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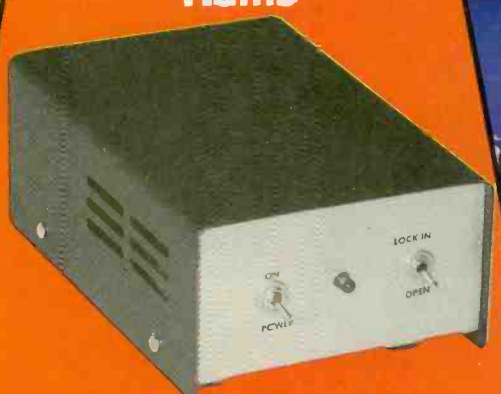

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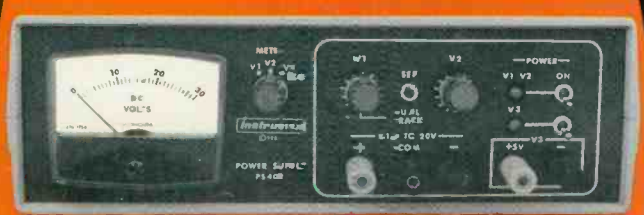

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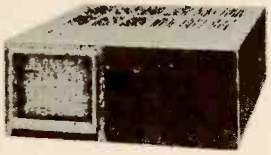

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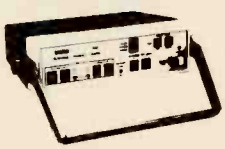

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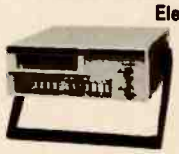

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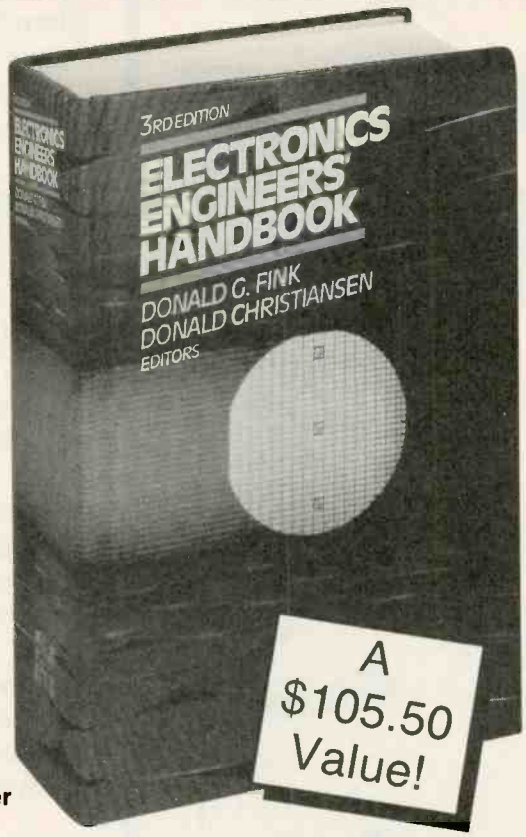

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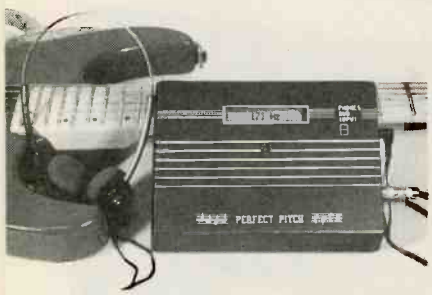
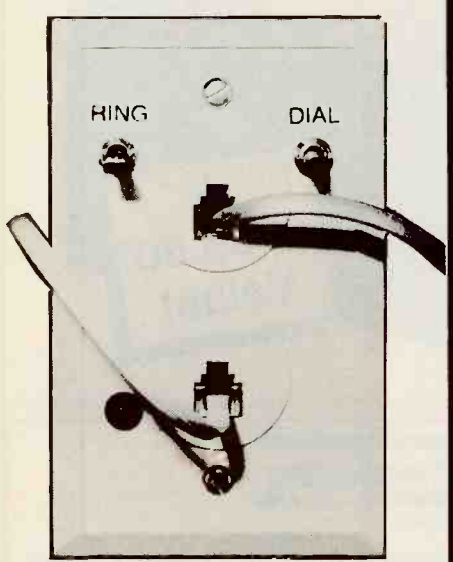
See page 67



Musician's Friend—Perfect Pitch
See page 25



Phone-Line Simulator
See page 32

Talking Telephone Ringer
See page 15

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Contents

Micro TV Transmitter **11**
This wireless video mini-transmitter sends pictures to your TV set. It's ideal for security monitoring or observing the motion of nature and things.

Talking Telephone Ringer **15**
Don't listen to that annoying bell or turkey gobble sound—build this project and customize the way your phone rings.

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Hone your musical skills with Perfect Pitch—The microprocessor-based instrument tuner, headphone amplifier, and metronome combination.

Phone-Line Simulator **32**
Assemble this low-cost telephone-line simulator that tests phone-based equipment without tying up two phone lines, paying Ma Bell fees and hiring an assistant.

DTMF Decoder **37**
Here's an inexpensive way to decode dual-tone, multi-friendly tones that you hear on your scanner or ham rig.

Video Master **39**
Enjoy video programming throughout your house with the Video Master video distribution system.

Static ROM **47**
Build your own EPROM emulator for less than $60.

Wireless Guitar Transmitter **52**
Build a wireless FM guitar transmitter that is better than what you can purchase—and save money.

Smart Turn Signal **59**
Avoid potential road hazards, as well as potential embarrassment, with the Smart Turn Signal.

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Triple-Output DC Power Supply 62
This project is a power source you'll find quite useful around the home and shop.

Autopatch Selector for Radio Amateurs 67
With our autopatch selector you can control almost anything from your UHF transceiver.

Part 68 Interface 71
With the PMC-2 Part 68 approved phone-line interface, you can make all your telephone projects FCC type-approved.

Phone-Line Autocoupler 75
Now you can automatically connect your telephone line to a variety of projects.

The Phone Pager 80
This project will spare you from yelling and running up and down stairs.

PC-Based Universal Remote Control 87
An invisible robot in your PC will listen to your commands and do your bidding.

Build a Novel LCD Ammeter and RF Power Meter 91
Make useful and inexpensive ammeters, power meters, or temperature indicators from Duracell's Copper Top Testers.

Aurora Monitor 95
Build this monitor to sense disturbances in the Earth's geomagnetic field caused by auroras and sun spots. It will also detect approaching cars and other causes of magnetic anomalies.

Editorial 4

New for the Experimenter 6

New Literature—Hot Off the Press 10

Free Information Card ..... next to page 25

Advertising Index and Sales Offices 112

Micro TV Transmitter
See page 11

Aurora Monitor
See page 95

Wireless FM Guitar Transmitter
See page 52

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Summer 1994

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Since some of the equipment and circuitry described in *Summer 1994 Electronics Experimenter's Handbook* may relate to or be covered by U.S. patents, we disclaim any liability for the infringement of such patents by the making, using, or selling of any such equipment or circuitry, and suggests that anyone interested in such projects consult a patent attorney.

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EDITORIAL

Putting together Electronics Experimenter's Handbook seems fairly easy on the surface, but it *ain't!*

Hodgepodge assembly is A-OK when you're making a fudge-chocolate chip layer cake, but not so with a magazine that's jam packed with some of the most successful construction projects that appeared previously in *Electronics Now* magazine. Which ones do you use, and which ones do you exclude? Should the Editor go for a theme issue or buckshot the topical coverage? An honest response would be, "I am not too sure." So, how do you go about it?

For this issue of the handbook, I decided to include mostly small, economical projects that appeal to gadgeteers who build gizmos for their personal use. In so doing, several exciting telephone projects were included prompting some staff members to ask whether or not I was preparing a theme issue. Not really. It's just that telephone topics are real hot today and to exclude a few would not be considerate of our readers' needs.

Nevertheless, the other projects are quite diverse. We open the issue with an FM television micro-transmitter and swing into a static ROM project. We have a quality power supply project and a smart turn-signal gadget for your car. I could go on, but it would be wiser to refer to the contents page for accurate and complete details.

Start reading now and building as soon as you have acquired the parts. Then you will be having as much fun as I had preparing this issue.

