0: CLS
DEFINT A-X: DEFSTR Y-Z: DIM o(8), i(8): DEF SEG = 64
LOCATE 1, 15
PRINT "QUICK CHECKOUT OF Pc MINI LOGIC ANALYZER INTERFACE" LOCATE 2, 1: PRINT
STRING$(79, 220)
LOCATE 5, 15: INPUT "PARALLEL PORT ADDRESS (Enter for default): ", ad0
IF ad0 = 0 THEN ad0 = PEEK(8) + 256 * PEEK(9)
ad1 = ad0 + 1: ad2 = ad1 + 1: OUT ad2, 0: PRINT : PRINT
FOR i = 0 TO 7: a = 2 ^ i
OUT ad0, a XOR 255: GOSUB status1
IF 0 <> o(i + 1) THEN
PRINT "Problem with Output"; i + 1: "(Should be low)"
x = 1
END IF
IF 1 <> i(i + 1) THEN
PRINT "Problem with Input"; i + 1: "(Should be high)"
x = 1
END IF
OUT ad0, a: GOSUB status1
IF 1 <> o(i + 1) THEN
PRINT "Problem with Output"; i + 1: "(Should be high)"
x = 1
END IF
IF 0 <> i(i + 1) THEN
PRINT "Problem with Input"; i + 1: "(Should be low)"
x = 1
END IF
NEXT i
IF x = 0 THEN LOCATE 10, 32: PRINT "INTERFACE TESTS OK"
END
REM***** GET STATUS OF PRINTER PORT PINS *****
status1:
o(1) = INP(ad0) AND 1
o(2) = (INP(ad0) AND 2) / 2
o(3) = (INP(ad0) AND 4) / 4
o(4) = (INP(ad0) AND 8) / 8
o(5) = (INP(ad0) AND 16) / 16
o(6) = (INP(ad0) AND 32) / 32
o(7) = (INP(ad0) AND 64) / 64
o(8) = (INP(ad0) AND 128) / 128
OUT ad2, 0: REM: Pin 1 High
i(1) = (INP(ad1) AND 32) / 32
i(2) = (INP(ad1) AND 16) / 16
i(3) = -(((INP(ad1) AND 128) / 128) = 0)
i(4) = (INP(ad1) AND 64) / 64
OUT ad2, 1: REM: Pin 1 low
i(5) = (INP(ad1) AND 32) / 32
i(6) = (INP(ad1) AND 16) / 16
i(7) = -(((INP(ad1) AND 128) / 128) = 0)
i(8) = (INP(ad1) AND 64) / 64
RETURN

```

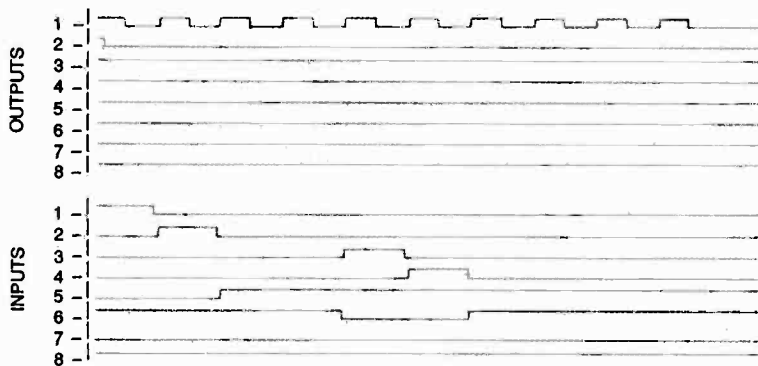


FIG. 8—RESULTING BIT PATTERN. The immediate problem is that the LED does not light, verified in the bit pattern showing that inputs 17 and 18 are not switching.

the bit counter is incremented and the next bit is sent out to the parallel port. The status of

the port is then read and the results are displayed. The software then loops back to the bit

counter, and the input/output process continues. There is more to the actual program code, but the basic analyzer operation is captured in just those few steps.

Construction

The circuit layout is not critical, so you can use either the PC board and parts-placement diagram shown in Fig. 4, or follow the schematic diagram and build the circuit on an experimenter's breadboard. For either assembly method, IC sockets are recommended.

Once the circuit is constructed, and before you begin the final wiring, decide on the case style (if any) for enclosing the analyzer. Because 16 wires and test clips extend from the circuit board, it is wise to choose a wire-coding arrangement that will help you easily recognize each input and output lead.

Use No. 20 stranded hookup wire for the 16 input/output leads, connecting one end to the 16 points identified as O1–O8 and I1–I8. Again using No. 20 stranded wire, connect a red lead to Clip 1 and a black lead to Clip 2, and also connect switch S1.

Decide if you want to have the parallel port cable connected to the board directly, or if you want to add a DB-25 connector. For the integral cable option, obtain 15 four-foot lengths of No. 22 or 24 stranded wire, or a four-foot length of 15-conductor cable. Then use those leads to connect the appropriate points from the circuit board to the pins of a male DB-25 plug. If you use a connector, make the appropriate connections from the circuit board to a female DB-25 socket mounted on the back of the case with wire cut to the size of the enclosure.

The last step is to attach connection devices to the 16 input/output lines and power leads. Use micro-clips for the 16 input/output lines, and insulated mini alligator clips for the power and ground leads. Route the wires through holes in the enclosure and attach the connectors. Complete the assembly

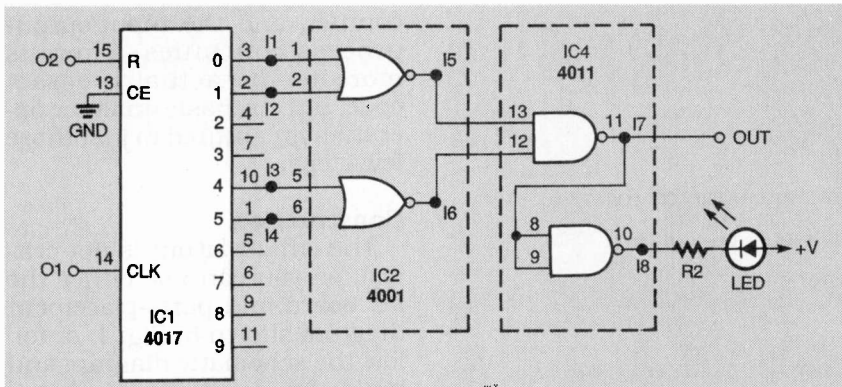


FIG. 9—A NAND FUNCTION will produce a low logic level when the two inputs are high, and produce a high logic level otherwise. Here's the revised circuit.

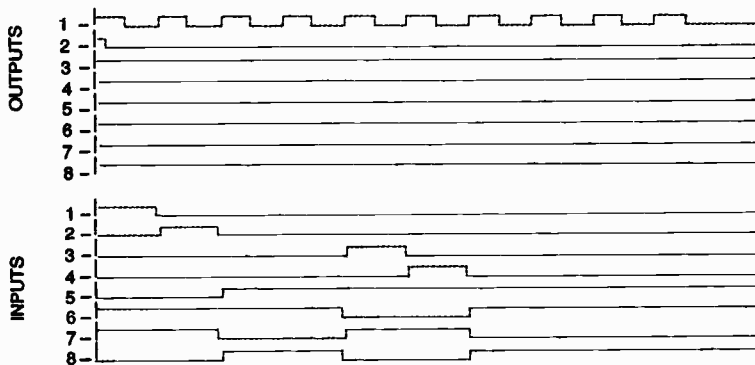


FIG. 10—RESULTANT BIT PATTERN of the circuit in Fig. 9.

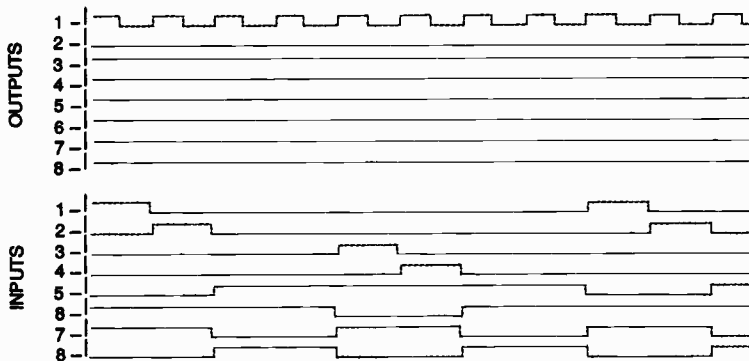


FIG. 11—THE 17 AND 18 WAVEFORMS would both be symmetrical if they ended after the eighth clock pulse. Routing the ninth output of IC1 to the reset pin will do this.

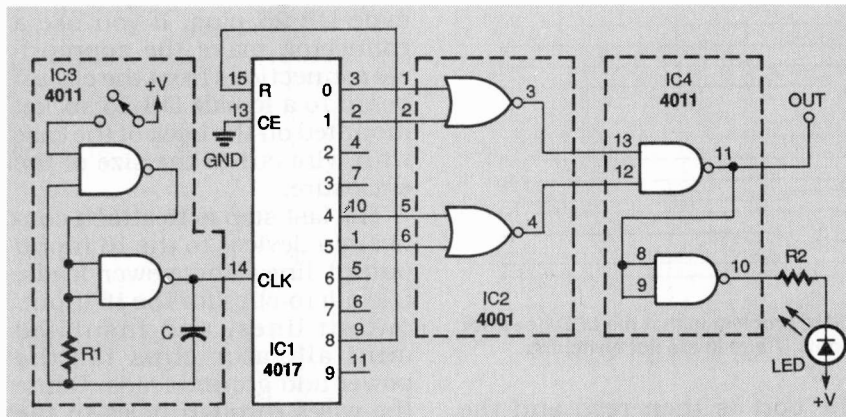


FIG. 12—THIS FINAL CIRCUIT configuration meets all of the original requirements; the output is the input divided by 4, it is symmetrical, and the LED lights.

by mounting the circuit board in the enclosure and mounting S1. Figure 5 shows the author's prototype unit.

Checkout

To test the analyzer, you'll need a 9-volt battery, a voltmeter, and a few jumpers. First make sure that there is no continuity between the board and the eight output leads O1–O8. Then connect the power terminals to the 9-volt battery (red to +, black to –). The voltage between each of the output leads and ground should be the battery voltage less the voltage drop across diode D1. For example, if your battery terminal voltage is 8.9 volts, the voltage at O1 should be about 8.6 volts. The actual voltage is not critical, because the drop across D1 and the individual transistors will vary slightly depending on the actual devices installed.

Next, connect O1 to P1 pin 3; O2 should now read between 0 and about 0.5 volt. Connect O1 to P1 pins 4 through 9 in turn, reading the outputs (O3 through O8 respectively). Finally, connect O2 to P1 pin 2 and read the output at O1. This entire procedure is summarized in Table 1.

To check the interface input circuits and parallel port connections, use the program MATEST.BAS shown in Listing 1. (All of the software for this analyzer project will be made available on the Gernsback BBS, 516-293-2283, v.32, v.42bis, as a file called MINI-ANAL.ZIP) Extract the program MATEST.EXE from the zipped file or type it in by hand and run it from QBasic. Connect each numbered output to its corresponding input (O1 to I1, O2 to I2, etc.). Connect the power leads to a 9-volt battery, and connect the analyzer output to your computer's parallel port. Place S1 in the CMOS position.

The program will use the outputs to create a logic 1 and then logic 0 for each of the eight inputs. It will read the inputs to determine if they were processed correctly. When you execute the program, it will ask you for the parallel port address.

Press ENTER if you're using LPT1 at the standard address of 888. Otherwise, type in the decimal address of the parallel port and

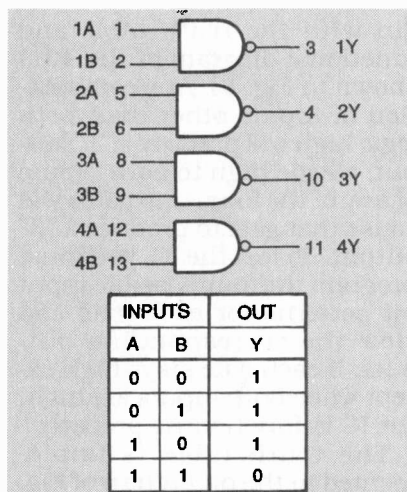


FIG. 13—TO USE THE ANALYZER to check a CD4011B NAND gate, begin with the truth table and functional diagram.

more messages indicating which inputs or outputs did not perform as they should.

Logic analyzer

To use the unit as a logic analyzer, begin with the following sample problem: Assume Fig. 6 is a self-clocking circuit that you designed to provide a squarewave output that is one quarter of the input frequency. The clock can be disabled with an external switch, and the LED should turn on with the rising edge of the clock. If wired as shown, the circuit does not operate properly. Most notably, the LED doesn't flash.

Before testing the circuit, IC3, a simple squarewave generator, must be replaced with one of the analyzer's outputs. If IC3 were left in the circuit, there would be no way to synchronize

programming an analyzer output to produce a squarewave.