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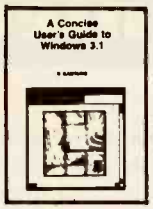

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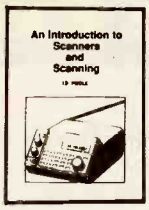

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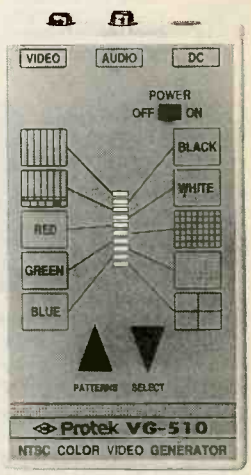
Responding to the increased public awareness of potential health risks from long-term exposure to low-level electromagnetic fields, *Environmental Electronics* has introduced the *MFD-1* magnetic-field detector. The sensitive *MFD-1* detects both the strength and direction of many of the low-level electromagnetic fields that have been linked to serious illness. Field strengths from 0.25 to 57 milligauss can be measured. The device's bandwidth goes from 20 to 10,000 Hz, enabling it to measure almost all extremely low frequency (ELF) and some very low frequency (VLF) fields. The ten-segment LED bargraph has two ranges and a power on/off indicator.

The MFD-1 magnetic-field detector, complete with one-year warranty, illustrated instructions, and a 9-volt battery, has a suggested retail price of $39.95. For further information, contact Environmental Electronics, Inc., P. O. Box 980, Goshen, IN 46527; Tel: 616-641-7645; Fax: 616-641-5738.

CIRCLE 53 ON FREE INFORMATION CARD

HANDHELD NTSC VIDEO-TEST GENERATOR

The pocket-sized *Model VG-510* NTSC video and audio generator from *Protek* will provide more than 40 hours of operation on four AA batteries. It offers ten test patterns: SMPTE; black burst; full-field color bars; red, green, blue, and white fields; center pulse cross; cross hatch; and dots. Intended for testing, adjusting, and repairing video equipment, the VG-510 is also a handy tool for video editing. Black burst can be used to lay down black on tapes and to record SMPTE color bars with tone at the beginning of the tape. Audio output is 1 kHz with an adaptor included for 120-volt studio use. The unit measures 5½ × 3¼ × 1½ inches and weighs less than a half pound without batteries.



The VG-510 handheld NTSC video-test generator costs $299 without SMPTE bars, $399 with SMPTE bars, and $540 with S-VHS output. Options include RF output, rechargeable batteries,

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CIRCLE 60 ON FREE INFORMATION CARD

DIGITAL VIDEO-PROCESSING CENTER

Home video editors can create near-professional quality videotapes using *Sima's Pro Ed/it 3X*, a combination editor and color processor that features digital technology and variable-speed

timing of fades from one to six seconds. During editing, the device creates automatic touch-button video and audio fades at the desired speed at the desired point in the tape. A patented bypass feature allows home editors to visually zero in on specific scenes to be inserted or deleted from the final edited tape.

The Pro Ed/it 3X's full-featured digital-video color processor enhances picture and color quality of the edited tape. Simple slide controls are used to adjust color intensity, tint, and detail. A video-enhance control boosts the video signal to restore washed-out colors. Digital color-processing capabilities allow the amateur video buff to create the best possible picture when editing.

Other features include two switchable input sources for easy editing from two tapes, and cross-fading, which allows one input source to be faded out and another to be faded in with the touch of a single button. Dual outputs allow the user to make two simultaneous copies of the edited tape. An audio mixer enables editors to add music and/or narration using the included high-fidelity microphone.

The Pro Ed/it 3X has a suggested retail price of $250. For further information, contact Sima Products Corporation, 8707 North Skokie Boulevard, Skokie, IL 60077; Tel: 708-679-7462; Fax: 312-286-7227.

CIRCLE 66 ON FREE INFORMATION CARD

HANDHELD FREQUENCY COUNTER

Intended for use in the test, communications, security/surveillance, two-way amateur radio, law-enforcement, and communications-monitoring markets, the latest model in *Optoelectronics' line of Handi Counters* represents a substantial improvement in features and capabilities. The *Model M-1* handheld frequency counter is a full-range counter with coverage from 10 Hz to 2.8 GHz that provides ultra-high-speed measurements as well as very high-resolution ten-digit measurements. It features ten user-selectable gate times, ranging from 13 milliseconds to 10 seconds, with corresponding resolution from 10 kHz to 0.1 Hz.

The M-1 is based on a high-speed application-specific IC that is capable of 250-MHz direct counting. An embedded

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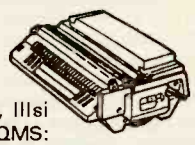

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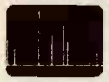
SPECTRUM PROBE



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This low circuit loading *scope probe* produces a spectrum analyzer display.

Technical tips show how scope amplitudes allow estimating field strength 300 µV/M to 100 V/M, to find and reduce RF radiation per FCC part 15.18;VDE. Other tips show how to build an RF current probe (4 µA to 100 mA) for less than $4 component cost, with a typical calibration curve. Also for RTCA/DO-160, MIL-STD-461C requirements.

An unusual tip shows how you can connect standard inexpensive components within an outlet strip. The outlets allow the operation of your equipment well isolated from power line noise. Included is the FCC line impedance (LISN) network, allowing you to measure the conducted EMI from your equipment per FCC part 15.18;VDE;MIL-STD.

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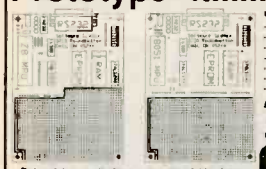

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For the Experimenter

(Continued from page 7)

pass the filter. An arm/store button sends captured data into a three-register stack that can be recalled later.

The addition of an asynchronous serial data port allows the TTL data to be level shifted to RS-232C using the optional accessory interface (*Model CX12*). The interface includes data-logging software that can be used with any PC to log and time-stamp frequency data.

A 16-segment relative signal-strength bargraph is sensitive to low levels of RF and can be used to verify transmitter output or locate a stuck transmitter or an unauthorized source of RF.

The M-1 costs $229. For more information, contact Optoelectronics Inc., 5821 NE 14th Avenue, Fort Lauderdale, FL 33334; Tel. 800-327-5912; Fax: 305-771-2052.

CIRCLE 55 ON FREE INFORMATION CARD

MULTIMETER WITH THERMOMETER

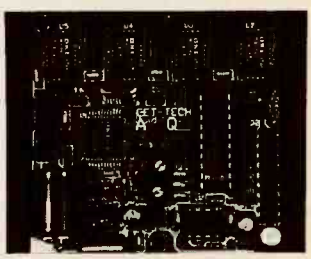
Extech's Model 380505 handheld multimeter offers seven functions, including a Type-K thermocouple input for temperature measurements from 0°–1999°F. The multimeter also monitors five ranges in both DC and AC voltage, DC amps, AC amps, and resistance. All functions are displayed on a 0.95-inch LCD readout. The unit also provides diode and audible continuity tests, as well as polarity and over-range indications. It comes complete with a rubber holster, test leads, a temperature probe, and a 9-volt battery.

The Model 380505 multimeter with thermometer costs $59. For additional information, contact Extech Instruments Corporation, 335 Bear Hill Road, Waltham, MA 02154; Tel. 617-890-7440; Fax: 617-890-7864.

CIRCLE 71 ON FREE INFORMATION CARD

DIGITAL VOICE RECORDER

GetTech's AudioQ-218 digital voice recorder will record up to 218 seconds of speech. The device offers four selectable sampling rates (4.8-, 8.5-, 9.6-, and 11-kHz), and sampling rates up to 17.8 kHz are available. As many as eight different variable-length messages can be stored in battery backed-up RAM. The recorder measures 2.6 × 2.6 inches.



Two independently adjustable audio outputs are provided. One high-level output will drive an 8-ohm speaker to 400 mW; the other can be used for output to an external amplifier or transmitter. An on-board regulator allows use from 8 to 15 VDC. An open-collector output for keying a transmitter or external device during playback is also available, as is customizing.

The fully assembled and tested AudioQ-218, including backup battery and 4 megabytes of RAM, costs $149 plus shipping and handling. For additional information, contact GetTech, 402 Riley Road, New Windsor, NY 12553; Tel. 914-564-5347. Ω

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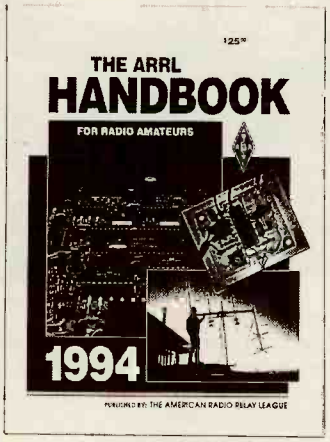
CIRCLE 51 ON FREE INFORMATION CARD

use full-color graphics and screen shots to show you exactly what you should see on your computer screen. Regardless of your competence level, these books help you learn quickly and easily without the hassle of costly, lengthy, hard-to-understand books.

Their latest effort, *Windows 3.1 Expanded* features detailed, step-by-step instructions showing you how to perform basic Windows tasks, use Windows accessories, and how to improve Windows performance. As you turn each page, a colorful sequence of illustrated events unfold detailing actions and results you will experience when you follow the simple directions with mouse and keyboard. Windows becomes as simple as flipping a page!

The AARL Handbook for Radio Amateurs 1994. The American Radio Relay League, 225 Main Street, Newington, CT 06111; Phone: 203-666-1541; Fax: 203-665-7531; $25.



CIRCLE 58 ON FREE INFORMATION CARD

This latest edition of the ARRL Handbook is a one-volume, 1100-page reference book that contains a wealth of practical information on electronics and related subjects. It covers the basics of amateur radio, electricity, and radio design as well as the principles of solid-state and vacuum-tube devices.

The handbook contains detailed information on radio principles, modulation methods, frequencies, and propagation. Included are schematics and parts placement diagrams for building such projects as power supplies, audio and video equipment, circuits that operate at high, very-high, ultra-high and microwave frequencies, antennas, and amateur radio station accessories.

New projects in this edition include an add-on circuit that converts an amateur station's fixed-voltage power supply into a variable-voltage supply, a high-frequency "Ugly

(Continued on Page 108)

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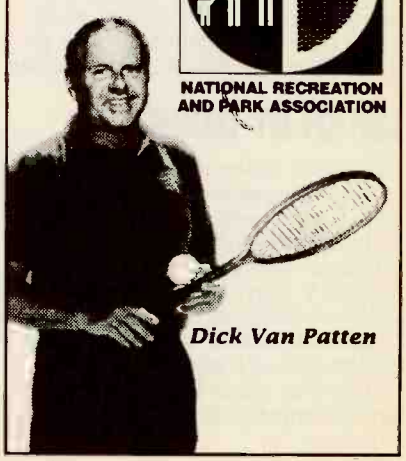


Dick Van Patten

BUILD A MICRO TV TRANSMITTER

This wireless mini video transmitter sends a picture to your TV set. It's ideal for security monitoring or observing nature.

MARTYN MCKINNEY, GARNET BRACE & KEITH FALCONER

THE MINIATURE SINGLE-BOARD VIDeo camera used in this project is an excellent example of how recent advances in integrated circuit and surface-mount technology have led to remarkable advances in video technologies. A complete, reasonably priced sclid-state camera will easily fit in the palm of your hand.

This article describes how you can build a simple modulator/transmitter and connect it to a commercially available video camera to obtain a portable, battery-operated camera that can transmit B&W or color pictures from remote locations back to your TV set. No antenna is needed to transmit to a nearby TV set, but if an external antenna is used, the modulator has enough power to transmit about 100 yards. The RF modulator/transmitter can transmit over standard NTSC channels 7 to 13 or UHF channels 14 to 29.

The mini video camera on which this project is based measures 0.91 × 1.81 × 2.76 inches and it weighs only 1.3 ounces. The camera requires a 6- to 12-volt DC power supply, and draws a current of only 65 milliamperes.

The applications for a battery powered, hand held TV transmitter are limited only by your imagination. Home or business security come most readily to mind. Because cables are unnecessary, there is no danger of an intruder cutting cables and disabling the camera. The camera can be placed in an unobtrusive location protected from the weather.

You can also use this camera transmitter to keep an eye on an infant in a crib or observe a disabled or bedridden person. And you could also put this camera to work as the "eyes" of a robot or for monitoring industrial welding or machining operations that would pose a safety threat to people standing too close.

If you are a farmer, you can monitor the behavior of livestock in a barn, and if you're a nature hobbyist, you can observe wild animals and birds at close range. The ability of the camera to "observe" action in reduced light will be particularly attractive.

The camera/transmitter system can be powered from an AC to DC wall-mounted adapter, or it can be powered from a standard 9-volt battery. The service life of an alkaline-manganese battery is approximately four hours.

Camera modules with several different configurations are available from the source given in the parts list. One is a super wide-angle (110° field-of-view) 3-mm, *f*1.8 lens; the other is a narrower angle (78° field-of-view) 4.3-mm, *f*1.8 lens. A 12-mm, *f*1.8 lens is available for those interested in aerial or nature photography. This camera, when placed behind the viewfinder of a single-lens reflex (SLR) still camera, will accept the full field-of-view of the still camera lens and permit remote

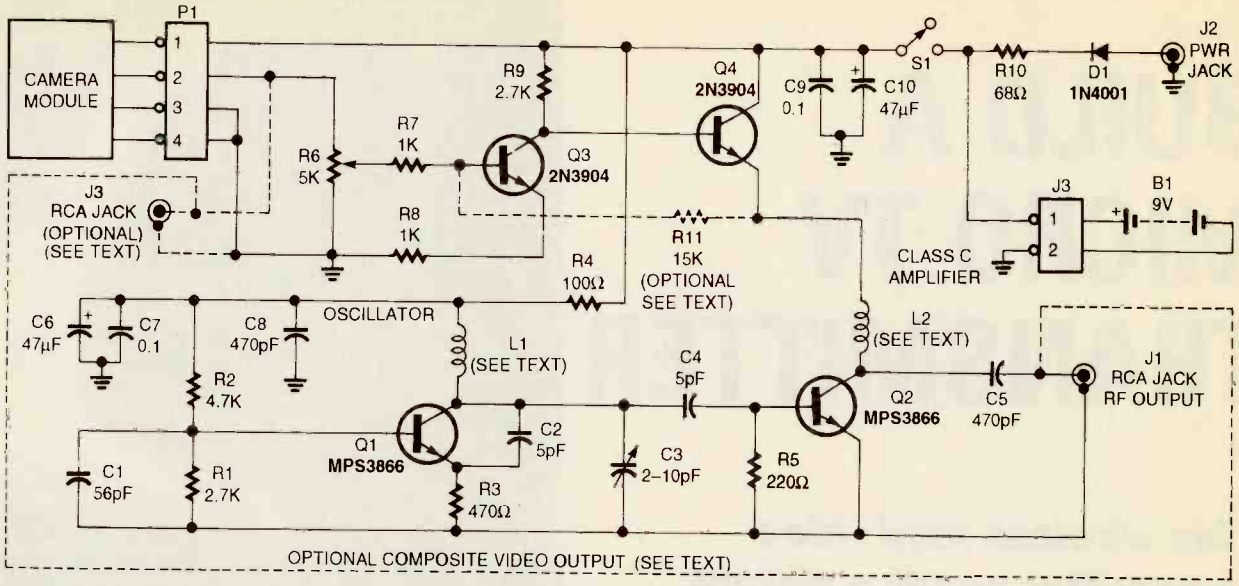


FIG. 1—MODULATOR SCHEMATIC. Coil L1 is the key component that determines the frequency of oscillation.

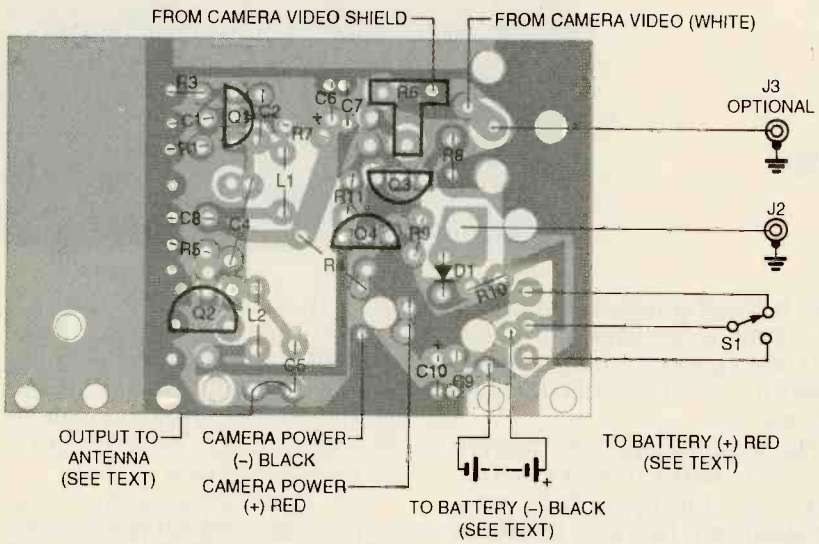
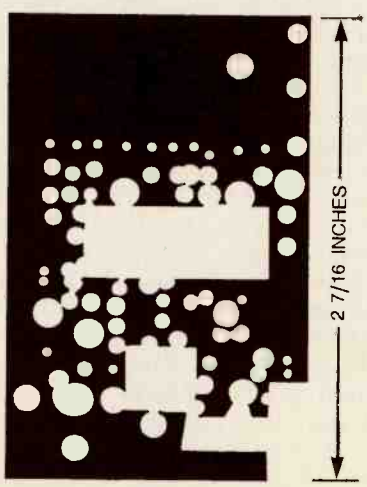
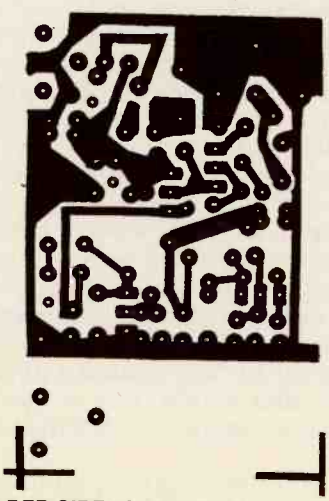


FIG. 2—PARTS-PLACEMENT DIAGRAM. Note that the board can be cut, if needed, to fit in a smaller case.