Although IC1 is a divide-by-ten counter, the analyzer has a 64-bit pattern that is not evenly divisible by ten. Again to avoid pattern drifting, a second output must be programmed to reset IC1 after ten clock pulses.

Finally, the correct monitoring points must be determined. For the best understanding of circuit operation, all possible points (A through H) should be monitored. The resulting test circuit is shown in Fig. 7.

The bit pattern obtained is shown in Fig. 8. The fault with the circuit was that the LED would not light. The problem is verified in the bit pattern showing that inputs I7 and I8 are not switching. However, the outputs of IC1 are performing as expected, and the outputs of the first two NOR gates (I5 and I6) are also valid. Re-examining the circuit with the help of the analyzer reveals the fault: At least one of the inputs (I5 and I6) to the third NOR gate (I7) is always logic high. That makes the output always logic low. The circuit really needs a NAND function to produce a low logic level when the two inputs are high, and to produce a high logic level at other times. The solution is to change the circuit to incorporate a NAND gate. The revised circuit is shown in Fig. 9, and the resultant bit pattern is shown in Fig. 10.

Replacing the NOR gate with a NAND gate has provided the desired signals at I7 and I8. (The fourth NOR gate was also replaced with a NAND gate arbitrarily—either gate can serve as an effective inverter/current sink for the LED). By looking at the new bit pattern, you might notice another problem. The circuit is dividing by four, but it is not producing a symmetrical squarewave. The pattern is symmetrical through the eighth positive clock pulse (O1), but then stays low for the remaining two clock pulses. In viewing the bit pattern this will be immediately obvious, and it is much better than attempting to watch the LED while determining what's wrong.

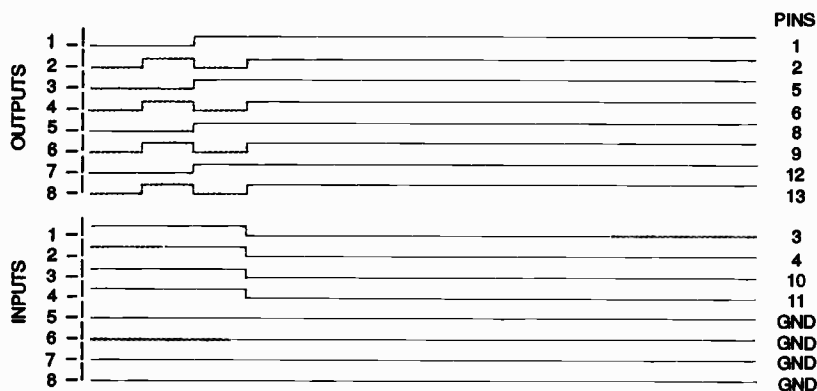


FIG. 14—THE TRUTH TABLE of the CD4011B is implemented in this bit pattern.

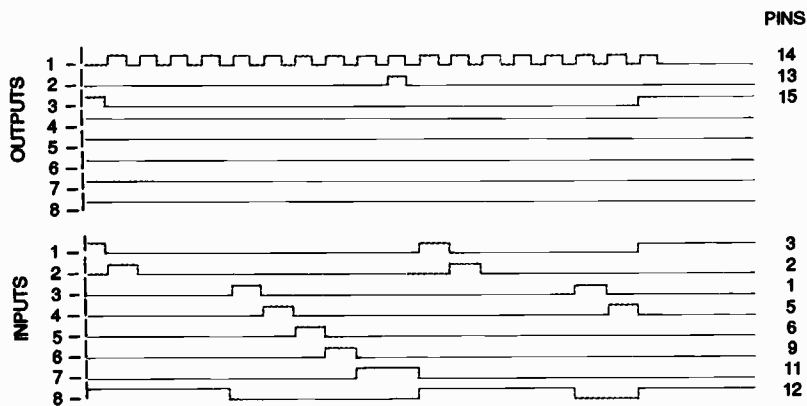


FIG. 15—BIT SCAN for the CD4017B CMOS decade counter/divider.

press ENTER. The program will then test all inputs and outputs, and give you the results. You will either get a message "Interface Tests OK," or one or

it with the analyzer, and the display would drift, resembling an oscilloscope trace without proper sync. The IC3 oscillator is therefore simulated by pro-

PARTS LIST

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

R1, R3, R5, R7, R9, R11, R13, R15, R17, R19-R24, R26—10,000 ohms
R2, R4, R6, R8, R10, R12, R14, R16—2200 ohms
R18—1000 ohms
R25—33,000 ohms
R27—22,000 ohms

Semiconductors

D1-D5—1N34A Germanium diode
Q1-Q10—2N2222A NPN transistor
IC1, IC2—CD4066 CMOS Quad Analog Switch

IC3—LM339A quad comparator

Other components

S1—SPDT switch
P1—Female DB-25 connector and male-to-male DB-25 cable (or use integral cable with male DB-25 on one end, see text)

Clip 1—Red miniature alligator clip

Clip 2—Black miniature alligator clip

Miscellaneous: Sixteen micro clips, three 14-pin IC sockets, 4-foot length of 15-conductor cable or 60 feet of No. 22 stranded wire (see text), No. 20 stranded wire, PC board, suitable case.

Note: The following items are available from JJ Barbarello, 817 Ten-nent Road, Manalapan, NJ 07726:

- PC Board (MA-PC)—\$15.00
- Disk containing both source code and executable file of the mini analyzer program, which includes additional capability for saving and retrieving data, on-line help, on-line directory of files, and more (MA-S)—\$12.00

symmetrical if they ended after the eighth clock pulse. This can be accomplished by routing the ninth output of IC1 (called output 8 because the first one is called output 0) to the reset pin. This will create a divide-by-8 counter instead of a divide-by-10, and it will generate the bit pattern in Fig. 11. Notice that the O2 reset pulse has been removed—it is no longer needed because a hardware reset has been incorporated. Because the circuit divides by 8, and the 64-bit pattern is divisible by 8, the bit pattern is stable, or syn-ments in that the output is the input divided by 4, it is sym-metrical, and the LED lights on the rising edge of the clock.

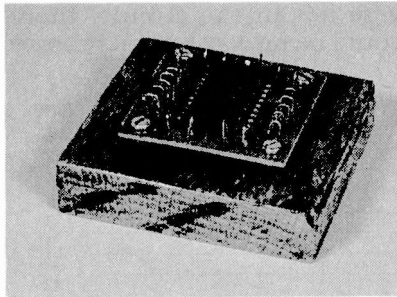
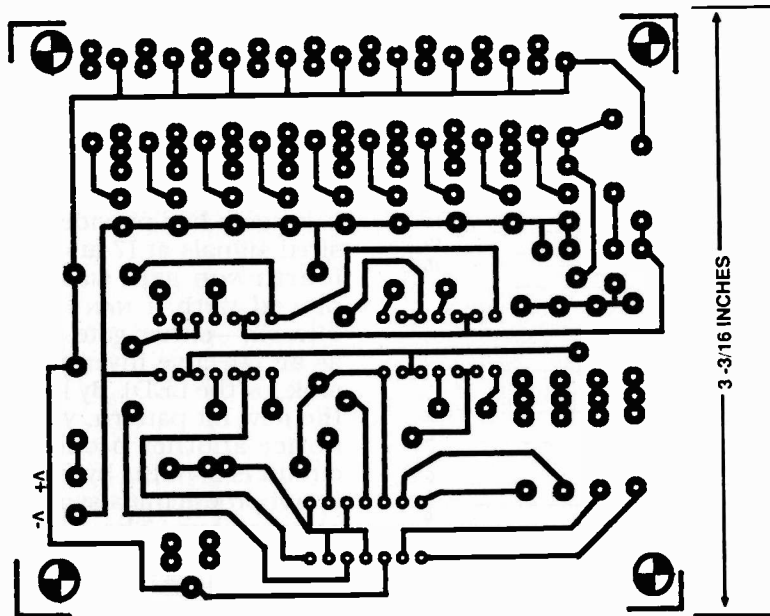


FIG. 16—THIS SIMPLE JIG makes connections to the IC pins easy.



FOIL PATTERN FOR THE MINI ANALYZER.

A look at the I7 and I8 wave-forms shows how to solve the problem. They would both be

chronized. The final circuit con-figuration is shown in Fig. 12. It meets all of the original require-

IC checker

This example will expand on the last example. The analyzer will check for proper operation of the CD4011B NAND gate. Begin with the truth table and functional diagram of the 4011 shown in Fig. 13. Any combina-tion of inputs other than both logic high will produce a "1" out-put; a logic high to both inputs of any of the four NAND gates will cause that gate to produce a "0" output. To test the IC, you must program the four possible input bit patterns for each gate and view the corresponding out-puts. If each gate stays high ex-cept when both inputs are high, the IC is functioning properly.

The truth table is imple-mented in the bit pattern of Fig. 14. Note that the pin connec-tions are indicated to the right of the traces. Inputs 5 through 8 are grounded to avoid stray pickup. Ground any unused in-puts to avoid stray signal pick-up through the high off-impedance inputs of the CD4066 switches. Alternatley, you can attach a pull-down (term-inating) resistor to each in-put. Any resistor value of 10,000 ohms or more will work fine and not load the source circuitry.

Instead of a single bit, a group of bits (five in this case) will be used for each state. Each set of inputs to the 4011 (O1 and O2, O3 and O4, O5 and O6, and O7 and O8) have the same pattern. The first five bits of each set are low. Then the second five bits are low on the first input and high on the second. Then the pattern flips, with the next five bits high on the first input and low on the second. Finally, the bit pattern shifts to both inputs high. In each instance, the ex-pected IC output pattern (I1, I2, I3 and I4) show a high input until the inputs shift to both high. Then the IC output goes low.

A bit scan for the CD4017B CMOS decade counter/divider is shown in Fig. 15. The input bit pattern from a reference book was used directly, except that IC outputs 2, 3, and 4 were not sensed (because the IC has 11 outputs, and the analyzer has

(Continued on page 109)

MAGNETIC FIELD METER

Determine your exposure to line-frequency magnetic-fields with our easy-to-build portable ELF gaussmeter.

REINHARD METZ

IF YOU ARE ONE IN A GROWING number of people who are concerned about the potentially harmful effects of exposure to magnetic fields, you will be interested in this important construction project. Now you can build your own gaussmeter, and determine the magnitude of magnetic flux densities in and around your home. Our handheld, battery-operated magnetic-field meter is sensitive from 0.1 microtesla (μT) to 20 milliteslas (mT), and has a frequency range from 50 Hz to 20 kHz.

Why all the worry?

Magnetic fields are all around us. They occur from the generation, distribution, and use of 50 and 60-Hz electricity, electronic equipment, and even from Earth's magnetic field, which has always been present throughout Man's evolution. Man has been "tuned" into Earth's steady magnetic field of about $30 \mu\text{T}$ (at sea level) for millions of years. Some sources of excessive magnetic fields that have caused the greatest public concern include power-distribution substations, power lines, CRT terminals, and use of appliances.

Magnetic field intensities can vary greatly, depending on the exposure source and the distance from that source. The rate at which the field intensity falls off with distance can vary from one source to another, depending on how well the current-carrying lines are balanced, or how well the opposing lines of magnetic

flux cancel each other out. Fields from coils, magnets, or transformers drop off rapidly with distance by a factor of $1/r^3$. In power lines, if currents flow in opposite directions, the drop-off is $1/r^2$ because of partial field canceling. When unbalanced current exists, the field intensity falls off less rapidly as $1/r$.