COMPONENT SIDE of the board.



SOLDER SIDE of the board.

monitoring of the picture to be taken.

The CCD mini camera is also sensitive to infrared (IR) radiation, and when paired with a simple infrared light source, can be used to see in the dark. For robotic or industrial applications, a single infrared-emitting LED emits enough energy to illuminate nearby objects.

The modulator is built on a 2¼ × 1½-inch printed-circuit board, which is mounted on insulating standoffs above the camera module. A wiring harness and plug connect the camera to the modulator.

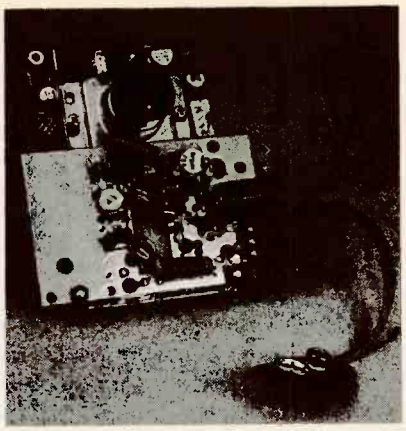
Modulator operation

The schematic of the transmitter is shown in Fig. 1. The circuit operates as follows: Transistor Q1 is the amplifier in a transistor oscillator that oscillates in the frequency range of VHF channels 7 to 13 (174 to 216 MHz) or slightly above (250 MHz), depending on the desired transmitter frequency. The output from the resonant tank circuit of the oscillator, formed by coil L1 and capacitor C3, is capacitively coupled by C4 to the base of the Class-C amplifier stage that includes Q2.

The combination of L2 and the parasitic capacitance of the PC board broadly tunes the output of Q2 to either the same range of frequencies as the os-

cillator stage, or to a frequency that is twice that of the oscillator stage, which permits the transmitter to cover Channels 14 to 29 (470 to 580 MHz).

The Class C amplifier stage is collector-modulated by a two-transistor modulator that consists of Q3 and Q4. The output from the camera is directly coupled to Q3 through variable resistor R6. The ratio of resistors R9 and R8 in the collector and emitter circuits of Q3 determines the gain of approximately three for this stage. The output of the camera is an NTSC composite video signal of approximately 2 volts peak-to-peak amplitude with a 0.7 volt DC offset. The output of Q3 is directly coupled to emitter follower Q4, which collector-modulates the Class C output stage.



THE MODULATOR BOARD after being mounted on the video camera module.

The modulator has been designed to work primarily with the camera described, but it can also be used as a modulator for any composite video device. This is accomplished by changing the value of R9 from 2700 ohms to 4700 ohms, thus increasing the gain of the input stage and adding 15 K resistor R11, which removes the DC offset from the amplifier stage. Provision has been made on the modulator printed circuit board to add an optional right-angled RCA connector that can provide baseband video output or accept baseband video input when the modulator is used with other devices.

Diode D1 and resistor R10 form a simple battery-charger circuit. Diode D1 also protects the camera from reverse voltage should a charger with the wrong polarity be connected accidentally.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise specified.

R1, R9—2700 ohms (see text)
R2—4700 ohms
R3—470 ohms
R4—100 ohms
R5—220 ohms
R6—5000 ohms, potentiometer
R7, R8—1000 ohms
R10—68 ohms
R11—15,000 ohms (see text)

Capacitors

C1—56 pF, ceramic disk
C2, C4—5 pF, ceramic disk
C3—2 to 10 pF trimmer
C5, C8—470 pF, ceramic disk
C6, C10—47 µF, 16 volts, aluminum electrolytic
C7, C9—0.1µF, ceramic disk

Semiconductors

Q1, Q2—MPS3866 NPN transistor
Q3, Q4—2N3904 NPN transistor
D1—1N4001 rectifier diode

Other components

L1—3 turns tinned bus wire wound on a 3/16-inch drill bit for channels 7–13 OR 2 turns tinned bus wire wound on a 3/16-inch drill bit for channels 14–29 (see text)
L2—Same as L1 (see above)
J1—Bulkhead-mounted RCA jack (optional)
J2—2.1 mm DC power jack
J3—-right-angle RCA jack (optional)
S1—-SPDT miniature switch
Miscellaneous: CCD Camera Module (Chinon CX-102), PC Board, plastic case, 9-volt alkaline battery, hardware, 5/16-inch nylon standoffs, ½-inch No. 2-56 screws and nuts, coaxial cable, wire, solder.

Note: The following items are available from Bayview Hobby Supplies, 14800 Yonge St. #110, Aurora, Ontario, Canada L4G 1N3. Tel: 905-841-7312. Fax: 905-841-4436:

- **Camera module including wiring harness—$229.00 (specify Model M100W with wide angle 3 mm lens and 110 degree field of view or Model M100N normal angle 4.3 mm lens and 78 degree field of view)**
- **Modulator PC board (M200)—$12.95**
- **Drilled plastic case (M201)—$14.95**
- **9-volt AC wall adapter (M202)—$14.95**
- **Modulator kit (M300)—$49.95**
- **Completed modulator (M301)—$99.95**
- **Kit including camera module, all parts, hardware, and case (M400)—$299.00**
- **Semi-kit, includes camera module and fully assembled and tested modulator board (M401)—$329.00**
- **Completely assembled and tested camera and modulator mounted in case (M402)—$349.00**

All prices in U.S. funds. Shipping and handling extra.

Construction

A complete modulator circuit board can be purchased from the source given in the parts list. However, foil patterns are provided for those who want to make their own. Note that the circuit board stock is 0.031-inch thick glass-epoxy with copper foil on both sides. (Paper-based PC boards should not be used at the high frequencies produced in this circuit).

Certain parts of the ground-plane foil on the component side of the board must be removed to provide insulated surfaces for some components. See the parts-placement diagram in Fig. 2.

Mount all components on the non-solder ground-plane side of the board. Mount all resistors vertically after forming the leads. Mount all disc capacitors as close as possible to the ground plane. Both electrolytic capacitors are mounted horizontally and their axes lie parallel to the surface of the board.

Begin by mounting the shortest components first. Start first with the variable capacitors, variable resistor, and the ceramic disc capacitors. Then add the transistors, resistors, and coils.

Although there are no critical component positioning requirements, take special care when installing the transistors. They look alike, but the circuit will not work if they are acciden-

tally interchanged. Capacitor C8 is an RF bypass capacitor that forms part of the tank circuit. Its leads should be as short as possible.

Coil L1 is a 2- or 3-turn coil (depending on the output frequency selected) of No. 22 AWG tinned wire wound on an 3/16-inch drill bit. The coil, in conjunction with variable-capacitor C4, determines the oscillator frequency. This frequency is in the range of 174 to 216 MHz for channels 7 to 13, or 235 to 280 MHz for channels 14 to 29. (The oscillator frequency is doubled to 470 to 560 MHz in the Class C stage for the higher channels). Diode D1 should be mounted with its anode closest to power jack J2.

After all components are soldered, install the battery clip, wiring, and plug for the TV camera module. These wires enter from a hole in the bottom of the board to provide strain relief, and they are soldered after insertion into holes in the top of the board. The modulator can be operated without an antenna but, if longer range is desired, an antenna can be connected to output capacitor C5 (see options section).

Alignment

When the board components have been assembled and soldered, check the current drain with the modulator connected to a 9-volt supply. The current drain should be about 25 milliamperes, and should drop to about 10 milliamperes when the main oscillator is inhibited (which is accomplished by touching L1 with a finger.) This simple test indicates that the oscillator is functioning and the Class C stage is amplifying.

After testing, mount the finished modulator board above the camera module with two 5/16-inch long nylon standoffs and two 1/2-inch long No. 2-56 screws and nuts.

After mounting the modulator board, the camera plug can be connected. At this time, check the current drain again. With the camera connected, the drain from a 9-volt supply should be about 85 milliamps.

With a television receiver tuned to the desired channel near the completed unit and power applied to the camera and modulator, tune C3 until a video image appears on the screen. Turn R6 clockwise to a position that gives a picture with maximum contrast and no "tearing."

If no video image appears on the screen after all other possible sources of assembly error have been eliminated, adjust L1 by separating its turns to raise the output frequency or compress the turns to lower the frequency. When using video sources other than the camera, it will be necessary to change R9 from 2.7K to 4.7K to increase the gain of the modulator. Also add the 15K resistor R11 to eliminate DC offset.