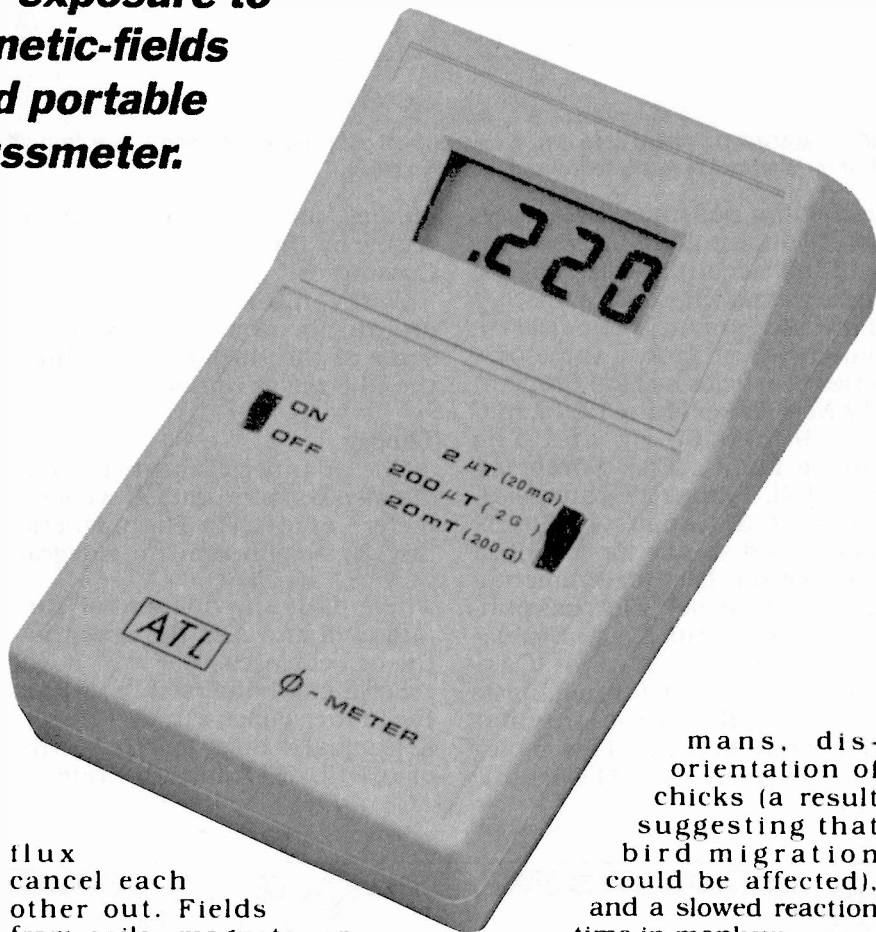
Figure 1-a, -b, and -c show drop-off rates of $1/r$, $1/r^2$, and $1/r^3$, respectively. Figure 2 lists some of the many sources of magnetic field exposure, with their range of intensities and drop-off rates.

Although a great deal of controversy still prevails, many people in the scientific community believe that exposure to magnetic fields of extremely-low frequency (ELF fields of 1-100 Hz) may pose a risk to human health. Some disturbing findings of exposure to ELF fields include a significant increase in serum triglycerides (a possible stress indicator) in hu-

mans, disorientation of chicks (a result suggesting that bird migration could be affected), and a slowed reaction time in monkeys.

A study conducted by epidemiologist Nancy Wertheimer and physicist Ed Leeper, found that exposures to magnetic fields as small as $0.25 \mu\text{T}$ correlated with a rise in cancer rates. In the study, the researchers examined wiring and transformers in the neighborhood of birth homes of children who had died of leukemia between 1950 and 1975, along with those of a control group of children who did not have the disease. The results of their studies were published in *The American Journal of Epidemiology* (March, 1979). Some experts argue that other factors, such as pollution and exposure to chemical carcinogens, make interpretation of those findings very difficult.

Standards for acceptable exposure to ELF fields are emerging, as are results of studies



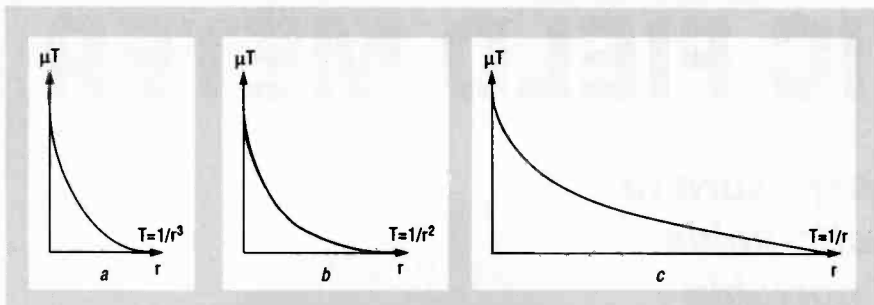


FIG. 1—MAGNETIC FIELD drop-offs. A fast drop-off of $1/r^3$ (a), $1/r^2$ (b), and a slow drop-off of $1/r$ (c) is typical of many sources of magnetic fields.

describing possible hazard levels. If you are more interested a detailed account of scientific findings and the political history of the effects of magnetic-field radiation, we suggest a three-part series of articles by Paul Brodeur, *The New Yorker* (June 12, 19, and 26, 1989). "60-Hz and The Human Body", *IEEE Spectrum*, Parts 1-3, Volume 27, Number 9, pages 22-35 (August, 1990) is also a good source for technical information. The Environmental Protection Agency (EPA) has published a report titled "The Evaluation of the Potential Carcinogenicity of Electromagnetic Fields", publication number EPA/600/6-90/005B. This report contains analyses of 64 scientific

studies, and is currently under review by the Scientific Advisory Committee.

Well, that's enough background for now. Let's examine some of the theory behind how the ELF meter works.

Theory

The quantity of magnetic flux density, \mathbf{B} , is in units of webers/meter², or tesla (T). The magnetic flux, ϕ , is defined by the integral

$$\phi = \int \mathbf{B} \cdot d\mathbf{s} = \mathbf{B} \times A$$

where $d\mathbf{s}$ is the differential surface area and A is the area that the coil encloses.

For a coil immersed in a field, the induced open-circuit voltage, E , is equal to the number of turns of a coil, N , times the rate of

change of flux through it.

$$E = N \times d\phi/dt$$

Note that the value of $N \times d\phi/dt$ is actually negative with respect to the induced voltage value, but for our purposes we will just consider the magnitude of the product. The direction of the induced current is such that its own magnetic field opposes the changes in flux responsible for producing it.

If we substitute for ϕ we get

$$E = N \times A(d\mathbf{B}/dt)$$

If the magnetic field of a sine wave is $\mathbf{B} = a(\sin \omega t)$, a is the amplitude in teslas and ω is the angular velocity ($2\pi f$), then

$$d\mathbf{B} = a\omega(\cos \omega t)dt, \text{ and}$$

$$E = N \times Aa\omega(\cos \omega t)$$

Since $\cos \omega t$ varies from +1 to -1, the peak magnetic field is defined as

$$E = NAa \omega$$

For a frequency of 60 Hz, ω equals

$$2\pi \times 60 = 377$$

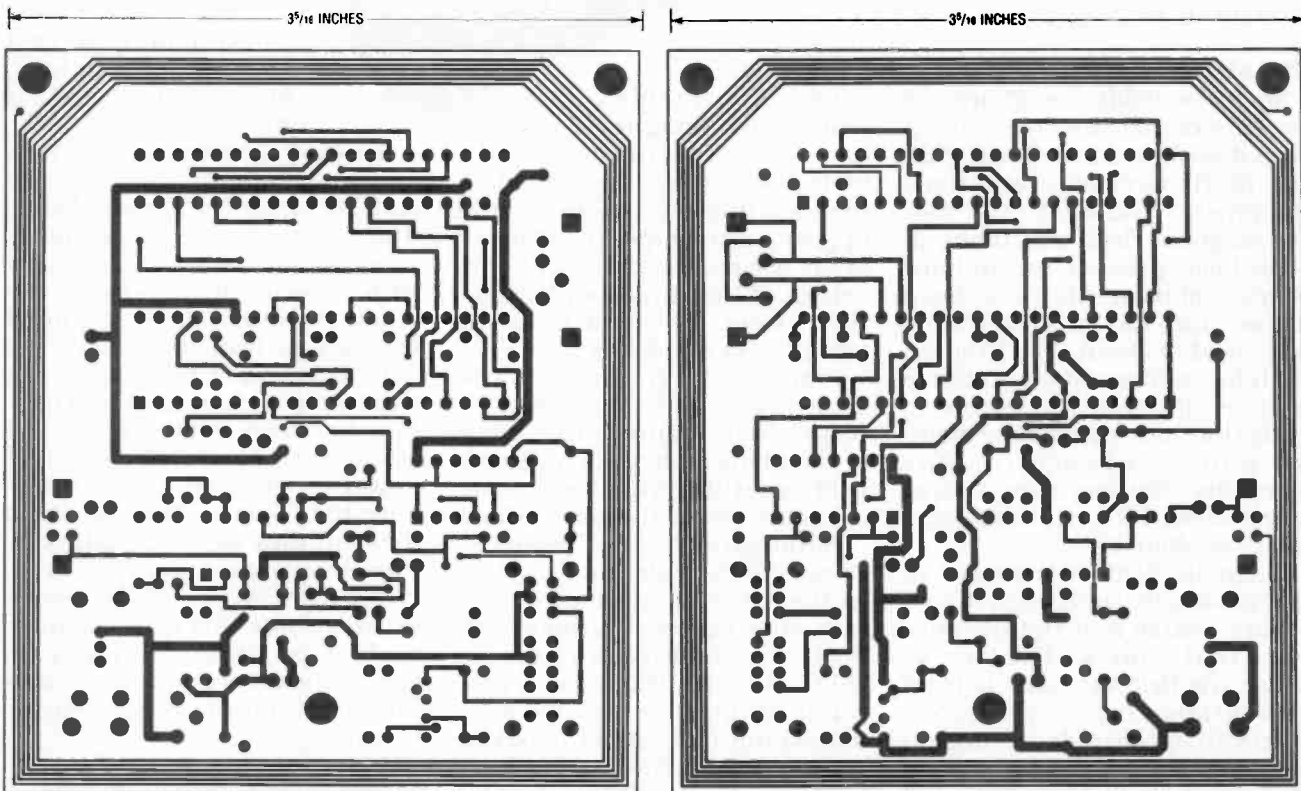
For a coil size of $3\frac{1}{2}'' \times 3''$, the area is .0068 m², and therefore

$$E = 2.56 N \times a$$

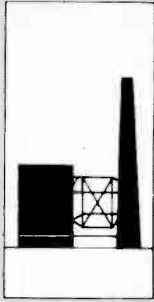
For the 12-turn pickup coil that we'll use, the sensitivity is 30 μV per μT .

Circuit description

The meter's 12-turn field pickup is integrated into the unit's



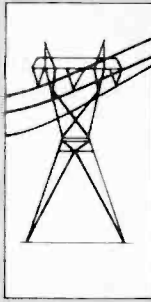
SOURCES OF MAGNETIC FIELD EXPOSURE



POWER GENERATING STATION
(20KV), 3.0mT



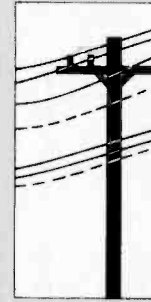
STEP-UP TRANSFORMER
5-20μT



TRANSMISSION LINES
(69-765KV)
5-70μT, WITH
MAGNETIC FIELD DROP-OFF
AT $1/r^2$



STEP-DOWN TRANSFORMER
5-20μT



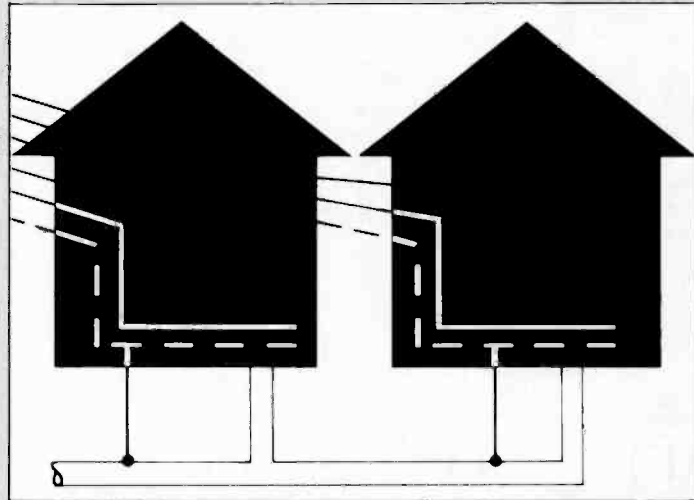
PRIMARY DISTRIBUTION LINES
(4-35KV)
1-5μT, WITH MAGNETIC
FIELD DROP OFF AT $1/r^2$



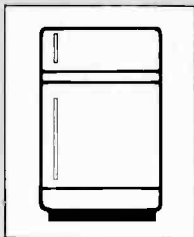
**DISTRIBUTION
STEP-DOWN TRANSFORMER**
0.1-1μT, WITH A
FAST MAGNETIC FIELD
DROP-OFF AT $1/r^3$



SECONDARY DISTRIBUTION LINES
(115/230V)
0.1-1μT, WITH A SLOW
MAGNETIC FIELD DROP-OFF
OF $1/r$ (DUE TO UNBALANCED
PHASE AND NEUTRAL LINES)



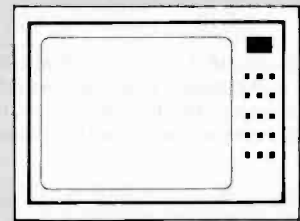
ELECTRIC UTILITY GROUND
HOUSEHOLD WATER PIPES
CARRY RETURN CURRENT AND
CREATE UNBALANCED FIELDS.