Once these adjustments are made, mount the completed unit in the plastic case and fasten the back in position with four self-tapping screws.

There is no voltage regulation to compensate for battery-voltage variation. The resistor values in the oscillator section have been selected so that the oscillator exhibits a minimum frequency shift over the usable battery range.

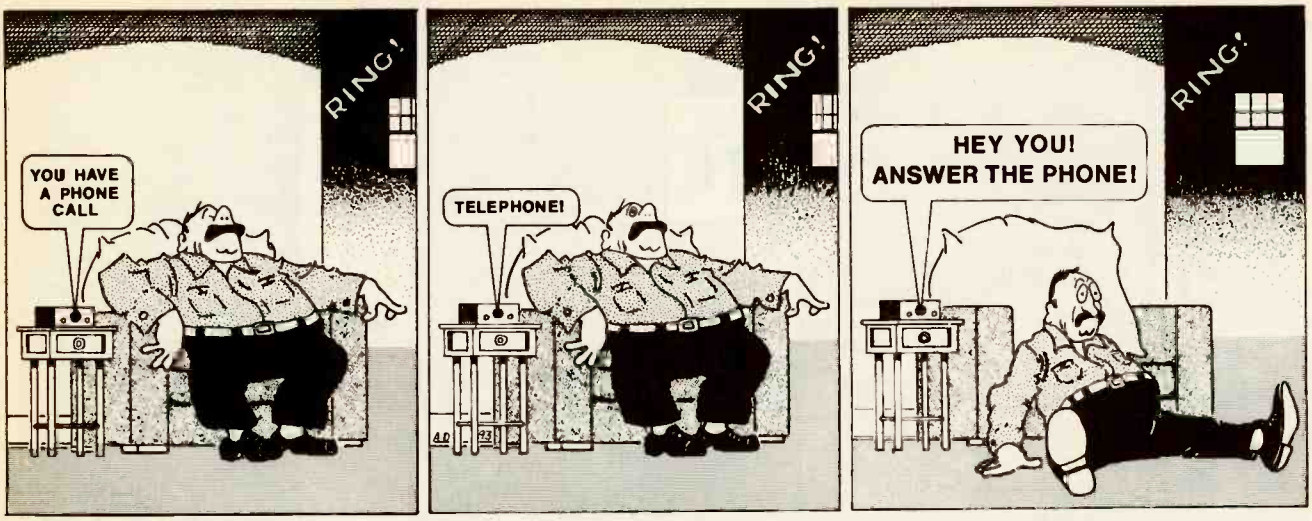
Options

Provision has been made in this design to offer the user a number of options to give the camera extra versatility.

- **Frequency.** The modulator is designed to operate either on Channels 7 to 13 or 14 to 29. For Channels 7 to 13, coils L1 and L2 are three turns of No. 22 wire wound on a 3/16-inch form. For Channels 14 to 29, coils L1 and L2 are *two* turns of No. 22 wire wound on a 3/16-inch form.
- **Enclosure**. You might want to mount the unit in its own enclosure such as a picture frame or lamp for surveillance. The modulator board can be mounted to the camera without modification, or it can be cut with shears along line A-A to make it smaller.
- **RCA Input/Output Jack**. Provision has been made on the PC board for a right-angle RCA jack. (Note that the board will not fit in the case pictured if this option is selected.) This option provides composite baseband output from the RCA jack, or composite video can be introduced to the jack from an external source.
- **Wall Adapter**. The camera unit can be powered from any negative ground (positive tip) 9-volt wall adapter. When a wall adapter is used, the battery should be removed. Be sure that the output of the adapter does not exceed 12 volts.
- **Rechargeable Battery**. A rechargeable nickel-cadmium battery can replace the suggested alkaline battery, although battery life will only be about half as long (two hours instead of four hours) before the battery needs a recharge. Resistor R10 has been selected to recharge the battery in approximately four hours. Many rechargeable 9-volt batteries actually have terminal voltages of 7.2 volts and will charge at a higher rate. Most wall-mounted chargers are poorly regulated and their voltage rises dramatically when lightly loaded. Make sure that the battery does not overcharge.
- **RF and Baseband Output**. For short range use (up to 30 feet), no antenna is necessary as long as there is an adequate antenna on the TV receiver. For longer range, a 1 foot length of No. 18 stranded copper hookup wire can be connected to output capacitor C5 and extended through the case. If you want both baseband output and RF output, an optional RCA jack can be mounted on the front panel of the case and the output from C5 can be connected to it by a short length of wire.

A length of coaxial cable from the camera harness can be connected from the jack to the camera output on the modulator board. (The cable effectively blocks RF from getting back into the camera.)

If you want baseband output, an RCA plug and cable inserted into the jack will provide composite video output to a video monitor. If you want RF output, an antenna can be inserted into the RCA jack. Ω



TALKING TELEPHONE RINGER

Don't listen to that annoying bell—build our talking telephone ringer and customize the way your phone rings.

STEVE LYMPANY

TELEPHONES RING AND THAT'S about all there is to it. True, some phones buzz, beep, or chirp, but that's hardly exciting. However, with the advent of IC's like the ISD 1016 Voice Messaging System, you can build our talking telephone ringer and record personalized messages that will be played whenever someone telephones. You'll never have to listen to the same old bell again!

With the recording capabilities of our ringer, you can include your own spoken messages, musical selections, your college fight song, or any other interesting sounds that you might want to try. You can also program several different messages that play in sequence with each ring. Using that capability, the author has programmed his ringer to produce the following sequence:

1st ring: "The phone is ringing" (in a polite voice)
2nd ring: "I said, the phone is ringing!" (in a slightly aggravated voice)
3rd ring: "Get the phone!" (in a noticeably irritated voice)
4th ring: "Pick up the phone!" (this time in a hysterical voice)

You may choose to program something a little kinder and gentler—the possibilities are limitless.

The ringer device, which does not interfere with normal telephone operation, plugs into one of your telephone jacks, and also requires external power from a 9-volt DC wall adapter. When someone calls you, the incoming ring signal triggers the message to be played.

Circuit operation

Figure 1 is the block diagram of the circuit. When a ring signal appears across the telephone line, the ring detector sends a start signal to the message-storage chip. The counter and logic sections tell the message-storage chip which message to play, based on how many times the phone rings.

Turn now to the schematic diagram in Fig. 2. A 20-Hz ring signal of 40 to 150 volts, present at P1's Tip and Ring (Green and Red, respectively), is divided down by R1, R2, and R3. Current then flows through C1 to pins 1 and 2 of IC1, a 4N25 optocoupler, which isolates the rest of the circuitry from the telephone line. The current flow through the input side of IC1 causes pin 5 to go low, which signals a start-playback request from the ISD 1016 messaging chip, IC4.

The sensitivity of the ring-detection circuit is set by R6; the 12K value was obtained assuming a nominal 100-volt incoming ring signal. If the ring voltage coming in on your phone line is lower than 100 volts, you may need to increase R6 to a value between 15K and 30K.

Metal-oxide varistor MOV1 protects the ringer from tran-

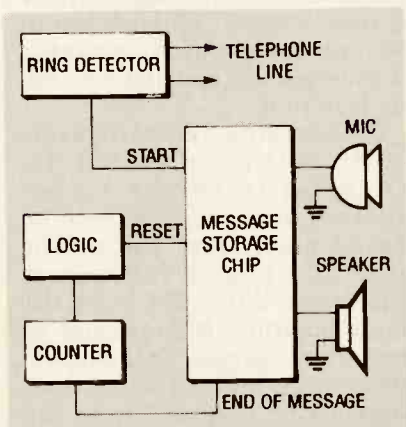


FIG. 1—BLOCK DIAGRAM showing the ring detector, a counter, and an audio storage and playback integrated circuit.