GROUND CURRENTS CAN BE
A PRIMARY SOURCE OF CONTINUOUS
EXPOSURE IN SOME HOMES, WITH
A SLOW DROP-OFF
AT $1/r$



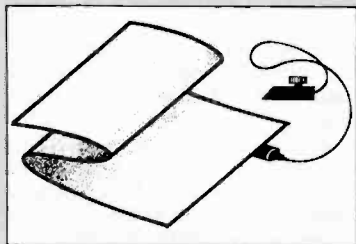
REFRIGERATOR
0.1-1μT, SOURCE
OF MAGNETIC FIELD
IS FROM MOTOR IN
BACK OF THE APPLIANCE,
SO EXPOSURE IS LOW, DROP-OFF
IS $1/r^3$



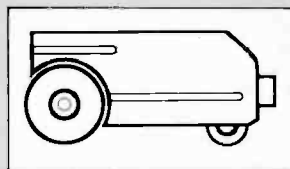
ELECTRIC RANGE
6-200μT, MAJOR SOURCE
OF MAGNETIC FIELD
IS RESISTIVE HEATING
ELEMENTS, DROP-OFF
IS $1/r^3$



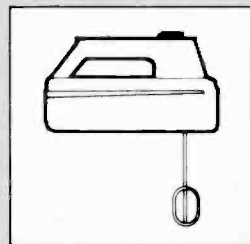
TELEVISION
2-50μT, MOSTLY
RF FIELDS BUT
POWER TRANSFORMER
AND VERTICAL SWEEP
PRODUCE MAGNETIC FIELDS,
DROP-OFF IS $1/r^3$



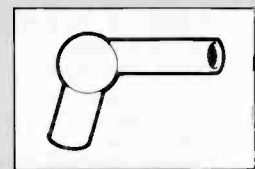
ELECTRIC BLANKET
1-5μT, HEATING ELEMENTS
ARE CLOSE TO BODY, AND FIELD
EXPOSURE CAN LAST OVERNIGHT,
DROP-OFF IS $1/r^2$



VACUUM
200-1000μT,
DROP-OFF IS $1/r^3$



MIXER
50-600μT, DROP-OFF
IS $1/r^3$



HAIR DRYER
10-2000μT, DROP-OFF
IS $1/r^3$

FIG. 2—HERE ARE SOME PRIMARY SOURCES of magnetic field exposure with the range of field intensity in teslas, and drop-off rates.

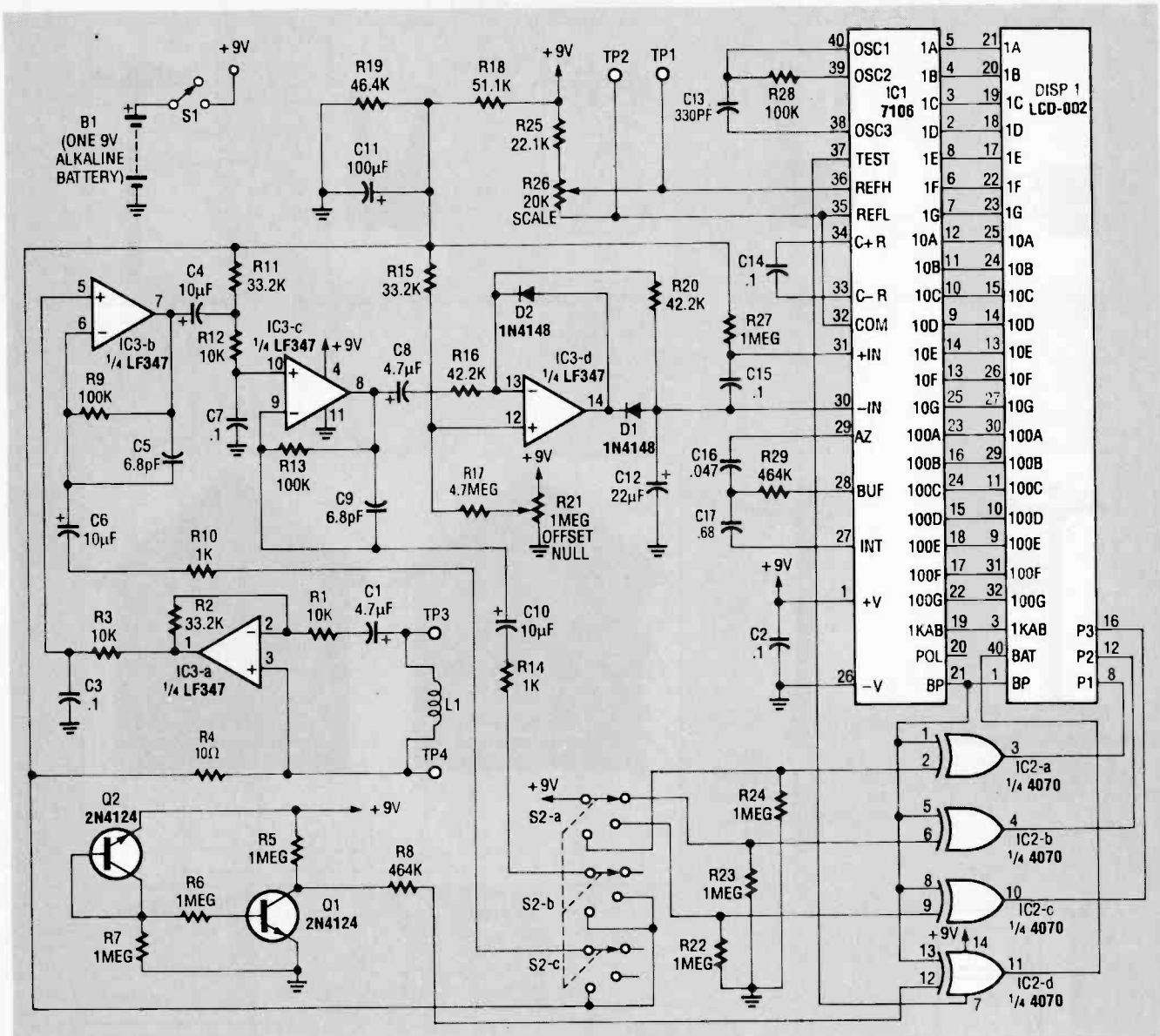


FIG. 3—SCHEMATIC OF THE MAGNETIC FIELD METER. The magnetic field is picked up by L1 and appears as a voltage that is proportional to the field strength at the input of IC3-a, which amplifies the signal to 100 μ V per μ T. The signal is then further amplified by IC3-b and IC3-c to achieve the three tesla ranges.

PARTS LIST

All resistors are 1/4-watt, 1%, unless otherwise indicated.

- R1, R3, R12—10,000 ohms
 - R2, R11, R15—33,200 ohms
 - R4—10 ohms
 - R5-R7, R22-R24, R27—1 megohm
 - R8, R29—464,000 ohms
 - R9, R13, R28—100,000 ohms
 - R10, R14—1000 ohms
 - R16, R20—42,200 ohms
 - R17—4.7 megohms
 - R18—51,100 ohms
 - R19—46,400 ohms
 - R21—1-megohm potentiometer, 5%
 - R25—22,100 ohms
 - R26—20,000-ohm potentiometer, 5%
- Capacitors**
- C1, C8—4.7 μ F, 10 volts, electrolytic
 - C2, C14—0.1 μ F, electrolytic or polyester

- C3, C7, C15—0.1 μ F, polyester
 - C4, C6, C10—10 μ F, electrolytic
 - C5, C9—6.5 pF, ceramic disc or mica
 - C11—100 μ F, 10 volts, electrolytic
 - C12—22 μ F, or 10 volts, electrolytic
 - C13—330 pF, polyester
 - C16—0.047 μ F, polyester or ceramic disc
 - C17—0.68 μ F, polyester
- Semiconductors**
- D1, D2—1N4148 switching diode
 - Q1, Q2—2N4124 NPN transistor
 - IC1—ICL 7106 A/D converter
 - IC2—4070 or 4030 quad 2-input exclusive-OR gate
 - IC3—LF347 quad JFET input op-amp
 - DISP1—LCD-002 liquid crystal display
- Other components**
- S1—MSS1200, SPST (Alco)
 - S2—MSS4300, SPDT (Alco)

- L1—18 turns, 3" diameter remote-sensing coil (optional, see text)
- B1—9-volt alkaline battery, with connector Case—Pac-Tec, HPS-9VB

NOTE: The following items are available from A & T Labs, P.O. Box 4884, Wheaton, IL 60187: A kit of all parts including PC board and case, without battery, \$79.00; an etched, drilled and plated through PC board with solder mask and silk-screened parts placement, \$15.00; a fully assembled and tested unit, \$109.00. Add 6.75% sales tax for Illinois residents, 5% shipping and handling in U.S., 12% shipping and handling in Canada. Check or Money order (UPS COD in contiguous U.S. only) is accepted.

circuit board. For remote sensing, an external field coil probe can be used. Figure 3 shows the complete schematic of the circuit. The magnetic field picked up by the coil appears as a voltage, which is proportional to field strength and frequency at the input of a cascaded amplifier IC3-a, -b, and -c. With a first stage amplifier gain of 3.3 set by R12-R10, the overall sensitivity is 100 μV per μT , or 100 mV per mT. The meter sensitivity is nominally 2 volts full scale, leading to the lowest level sensitivity of 20 mT full scale.

Op-amp IC3-a amplifies the signal to a normalized level of 100 μV per 1 μT . That voltage is further amplified by 1, 100, or 10,000 by IC3-b and -c. The three amplifier stages provide the three magnetic field ranges of 2 mT, 200 μT , and 2 μT (full scale). Components R3-C3 and R12-C7 establish a frequency roll-off characteristic that compensates for the frequency-proportional sensitivity of the pickup coil, and set the 20-kHz cut-off point.

Finally, IC3-d is a precision rectifier and peak detector. Its output drives IC1, a combination analog-to-digital converter and LCD driver. Components R25-R29 and C13-C17 are used by IC1 to set display-update times, clock generation, and reference voltages. The decimal points are driven by IC2, as determined by the range-select switch S2. Transistors Q1 and Q2 serve as a low-battery detector, and turn on the battery annunciator in the LCD when the battery voltage drops below 7 volts.

Assembly and checkout

The finished unit shown in Fig. 4 uses a double-sided PC board, which is available from the source mentioned in the parts list. We also show the component side and solder side of the PC board if you choose to make it yourself. You can, however, build the circuit on a perforated construction board if you like, but remember to include the 18-turn remote sensing coil, L1, as indicated in the Parts List. Mount all parts below the LCD display first. It's easier to fix assembly problems if a socket is used with the LCD. Install all parts as shown in

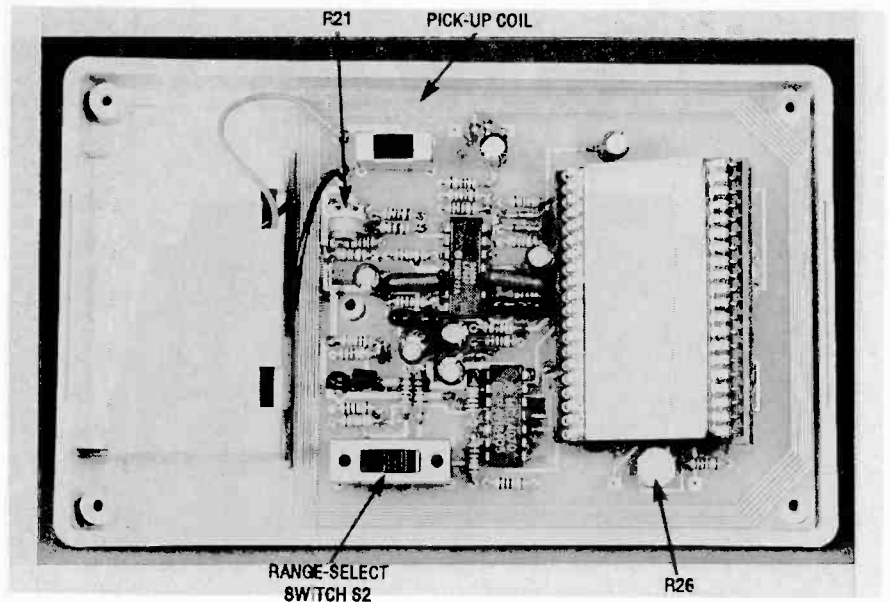


FIG. 4—THIS IS AN INTERNAL VIEW of the magnetic field meter. Assembly is easy, just install all components below the LCD first.