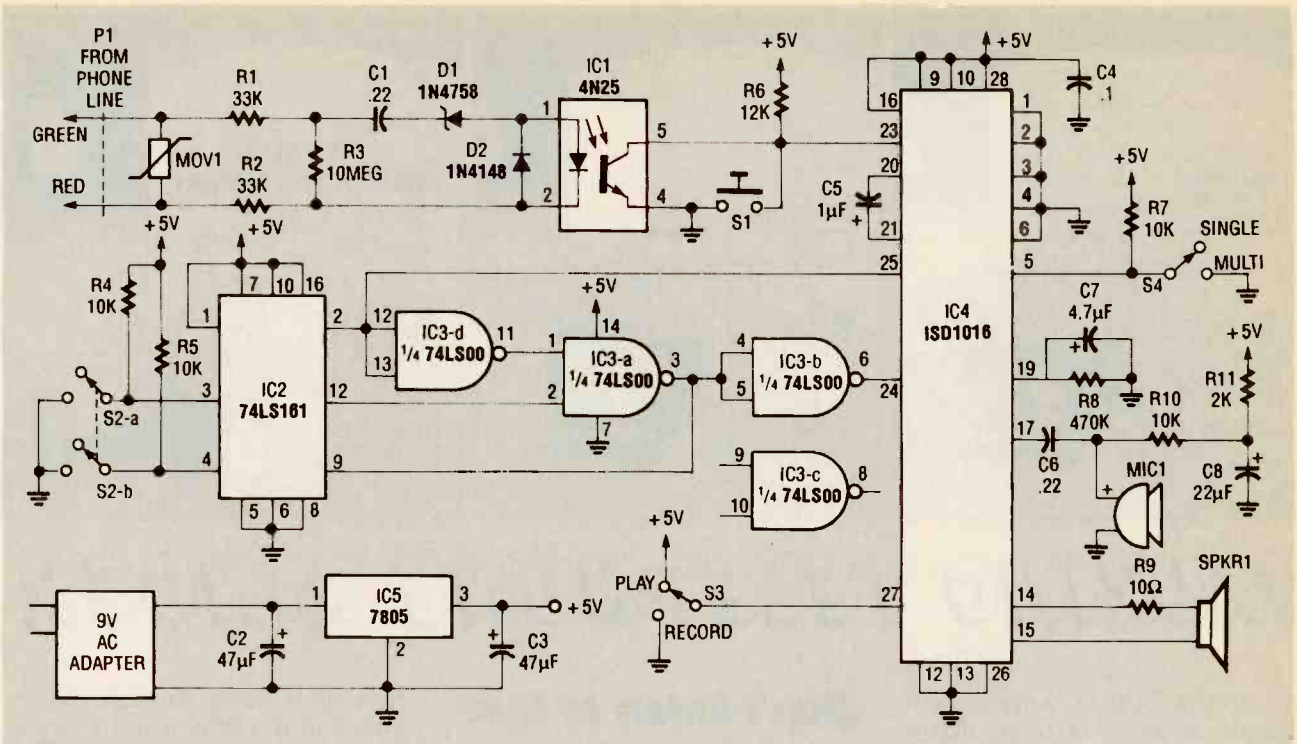


FIG. 2—SCHEMATIC DIAGRAM. A ring signal starts playback from the ISD 1016 messaging chip, IC4.

sient voltage spikes caused by lightning-induced current on the telephone line. Diode D1 protects the input LED of the optocoupler from reverse voltage during the negative cycle of the AC ring signal. Diode D2 establishes a transient threshold to prevent the ringer from triggering when you pick up the phone or when dialing with a rotary telephone.

Pushbutton switch S1 has two functions: When S3 is in the PLAY position, S1 acts as a test button that permits you to play back the messages under manual control. When S3 is in the RECORD position, pressing S1 enables the circuit's recording function.

The operation of IC2 depends on the setting of switch S4. When S4 is in the SINGLE position, one message will be played each time the phone rings (IC2 has no function in this case). When S4 is in the MULTI position, IC2 operates as a counter circuit that counts the number of individual messages to be played. Up to five different messages can be sequenced with each successive incoming ring signal. Settings for the number of plays is shown in Table 1. Quad NAND gate IC3 works in conjunction with IC2 to provide logic control for resetting IC4 when the proper number of playback messages has been reached.

The ISD 1016 messaging chip (IC4) stores up to 16 seconds of high-quality audio. Audio for recording is input to the chip via the electret microphone MIC1, while playback occurs through the 8-ohm speaker SPKR1. (For more details on the IC, see the article "Single Chip Messaging System," by Richard D. Tenney, in the March 1992 issue of **Radio-Electronics**.)

Power to the circuit is provided via a 9- or 12-volt DC wall adapter. A 7805 regulator (IC5) provides 5-volt regulated power to the rest of the circuitry.

Construction

Because this project is relatively simple, you can use any accepted wiring technique to assemble the circuit. The use of a PC board provides the best results. You can make your own PC board using the foil pattern we've provided, or buy a premade board from the source mentioned in the Parts List.

The Parts-Placement diagram is shown in Fig. 3. It is a good idea to use a 28-pin DIP socket for IC4, and it can't hurt to use them for all the other IC's. Make sure you properly orient the diodes, electrolytic capacitors, and IC's before soldering them in place. Note that there is an 8-pin DIP pattern at the S2 location on the board. That allows you to install a 4-position DIP switch, even though only two of the switches are used. Don't forget to install wire jumpers at all locations marked "J." Switches S1, S3, and S4, and MIC1 and SPKR1 are mounted on the enclosure. Use about five inches of insulated wire attached to each terminal to connect those components to the PC board.

When you have soldered all components in place, you can test the circuit. With IC4 still not installed in its socket, plug the AC adapter into a wall outlet. Check for 5-volts DC between pin 3 of IC5 and ground. If you do not obtain a proper reading, make sure the 9-volt adapter is indeed delivering 9-volts DC (or more) when not connected to the ringer. If it is, check the orientation of IC5. Correct any wiring errors and/

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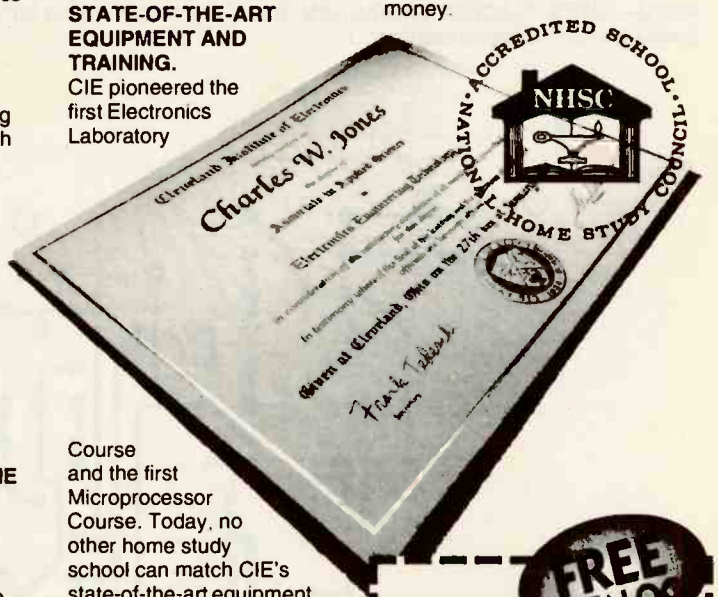

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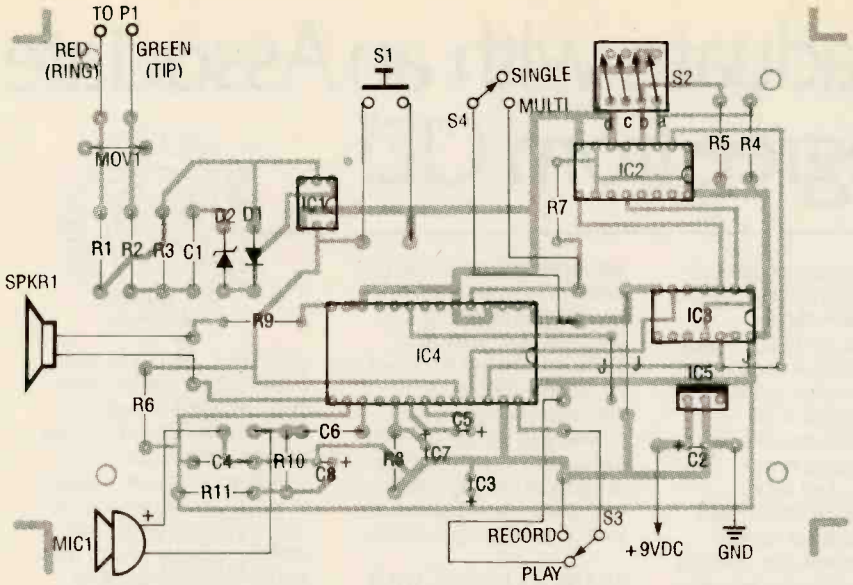
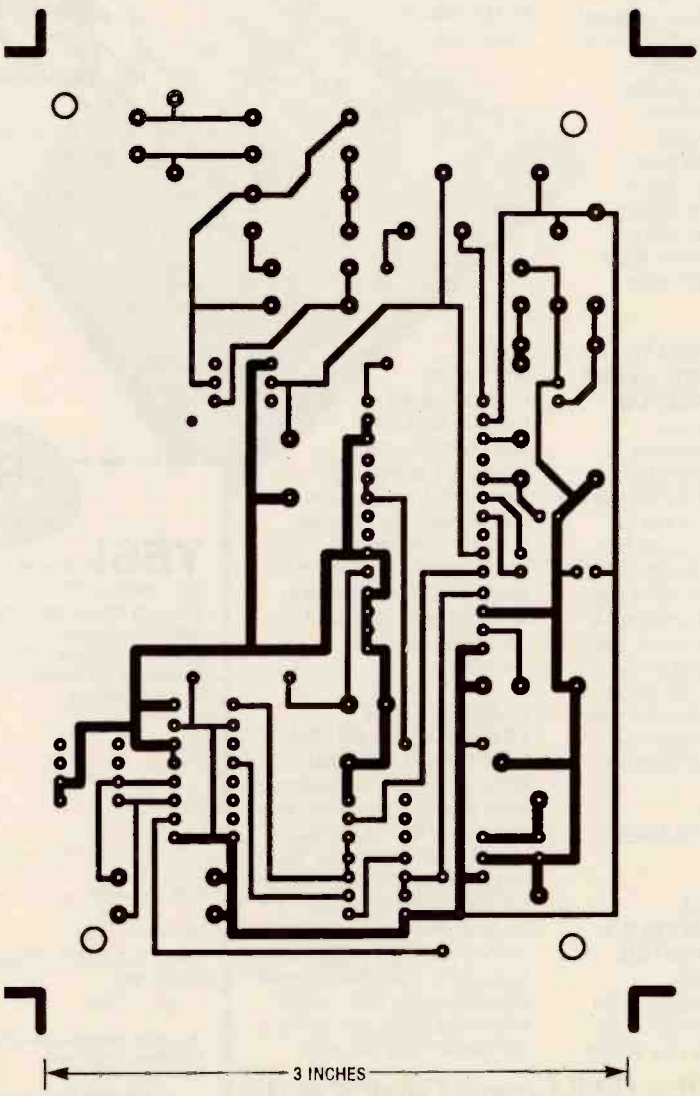


FIG. 3—PARTS-PLACEMENT DIAGRAM. Use a 28-pin DIP socket for IC4. Install wire jumpers at all locations marked "J."



FOIL PATTERN for the single-sided board.

PARTS LIST

All resistors are ¼-watt, 10%, unless otherwise specified.

R1, R2—33,000 ohms
R3—10 megohms
R4, R5, R7, R10—10,000 ohms
R6—12,000 ohms
R8—470,000 ohms
R9—10 ohms
R11—2000 ohms

Capacitors

C1—0.22 µF, 250 volts, metal film
C2, C3—47 µF, 35 volts, electrolytic
C4—0.1 µF, 50 volts, ceramic disc
C5—1 µF, 16 volts, tantalum electrolytic
C6—0.22 µF, polystyrene
C7—4.7 µF, 16 volts, tantalum electrolytic
C8—22 µF, 16 volts, tantalum electrolytic

Semiconductors

IC1—4N25 NPN-transistor-output optocoupler
IC2—74LS161 counter
IC3—74LS00 quad NAND gate
IC4—ISD1016 Voice Messaging Chip (Hamilton Hallmark)
IC5—7805 5-volt regulator
D1—1N4758A 56-volt Zener diode
D2—1N4148 diode

Other components

MOV1—metal-oxide varistor
P1—telephone line cord
S1—momentary pushbutton switch
S2—2-position DIP switch
S3, S4—SPDT toggle switch
SPKR1—8-ohm speaker
MIC1—electret microphone
Miscellaneous: 9-volt AC adapter, enclosure, mounting hardware, wire, solder, rubber grommets

Note: The ISD1016, $7.50 at the time of this writing, is available through Hamilton Hallmark, 1-800-332-8638. An etched, drilled, and plated PC board is available for $14.00 by requesting PC board "SquakerRevA" from Atlas Circuits Company, P.O. Box 892, Lincolnton, NC 28092.

or replace any defective components before proceeding.

Once you obtain the proper +5-volt reading from IC5, disconnect power from the ringer, and install IC4 in its socket. Power up the ringer again and place S4 in the SINGLE position and S3 in the RECORD position. While pressing and holding S1, speak a test message into the

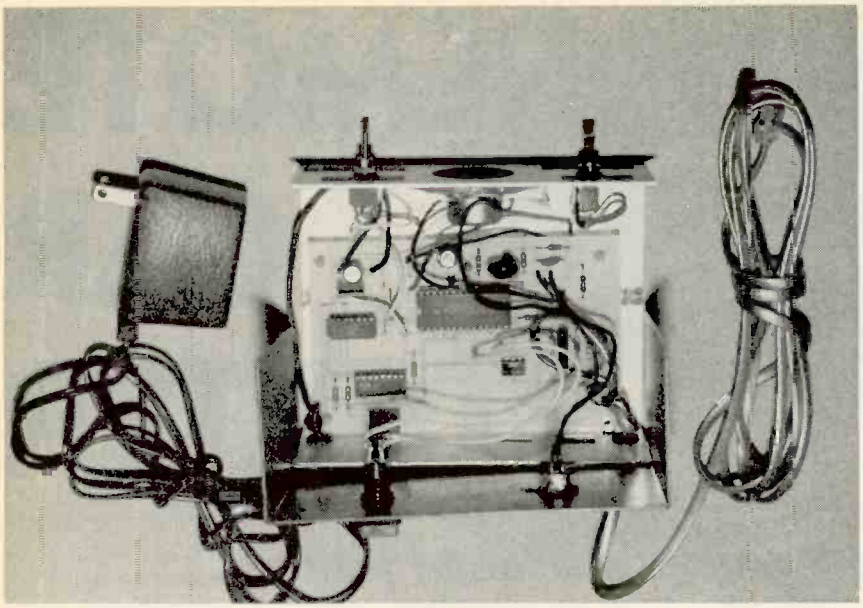


FIG. 4—THE AUTHOR'S completed and tested prototype, shown here installed in a metal project case.

TABLE 1—SWITCH SETTINGS

Desired Number of Messages	S4	S2-a	S2-b
1	Single	X	X
2	Multi	L	L
3	Multi	H	L
4	Multi	L	H
5	Multi	H	H

microphone. Then release S1 and place S3 into the PLAY position. A momentary pressing of S1 should now result in the playback of your test message. If those results are obtained, your ringer is ready to be mounted in an enclosure.

Any plastic or metal enclosure that will accommodate the PC board, switches, and speaker will suffice. Drill the selected enclosure to provide mounting holes for the circuit board assembly, S1, S3, S4, SPKR1, MIC1, and access holes for the power cord and the telephone line cord. If you are using a metal enclosure, deburr all holes and insert rubber grommets for the AC line cord and the telephone cord.

Mount the circuit-board assembly in the enclosure using ½-inch spacers. Then mount all off-board components in their respective mounting holes. Pass the AC cord and the telephone cord through their rubber grommets and tie a knot in each one, about 5 inches from the free ends inside the enclosure to serve as strain relief for each cord. Strip the ends of each wire and tin them with solder. Then solder the free ends in their respective circuit board holes, referring to Fig. 3 for details. Figure 4 shows the author's completed prototype installed in a metal enclosure.

Once the unit is complete, plug the adapter into an AC outlet and plug the telephone cord from the ringer into an unused telephone jack. If you need to attach the unit to a jack that already has a phone connected to it, you'll need a duplex jack. It is a "Y" adapter that lets you plug two phones into one jack, permitting you to use the voice ringer and the telephone at the same time. You also might want to shut off the telephone's internal ringer, so you can clearly hear the voice ringer and its unusual message.

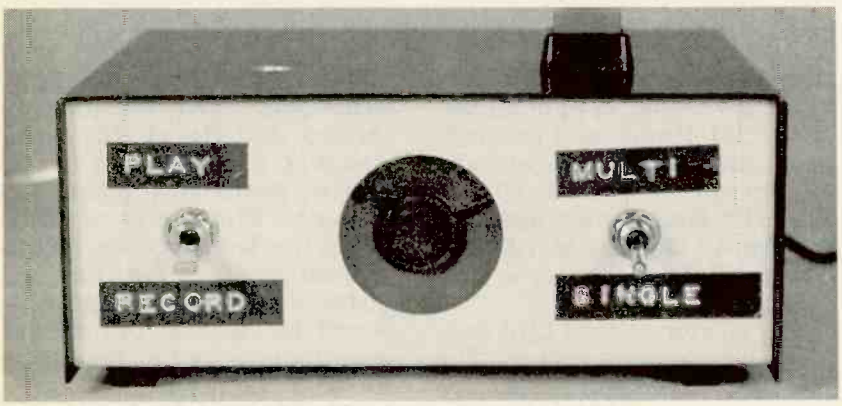


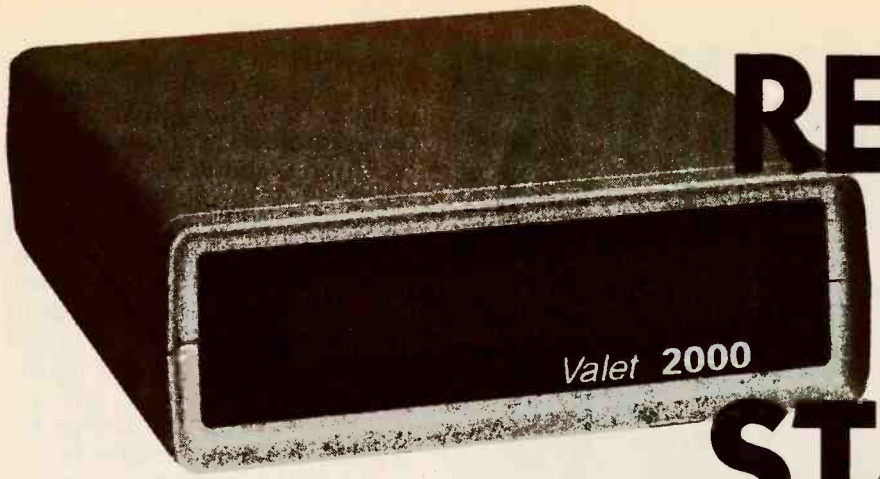
FIG. 5—HERE'S THE FRONT PANEL of the author's prototype.