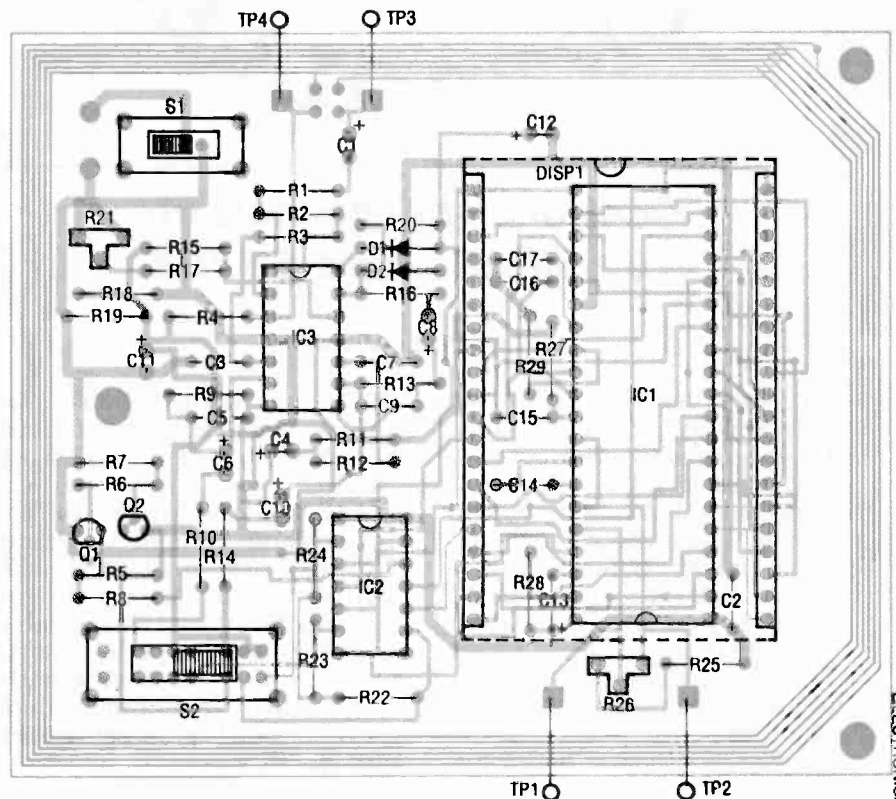


FIG. 5—PARTS PLACEMENT DIAGRAM.

Fig. 5 paying attention to component values and capacitor polarities. If you are using the internal sensing coil, install jumpers between L1-TP3 and L1-TP4.

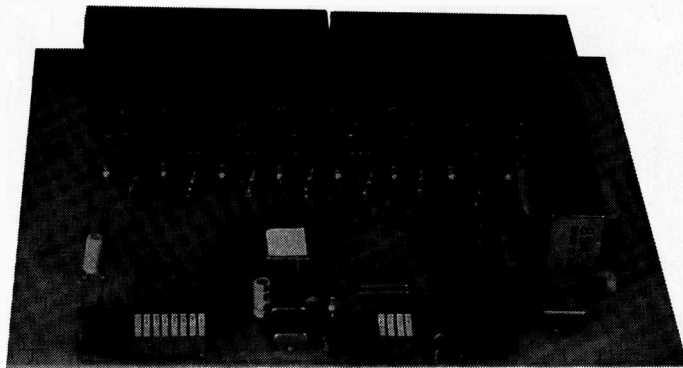
If you are using the case specified in the parts list, raise and angle the display as necessary with wire-wrap IC sockets. Make holes in the front panel for S1 and

S2. Mount the finished PC board in the case using a spacer for the single screw holding the center bottom of the board, and attach the battery connector.

With power on, adjust R26 for 1.000 volt between TP1 and TP2. Then, select the 20 mT range and short the pickup coil with a very

(Continued on page 108)

POWER



CONTROLLER

Control eight channels of 120-volt AC with a 68705.

RICHARD L. ROANE

HAVE YOU EVER WANTED TO VARY the power delivered to a 120-volt AC load under software control? In this project a 68705 microcontroller will do just that. Specifically, it can control eight discrete power Triacs, each of which delivers power in 32 smoothly graduated steps ranging from 0 to 97% of full power. The value delivered to one channel is independent of the value delivered to any other channel. Loads can include light displays, universal motors, heaters, and other appliances.

In this circuit, the power level is set by software, not a potentiometer. The software includes a basic set of routines for processing interrupts and setting the power level. The software also includes five test and demonstration routines for putting the circuit through its paces. Moreover, there's plenty of room to add your own routines to the

68705's built-in EPROM. An easy-to-build single-sided circuit board makes assembly easy.

The basic circuit is simple, yet versatile enough to accept inputs from on-board DIP switches; alternatively, the inputs can be driven from a microcomputer bus or parallel port, or a stand-alone device with TTL-compatible outputs. There are 12 input bits to set modes and specify values.

Circuit design

The circuit, shown in Fig. 1, consists of a power supply, AC line synchronizer, Triac output control, input circuitry, and support devices.

The power supply is a conventional 5-volt circuit built around a 7805 regulator (IC3) and several other components (transformer T1, bridge BR1, and C1-C4). The AC line syn-

chronizer consists of an optocoupler (IC2), a current-limiting resistor (R1), and a bias resistor (R2). The power controller generates variable power levels with phase-control techniques. When using a Triac to control a load, the power delivered can be varied by triggering the Triac after the start of an AC half-cycle.

For example, by triggering the Triac shortly after the start of a half-cycle, the load will receive almost full power. Triggering in the middle of a half-cycle will supply the load with half power and triggering close to the end of a half-cycle will result in the load receiving little power.

In this project the controller is synchronized to AC power-line zero crossings, which occur at a rate of 120 times per second. The microprocessor's internal timer then divides the interval between crossings into 32 steps, thus delivering gradually increasing amounts of power to the load.

The output of the optocoupler is a negative-going pulse that drives the microcontroller's interrupt input directly at a rate of 120 hertz. Each time IC1 receives an interrupt, it recalculates the time to generate Triac trigger pulses on Port B of IC1.

Each bit of Port B is connected to a Triac control circuit; since they're all identical, only Port 7 will be described in detail. Port B7 of IC1 drives transistor Q1 via resistor R4. (Q1 is required because the 68705 can't sink enough current to trigger Triac-driver IC4 directly.)

When it's time to turn on Triac TR1, the microcontroller delivers a 10-microsecond negative-going pulse to port PB7. That pulse briefly enables the transistor, which causes current flow through the LED inside IC4. Although a Motorola MCP3011 Triac driver was used in this design, any similar device could be used, as long as it doesn't have an internal zero-crossing detector. That type of driver allows only two modes of operation: full on and full off.

The Triac driver's LED then triggers the photon-coupled Triac within the IC, which in turn

triggers TR1 and delivers power to the external load. Resistor R5 provides current limiting for IC4, and R6 and C7 form a snubber network to filter line transients that could cause the Triac to trigger falsely.

The hot side of the power line connects to the MT1 terminal of all the power Triacs (TR1-TR8). The specified Triacs are rated for 4 amperes at 200 volts. They are isolated-tab versions, and were selected because heatsinking is mandatory. With the specified Triacs, the maximum load is 100 watts per output. Larger loads can be handled by substituting Triacs with higher current ratings. Be sure to use proper heatsink and isolation techniques.

Input circuit

The input circuit consists of Ports A and C of the microcontroller, along with two banks each of DIP switches (S1 and S2), SIP resistors (RN1 and RN2), four sets of 0.1 inch header jumpers (P1-P4) for mode selection, a 14-pin header (P5) connected to Port A, and a four-pin header (P6) for input selection.

The P1-P4 jumpers allow both the common resistor legs and the common switch poles to be tied to either ground or +5-volts DC, or to be disconnected from the circuit entirely. If programmed as inputs, the ports should not be left floating because this might cause erratic operation. Connector P6 allows

an external device (e.g., a computer) to drive the controller's inputs.

The 68705P3 requires a few support components. Crystal XTAL1 runs at a frequency of 3.58 megahertz, which should not be altered. Capacitor C5 loads the oscillator to keep it at the correct frequency, and capacitor C6 keeps the reset pin low for an instant, thereby giving the 68705 time to stabilize after power up. Momentary switch S3 provides for resetting the circuit. Although unused in the prototype, an external connection is provided to the microcontroller's RESET input, which could allow an external device to reset the circuit when desired.

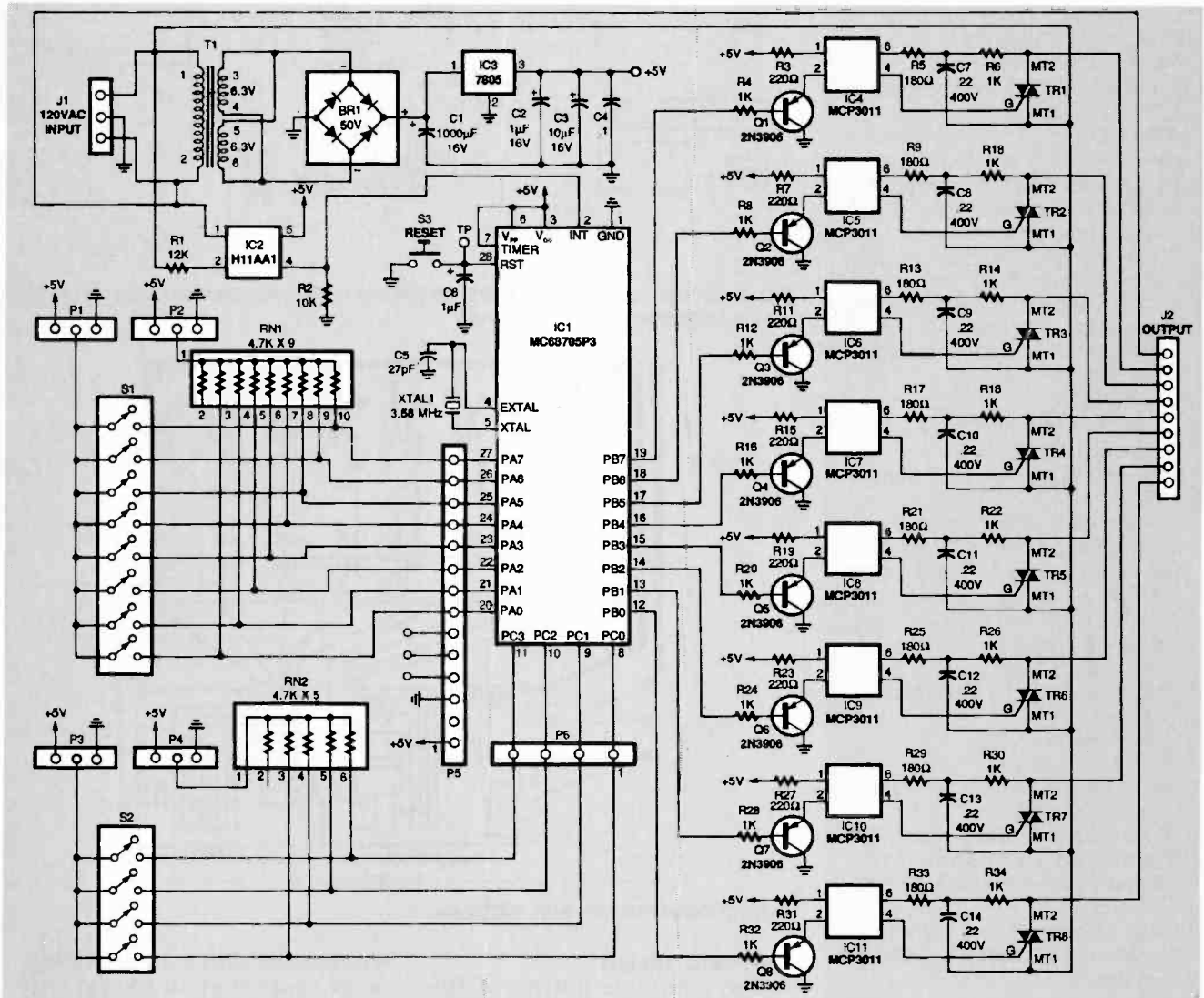


FIG. 1—COMPLETE SCHEMATIC OF THE 68705-based power controller. The controller reads switch values from Ports A and C, and delivers software-controlled 120-volt AC power to Port B.

PARTS LIST

All resistors are 1/4-watt, 5%, unless otherwise noted.

R1—12,000 ohms, 1 watt

R2—10,000 ohms

R3, R7, R11, R15, R19, R23, R27, R31—220 ohms

R4, R6, R8, R10, R12, R14, R16, R18, R20, R22, R24, R26, R28, R30, R32, R34—1000 ohms

R5, R9, R13, R17, R21, R25, R29, R33—180 ohms

RN1—4700 ohms × 9 resistor network, common terminal

RN2—4700 ohms × 5 resistor network, common terminal

Capacitors

C1—1000 μ F, 16V, radial electrolytic

C2—1 μ F, 16V, tantalum

C3—10 μ F, 16V, radial electrolytic

C4, C15—0.1 μ F, monolithic

C5—27 pF, ceramic

C6—1 μ F, 16V, radial electrolytic

C7—C14—0.22 μ F, 400V, poly film

Semiconductors

IC1—MC68705P3 microcontroller

IC2—H11AA1 AC optocoupler

IC3—MC7805CT 5-volt regulator

IC4—IC11—MCP3011 Triac driver

Q1—Q8—2N3906 NPN transistor

TR1—TR8—Q2004L3 Triac, 200V, 4A, isolated tab

BR1—Bridge rectifier, 50V, 1A, DIP

Other components

J1—3-terminal AC power connector
J2—9-terminal AC power connector

P1—P4—3-pin single-row 0.1 inch male header

P5—14-pin single-row 0.1 inch male header

P6—4-pin single-row 0.1 inch male header

S1—8-position DIP switch

S2—4-position DIP switch

S3—SPST momentary pushbutton switch

T1—Transformer, 120V primary, dual 6.3V secondaries (Digi-key T101-ND or equiv.)

XTAL1—3.579545 MHz crystal, HC-18

Miscellaneous

Shorting jumpers for P1—P4, heat-sink for TR1—TR8, PC board, solder, wire, etc.

Note: The following items are available from Richard L. Roane, Route 601, Cologne, VA 23037:

- Source code listing and programmed MC68705P3—\$24.95 postpaid

VA residents must add appropriate sales tax.

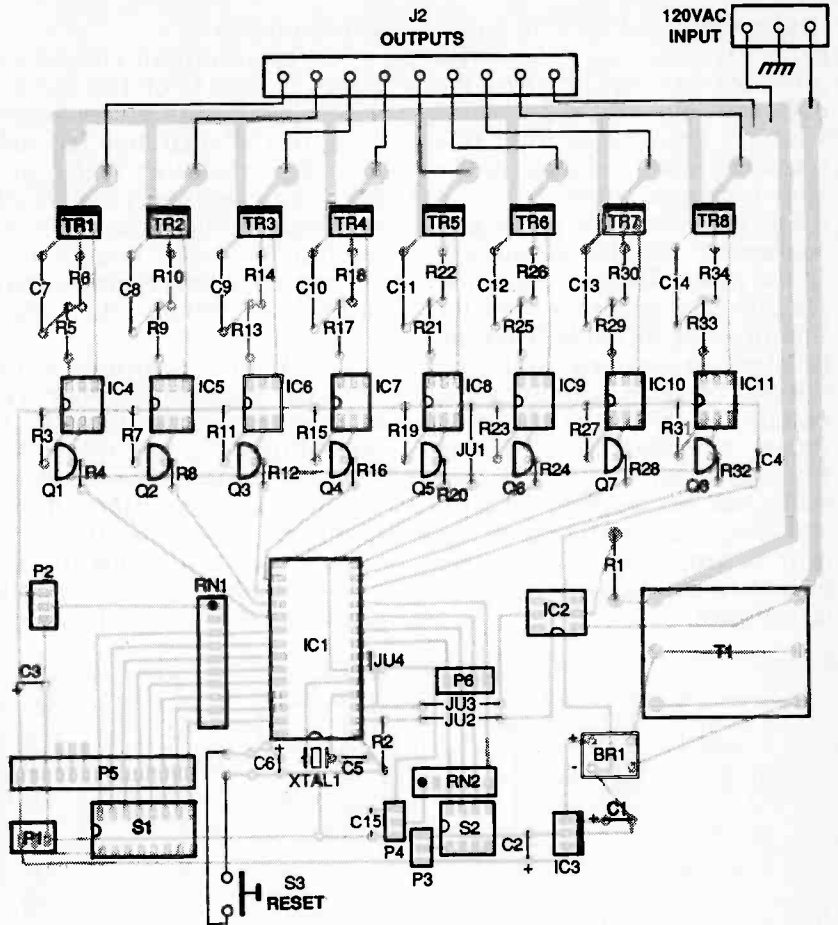
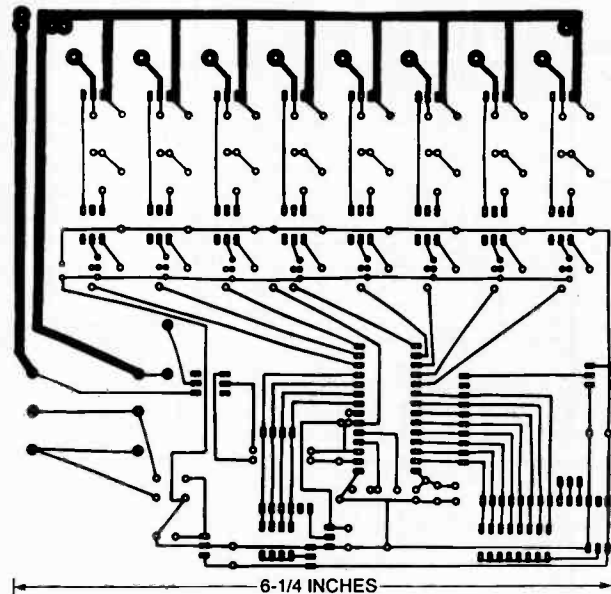


FIG. 2—MOUNT ALL COMPONENTS AS SHOWN HERE. Note that four jumpers mount on the component side of the board.



POWER CONTROLLER FOIL PATTERN.

Software design

The complete listing of the software is available from the author, as detailed in the Parts List. It is also available on the

Gernsback BBS (516-293-2283, v.32, v.42bis); look for file POWCON.ASM. An overview of the major routines follows:

The interrupt routine sets up

TABLE 1—POWER LEVELS

Power Level	Voltage (VAC)	Percent On (%)
0	1.2	1.0
1	1.9	1.6
2	2.6	2.2
3	6.6	5.5
4	9.2	7.7
5	12.2	10.2
6	15.6	13.0
7	19.5	16.3
8	23.6	19.7
9	27.9	23.3
10	32.8	27.3
11	37.7	31.4
12	42.9	35.8
13	48.2	40.2
14	53.6	44.7
15	59.0	49.2
16	64.4	53.7
17	70.8	59.0
18	75.2	62.7
19	80.2	66.8
20	85.2	71.0
21	90.0	75.0
22	94.5	78.8
23	97.8	81.5
24	101.6	84.7
25	105.3	87.8
26	107.3	89.4
27	110.2	91.8
28	112.7	93.9
29	114.8	95.7
30	116.4	97.1
31	0.0	0.0

**TABLE 2
APPLICATION AND JUMPER SELECTION**

Value	Application	JU1	JU2	JU3	JU4
0	Manual	GND	+5	+5	GND
1	External	-	-	+5	GND
2	Sequencer	-	-	+	GND
3	Run and Flash	-	-	+	GND
4	Test	-	-	+5	GND
5-15	Not used				

**TABLE 3
MANUAL MODE POWER LEVELS**

Port C Data Decimal	Power Level Decimal
0	31
1	0
2	2
3	4
4	6
5	8
6	10
7	12
8	14
9	16
10	18
11	20
12	22
13	24
14	26
15	30

the microcontroller's internal timer to produce 31 timer interrupts per half-cycle. Together with the full-off value, those interrupts provide the 32 power levels. Table 1 lists power level, corresponding voltage, and percentage of full on. A power value of 0 represents the lowest on voltage, 30 represents the highest, and anything greater than 30 represents a voltage of 0.0.

Eight bytes of RAM (PWRC0-PWRC7) function as control bytes, each corresponding to a Port B output bit. Each byte stores one item of power level data (as shown in column 1 of Table 1). To see how a value in a control byte is translated into an output voltage, follow this example.

Suppose that an application calls for a power level of 16 at Output 3, and a level of 30 at Output 7. In that case simply store values of 16 and 30 in control bytes PWRC3 and PWRC7, respectively. The outputs will immediately and simultaneously reflect these levels. Note that although the desired voltages were specified in decimal form, you must store the corresponding hexadecimal value in the output-control byte.

A "hole" was left in the microcontroller's EPROM (addresses \$80-\$5FF) for application programs. The five demonstration routines discussed earlier occupy those addresses. You are free to create your own applications, but leave the addresses

ASSEMBLER VARIATIONS

In developing the software for this article, the intention was to provide a single source file that would assemble correctly under three assemblers: the TECI 6805 Assembler, Motorola's 6805 Assembler, and Motorola's Freeware Assembler. In the course of testing, a bug was discovered in the Freeware assembler. After encountering an instruction that uses direct addressing on page zero of memory, the assembler starts generating garbage. Both of the other assemblers force extended addressing, thus avoiding the problem. The only point in the code where this is a problem is in the jump table, where there is the instruction:

```
JMAN: JMP MAN
```

By changing that instruction as follows, the problem can be avoided:

```
JMAN: BRA MAN
```

Branching, rather than jumping, works because the target routine is within 128 bytes of the jump table.

outside that range alone. Addresses below \$80 are reserved for constant and variable storage; addresses above \$5FF contain the reset and interrupt routines. All 68705 registers, except for the timer, are available for use by application routines.

Construction

Assembly is straightforward. Figure 2 shows the parts layout on the single-sided circuit board. Load the board by inserting lowest- to highest-profile

components. Make sure that you observe polarities of all semiconductors, SIP resistors, and electrolytic capacitors.

For the prototype, four Triacs were mounted each to two 90° aluminum heatsinks. The AC power input was brought to one heavy-duty, three-terminal connector, and the eight Triac outputs plus AC common were brought to a separate nine-terminal connector.

The circuit board has 120-volt AC signals on it, so check and double-check your work before plugging in and testing the project. Figure 3 is a photo of the author's prototype.

Built-in applications

On power up, a selection routine reads Port C and selects the corresponding application. Note that following power-up, Port C can be used for other pur-

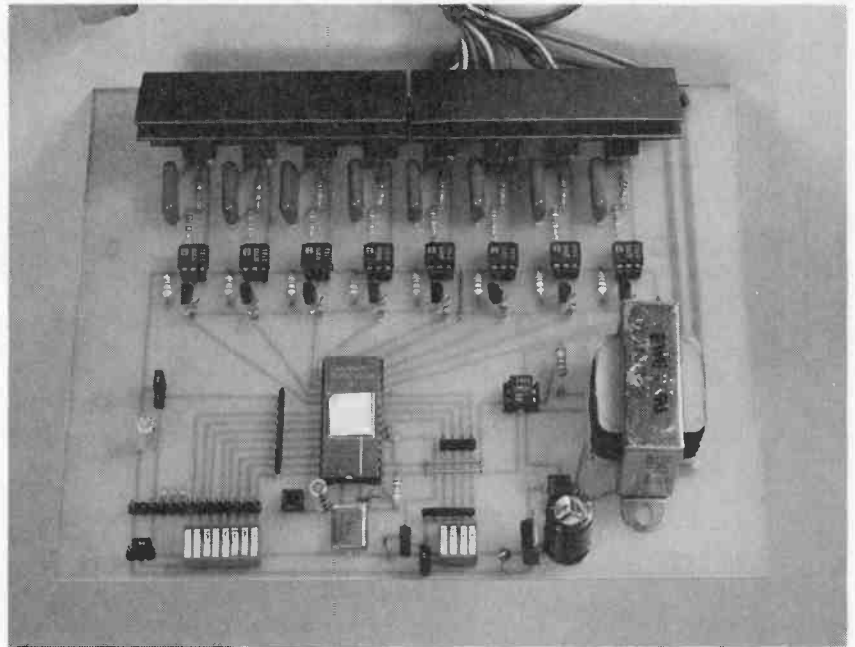


FIG. 3—COMPLETED UNIT. The circuit board has 120-volt AC signals on it, so check and double-check your work before plugging in and testing.

SOUND INPUT

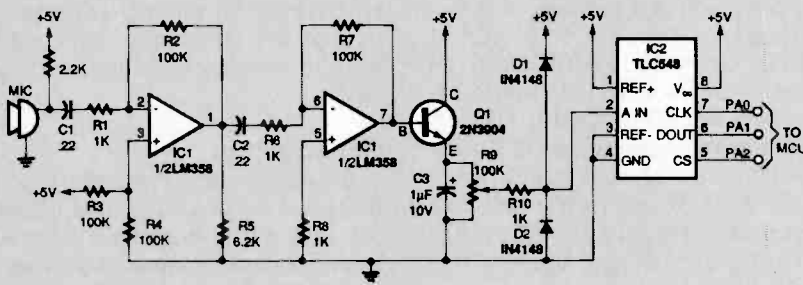
The accompanying schematic shows a simple circuit for letting an audio sound source control the power-controller output. The circuit accepts input from a standard crystal microphone, and amplifies the signal using two op-amp stages. The signal then passes through an emitter-follower circuit that drives a TLC548 A/D converter. Potentiometer R10 functions as a sensitivity control.

The software, presented below, simply clocks the A/D converter eight times, accumulates the result, then stores it in all eight output registers, from where they are applied to the Triacs in the usual manner. To use the routine, you'll have to declare the variable SDDATA, add the routine itself to the jump table, and add a new S1 switch setting to the application-selection power-up routine.

SOUND MODE ROUTINE

```

SOUND:   LDA #S05
         STA DDRA
         BSET 2, PORTA
STARTAD: CLRA
         LDX #S08
         BCLR 2, PORTA
         BSET 0, PORTA
         BRSET 1, PORTA, COLLECT
COLLECT: ROLA
         BCLR 0, PORTA
         DECX
         BNE LOOPAD
         BSET 2, PORTA
         CMP #30
         BHI ADADJUST
STORESD: STA SDDATA
         BSR APPSD
         BRA STARTAD
ADADJUST: LDA #30
         BRA STORESD
         LDA SDDATA
         STA PWRC0
         STA PWRC1
         STA PWRC2
         STA PWRC3
         STA PWRC4
         STA PWRC5
         STA PWRC6
         STA PWRC7
         RTS
  
```



poses. Table 2 lists Port C values, along with the corresponding routines and PC-board jumper settings. In general, if no host is connected and Port A will input data from S1, set the jumpers as shown for application 0 (manual). Also note that in the design, once a routine has been selected, the only way to change to a new routine is to reset the system. The following is description of each in detail.

Manual

The software scans Port A waiting for a bit to go low. When that occurs, the microcontroller loads power-level data from Port C and stores it in the power-control byte specified by the value in Port A. For example, placing 05 on Port C and bringing PA2 low will set output 2 to power level 8. Because Port C has only four input bits, it can only specify 16 power values ($2^4 = 16$). Thus a look-up table (shown in Table 3) spreads the 16 specifiable values across the entire 32-value range.

Sequence

This routine demonstrates the controller's ability to power light displays. It turns on the first output, waits, then turns it

(Continued on page 106)

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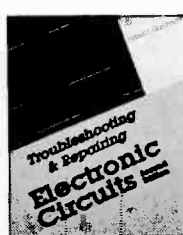
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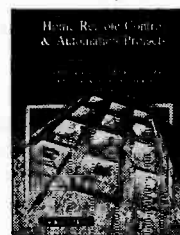
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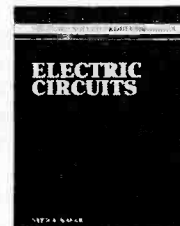
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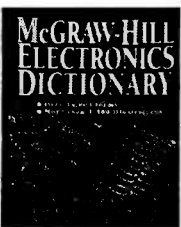
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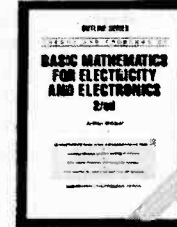
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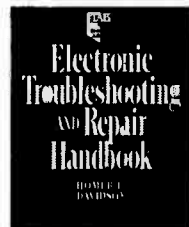
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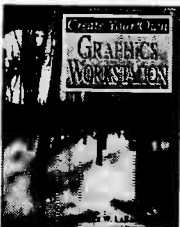
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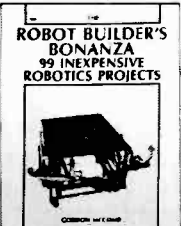
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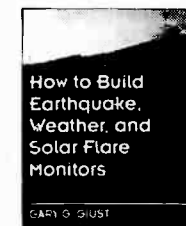
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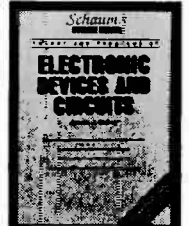
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POWER CONTROLLER

Continued from page 104

off. It then repeats that action for output 2, and so on. After output 7 toggles, the software then repeats the cycle.

Run and flash—This is a variation of the sequencer application. It sequences the outputs for five cycles, then flashes all eight three times and repeats the cycle.

Test—The test application tests the controller. The routine steps the outputs through all 32 power levels, pausing one second between each.

External—Here's where things get interesting. This routine allows an external source, such as an intelligent I/O module or a computer, to control power levels. To get into this mode, set switch S2 to a value of 2, install the correct jumpers, then reset the circuit. From then on, input Port C0 functions as a strobe that causes the microcontroller to read the value on Port A and perform the proper function.

When PC0 goes low, the microcontroller reads Port A. It then splits the value into a 5-bit power specification (PA0-PA4), and a 3-bit output port (PA5-PA7). The 5-bit power specification allows 1 of 32 values; the 3-bit output port allows 1 of 8 ports.

For example, assume you place the value \$57 on Port A and strobe PC0 low. In binary, \$57 = 0101 0111. Taking the upper three bits yields 010, or 2. Taking the lower 5 bits yields 10111, or 23. Thus the controller will set output 2 to level 23.

Summing up

As you can see, both hardware and software are simple and suitable for being customized. For example, you could connect the output of an A/D converter to Port A, then vary power levels based on some analog quantity.

When creating your own routines, be sure to include it in both the power-on Select routine and the Jump Table. That way the controller will know where to find it. Ω

the circuit to be matched to the direct signal from the guitar.

A transconductance amplifier has an extra input, and it is this extra input that makes these components so useful in voltage-controlled filters and amplifiers. The output current is governed by the differential input current and the current fed to the control input. In effect, the gain of the amplifier is controlled by the current fed to the control input. In this case R13 is connected in series with the control input, so that it is voltage rather than current control that is obtained. R12 provides a small bias current to the control input under quiescent conditions. Without R12 there is a tendency for the output signal to decay a little too fast. Also, when the VCA provides very high attenuation levels the output signal seems to become heavily distorted, and produced a rather unmusical "buzzing" sound. R12 completely eliminates both problems.

The transconductance amplifier in the LM13700N has a fourth input, and this can be used to supply a bias current to linearizing diodes at the input of the amplifier. This enables higher signal levels to be handled. In this circuit R10 provides the bias current to the linearizing diodes. The LM13700N used for IC2 is actually a dual transconductance amplifier and buffer amplifier, but in this circuit only one amplifier and buffer stage are utilized. No connections are made to the other amplifier and buffer stage. Note that the LM13600N is virtually identical to the LM13700N, and will work just as well in this circuit.

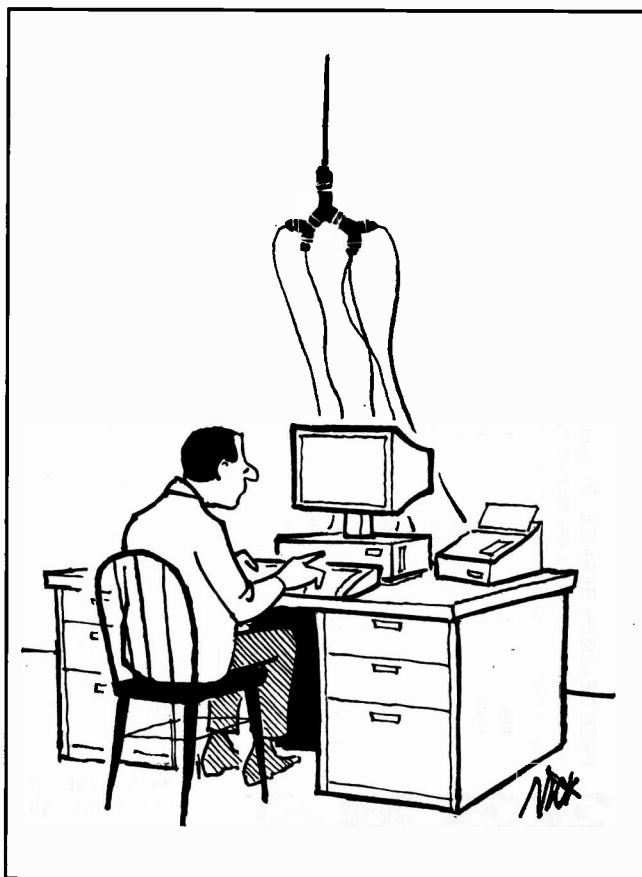
Chip IC3 is used in the amplifier which drives the smoothing and rectifier circuit. This is an inverting amplifier which has its closed-loop voltage gain controlled by VR3. The maximum voltage gain is about 120 times, and this is obtained with VR3 at maximum resistance. The wide range of gains available should enable good results to be obtained using most guitar pick-up.

The rectifier and smoothing circuit is a simple half-wave type based on D7 and D8. Germanium diodes are used for D7 and D8 because they have lower forward voltage drops than silicon types, and they therefore give a DC output voltage which is a more accurate reflection of the input signal's amplitude. The attack and decay times of the smoothing circuit are kept quite short so that the output envelope accurately follows the envelope of the input signal. On the other hand, the decay time is made sufficiently long to avoid

unwanted distortion products on the output signal.

The current consumption of the circuit is about 8 milliamps. This can be supplied by a 9-volt transistor radio battery, but it would be more economic to use a higher capacity battery (six AA cells or larger in a holder) if the unit is likely to receive a lot of use.

Adjustment. Adjust VR1 to give the best distortion effect. It is advisable to use the lowest resistance that gives good results, as higher resistances will give greater voltage gain, which will in turn encourage problems with feedback and general electrical noise. VR3 should be adjusted before giving VR2 its final setting. Adjusting VR3 is again just a matter of finding the setting that gives what is judged to be the best effect. Setting VR3 too low in value will result in rather a low-output level, and generally unimpressive results. Using a value that is too high will give plenty of output signal, but the initial part of the output envelope might be compressed slightly. This will give an output that is slightly lacking in terms of "twangyness." In between these two extremes there should be a fairly broad range of settings that give good results. Once VR3 has been given a suitable setting, VR2 is adjusted to balance the volume levels obtained with the effect switched in and out. Ω



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FREE**MAGNETIC FIELD METER**

Continued from page 99

short lead between TP3 and TP4. Adjust offset-null potentiometer R7 for 0.00. Remove the jumper, and the meter is complete.

Calibration

Calibration of the meter is basically determined by the pickup-coil characteristics, amplifier gains, and meter reference-voltage setting. The amplifier gains, as we previously discussed, are chosen to match the coil characteristics as closely as possible.

If you desire to calibrate your meter more exactly, you will need to generate a known magnetic field intensity. One way to do that is to pass a known current through a coil configuration whose field pattern characteristics are known. Figure 6 shows such a calibration setup. A good controllable signal source is a sine-wave generator and an audio amplifier, whose output is coupled to a coil through an 8-ohm resistor. Measuring the voltage across the resistor gives the

current. Then, calculate the magnetic field according to Fig. 6. (Note that while all references to field strength here are made in teslas, gauss are also commonly used. The conversion is easy: 1 tesla = 10,000 gauss.)

Place the meter inside the coil and turn it on. Use the highest sensitivity scale that does not overrange the display. An overrange is indicated by a display of 1 followed by three blanks. In most cases, the 2 μ T range is satisfactory.

Measurement interpretation

A great deal of controversy exists in the emerging understanding of potential health hazards of low-frequency magnetic fields. The International Radiation Protection Association (IRPA) has set some interim standards based on 1984 World Health Organization guidelines. Those IRPA standards specify a continuous maximum magnetic field exposure for the general public of 100 μ T, and 500 μ T as the maximum occupational exposure allowed over the entire working day. Ω

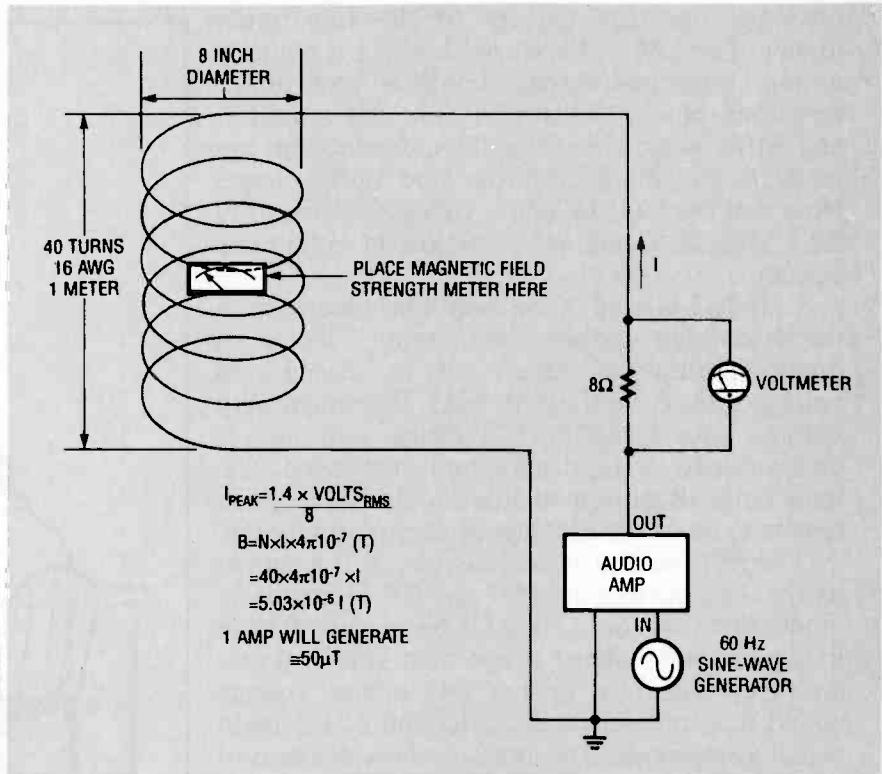


FIG. 6—USE THIS TEST SETUP TO accurately calibrate your meter. A known current is passed through a coil whose field intensity is known. A sine-wave generator provides the 60 Hz frequency, and an audio amplifier is coupled to the coil by an 8-ohm resistor. Measure the voltage across the resistor, and use the calculations shown.

NEW PRODUCTS

Continued from page 12

rate tester (BERT).

The Model 904 can be connected to any personal computer through any available serial port. The analyzer uses the serial port in a way that provides a high-speed data channel along with a serial control channel. The analyzer's embedded coprocessor permits the monitoring and emulation of data lines rated to 64 kilobytes per second on a full-duplex basis.

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That information permits extensive post-capture analysis of data, even at a different location. Any combination of data line events can be searched or trapped. This allows the review of live data or search through captured data. Captured data can be saved as a DOS file on disk for later viewing, analysis, or printing. The included protocol emulator program interface allows the use of Telebyte off-the-shelf test analysis programs or the user can write his own custom programs.

In addition to monitoring, the Model 904 has emulation capabilities. A menu-driven program on the PC



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allows the selection of many combinations of communications options to emulate X.25, HDLC, Async, and BiSync. A built-in BERT tester offers a choice of test patterns and modes of operation. The analyzer is supplied with standard RS-232C monitoring software and two additional programs for X.25 and HDLC.

For portable field operation the Model 904 will run for 2 hours on a standard 9-volt battery. Since problems don't always happen in the same place, being able to hook up to the nearest PC without having to open the PC's case is convenient.

The Model 904, supplied in a carrying case with cables, software, and manuals, is priced at \$499.00

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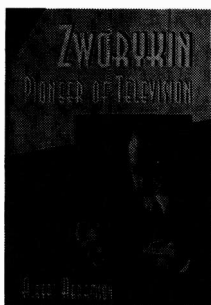
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NEW LITERATURE

Continued from page 15



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of the iconoscope, the first practical television camera tube. To write this book, Abramson researched Zworykin's original patents and both his published and unpublished notebooks and papers, and he interviewed many television pioneers, including Zworykin himself.

This biography reviews the life of this television pioneer and scientist, including its often dramatic periods. It covers Zworykin's early years in Russia as well as his career at the RCA laboratories. He was invited there by RCA founder David Sarnoff. More than 50 photographs in the book highlight Zworykin's work. Ω

THERMOMETER

Continued from page 42

perature of ice water (32°F) and 80°F water be the test points.

The temperature of the hot water can be determined accurately with a standard laboratory mercury thermometer, but a high-quality, liquid-filled confectioner's thermometer will also give satisfactory results.

Measuring temperature

Observe common sense precautions when measuring temperature with your digital thermometer. If the transistor/sensor is held near an open flame or heating coil it will be damaged or destroyed.

If you put the digital thermometer in a protective case to protect it from dust, rain, and salt spray, it will work reliably out of doors, in boats, or even on camping trips.

Keep the digital thermometer's temperature measurement limits in mind. The Harris ICL7106CPL has a rated temperature range of 0 and 70° Celsius. Ω

MINI ANALYZER

Continued from page 94

only eight). This approach checks all the functions of the 4017, including reset, clocking, clock enabling, and carry out. A second scan could be performed to sense the previously unchecked outputs instead of IC outputs 6, 7, and 8.

Most digital ICs can be tested in a similar process. That is, you must determine the necessary inputs to exercise all functions of the IC, program those inputs, determine where to observe the outputs and what those outputs should be. Then you can compare the results.

To make a simple jig for this purpose, you can use a general-purpose IC PC Board (Radio Shack Part No. 276-159) and a 20-pin IC socket. Solder the socket in place, and solder a solid wire loop on each of the input/output pads. The jig is shown in Fig. 16. Ω

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ISOLATION TRANSFORMER

Continued from page 45

agram (Fig. 1) and begin the wiring by connecting the hot side of the line cord (black wire) to one side of the fuse holder. Next solder a wire from the other side of the fuse holder to one terminal of the main power switch, S1.

Connect the other terminal of S1 to the other side of the fan and to one terminal of S2. Connect power indicator NE1 across the fan terminals so it will indicate when power is applied to the fan and to S2.

Standby switch S2 allows power to the transformer to be shut off while still allowing the fan to work. Wire indicator NE2 across S2 so that it illuminates when S2 is open, or when the unit is in the standby mode. Next, connect S2 to the other side of the transformer. Connect the neutral (white) wire from the line cord to one side of the fan and also connect it to one terminal on the input side of the transformer.

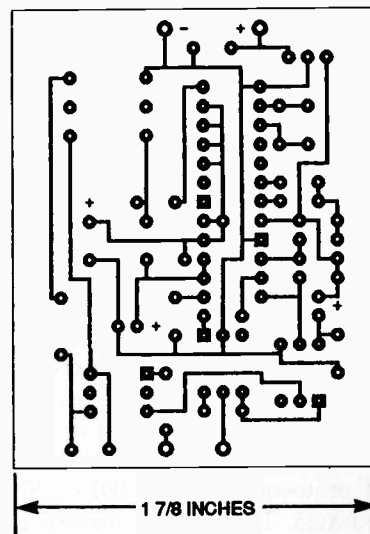
Connect both output leads of the transformer to the AC receptacle SO1. Next connect the output-power indicator NE3 across the receptacle. As a last important step, run a ground connection from the line cord (the green wire) to the base of the transformer and to the fan. If the transformer has not been grounded to the chassis, be sure to do so now with a separate wire.

Before closing up the case, plug an appliance such as a coffee maker, a lamp, or another appliance that draws about 500 watts into the isolation transformer outlet and turn on the power. Run the transformer with the load turned on for approximately 30 minutes while checking it every five minutes or so for excess heat.

The prototype was tested with an 800-watt coffee maker, and the transformer ran warm—but not hot—to the touch. Do not use the isolation transformer to power anything with that high a power rating for extended periods of time. Ω

PHONE ON HOLD

continued from page 38



FOIL PATTERN for the universal hold circuit's single-sided board.

the case.

Before closing up the case, connect the hold circuit to the telephone line and plug the wall transformer into an AC outlet. Pick a phone up, press the # key, and hang it up within five seconds; the LED should light. Pick a phone up and the LED should go out. Press the # key, wait about eight seconds, and hang the phone up; the LED should not light.

Operation

The power supply, DTMF decoder, and timing circuits are isolated from the telephone line by the optoisolators and transformer. The five-second timing cycle that starts after the # key is released gives ample time to hang up a phone with a keypad on the handset. If the keypad is on the telephone base, the # key can be pressed while the phone is hung up.

If the # key is pressed for reasons other than to place a call on hold, such as to signal the end of a number entry after using a fax-back service, the timing cycle will end after five seconds and will probably not be active when the phone is hung up. To be sure that the line is not on hold after using the # key, just pick the phone up and hang up again. Ω

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PROTOTYPING STATION

Continued from page 26

amplifier, a speaker, and a terminal strip. The signal generator circuit, shown in Fig. 12, consists of an astable 555 oscillator circuit, in which R1, in conjunction with C1 or C2, sets the output frequency. Switch S1 selects either the 0.01- μ F capacitor that generates frequencies from 20 hertz to about 5 kilohertz, or the 1- μ F capacitor that generates frequencies from 2 to 10 kilohertz. Potentiometer R3 controls gain or volume.

The audio amplifier circuit (Fig. 13) uses an LM 386 in a basic configuration. With just

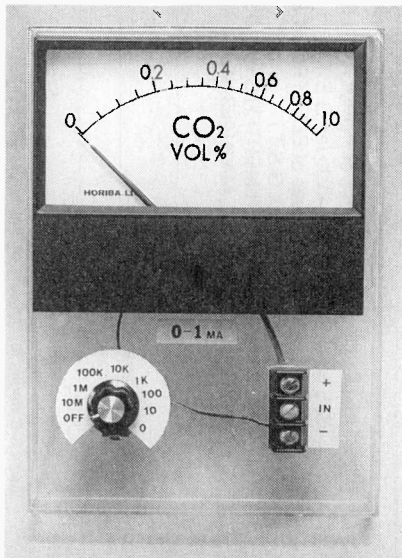


FIG. 18—THE METER MODULE contains a factory-made 0- to 1-milliampere movement.

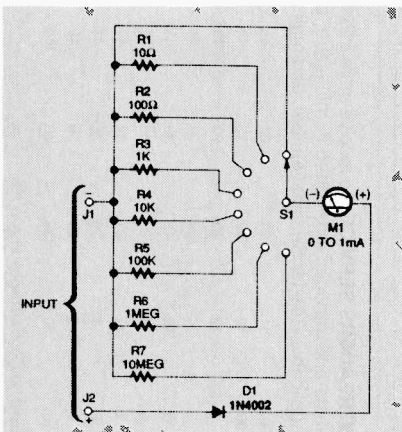


FIG. 19—AN 8-POSITION ROTARY SWITCH allows the input to be connected either directly to the negative meter pole, or through one of seven dropping resistors.

three components, a gain of about 20 is achieved; that can amplify the signal from a microphone, a Walkman-type radio, or any similar audio gear. The amplifier outputs about 500 milliwatts; if more power is needed, install an LM 380 amplifier IC that produces about 2 watts. Potentiometer R1 acts as a volume control by limiting the input voltage. The input and output to the amplifier are accessed from the terminal strip, as are the speaker and signal generator. This circuit is so simple that point-to-point wiring is used, as shown in Fig. 14.

The three-digit decoder-driver shown in Fig. 15 adds another practical function block. The circuit, shown in Fig. 16, will interface with any standard BCD output to produce a digital display. The circuit contains a CD4553 three-digit BCD counter and a 74LS48 seven-segment decoder. The decoded data is routed to a three-digit, common-cathode display.

A logic probe is also included in the BCD decoder module. This simple circuit will indicate logic status, either high or low, at any given test point. Figure 17 is the schematic of the logic probe, which lights the red LED (LED2) for high logic levels, and the green LED (LED1) for low. If desired, common-anode, seven-segment displays can be substituted for the single LEDs. The cathodes of the b, c, e, f, and g segments of one display can be wired together to form an "H" to indicate a high, and the f, e, and d segments of the second display can be wired together to form an "L" to indicate a low.

The meter module shown in Fig. 18 makes use of a factory-marked 4½-inch, 0- to 1-milliampere movement, bought at surplus. As shown in Fig. 19, an 8-position rotary switch (S1) allows the input to be connected either directly to the negative meter pole, or through one of seven dropping resistors ranging in value from 10 ohms to 10 megohms. When using this meter, it is best to start with the highest setting, and then work down to prevent pinning the pointer. Ω

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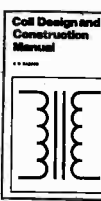
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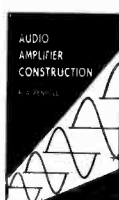
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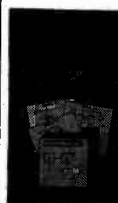
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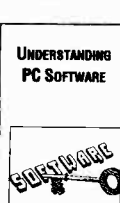
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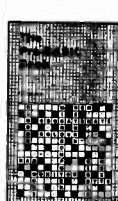
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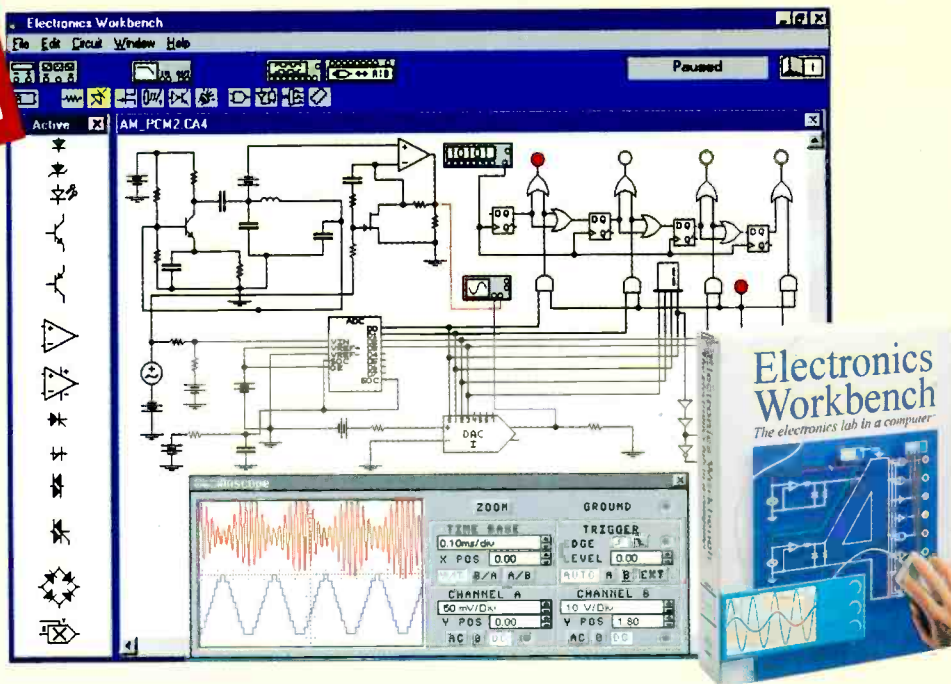
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