Recording tips

To record multiple messages, perform the following procedure:

1. Place S4 in the MULTI position.
2. Set S2-a and S2-b as listed in Table 1 for the number of messages you desire.
3. Press and hold S1 to record the first message.
4. Release S1.
5. Press and hold S1 again to record the second message.
6. Release S1.
7. Repeat steps 5 and 6 for each additional message.
8. Place S3 in the Play position after recording your last message.
9. Test the sequence by successively pressing S1 for each message.

Since a standard ring signal is on for 2 seconds and off for 4 seconds, you'll want to make your messages at least 2 seconds long to prevent successive triggering by one ring cycle. This can easily be accomplished, even on short messages, by holding the record button down for at least 2 seconds for each message. Ω



REMOTE CAR STARTER

Build this RF remote starter for your car.

MARTIN FOURNIER

THERE SEEMS TO BE A UNIVERSAL hatred of getting out of bed on a cold winter morning. But most people will agree that going outside and warming up a freezing cold car is even worse. It always leaves you shivering for at least fifteen minutes. Wouldn't it be great if you could have someone else go outside and start your car so that you could jump right into a warm car and drive away?

Well you can scratch that one off your wish list. Our remote car starter will let you start your car remotely, from indoors, so that it's warmed up and ready to go when you are. And starting the car is not all it will do; it will also let you control power doors, trunks, and other car accessories.

Although this project is not difficult to build, it should not be attempted by anyone who is not intimately familiar with automotive installations. It is impossible for us to give detailed hookup instructions because every car model will need a different installation procedure. A complete installation requires tapping into your car's ignition, starter, door-lock, and other systems. Professional, experienced installation assistance is strongly recommended.

How it works

The RF remote starter consists of two major systems: an RF transmitter/receiver system and a starter control unit. Because RF remote controls are so difficult to tune, and expensive to build, the system uses a commercially made RF remote transmitter/receiver system, called the Enforcer, made by Seco-Larm. However, you can use any other RF remote-control system as long as it has a contact output. If you already have one, you might be able to modify it for use with this project.

The starter control unit is based on the 68HC705C8S microcontroller from Motorola. This chip consumes 4–10 milliamps in the operating mode and can go as low as a few microamps in its sleep mode. There are lots of microcontrollers that can do the job, but our choice was the 68HC705 with a "C8S" suffix which means that it's an extended temperature range device. Assembly-language source code for the microcontroller will be posted on the RE-BBS (516-293-2283, 1200/2400, 8N1), as a file called STARTER.ASM. If you can't program your own, a pre-programmed microcontroller is available from the source mentioned in the Parts List. Figure 1 shows the schematic of the starter control unit.

The starter control unit contains two power supplies. The ICL7660 (IC2) supplies the −5 volts for the LCD. The chip provides a stable −5 volts when you apply 5–12 volts DC to pin 8. The LM7805 (IC4) feeds all the circuitry with +5 volts derived from the car's 12-volt supply.

Software

The flowchart for the microcontroller's main operating program is shown in Fig. 2. When the operator pushes the transmitter button once for less than 3 seconds, the microcontroller unlocks the doors. If nobody opens the doors within 20 seconds it will automatically relock them. If the operator unlocks the doors and pushes the transmitter button again within 5 seconds, the trunk will open. When the operator holds down the button for more than 3 seconds, the microcontroller executes the start routine.

The start routine, whose flowchart is shown in Fig. 3, operates as follows: First assume that the engine isn't running. The start request is acknowledged by the flashing of the car's headlights. Then the program verifies that the engine is not running, and turns on the accessory power of the car for 4 seconds. That delay is sometimes needed to let the fuel injection pump raise the pressure. Next, the starter relay closes for at least 0.5 second, and the program again checks to see if the engine is running by monitoring the signal from

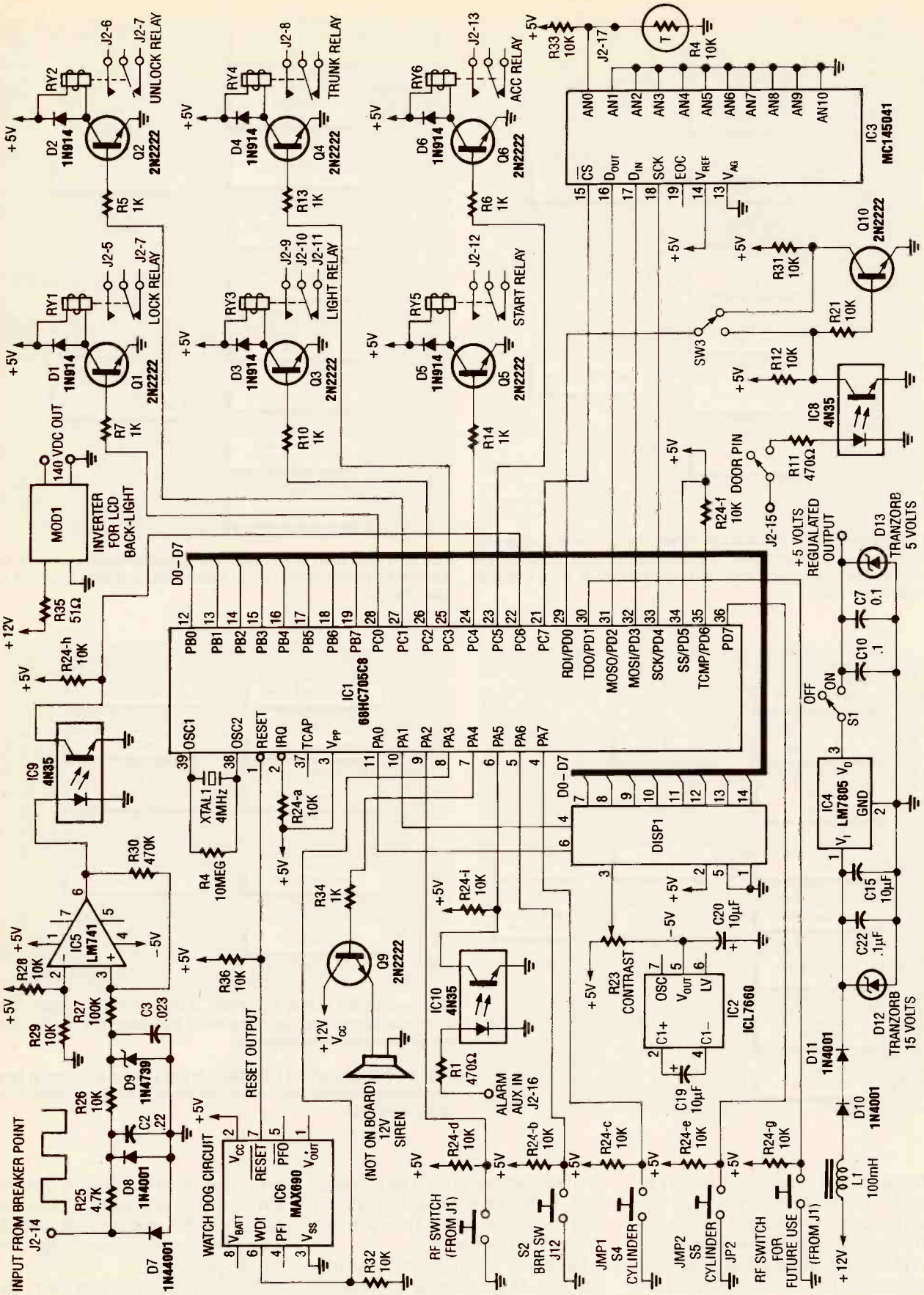


FIG. 1—STARTER SCHEMATIC. IC2 generates −5 volts from a 5–12 volt DC source and IC3 generates +5 volts from the car's 12-volt supply.

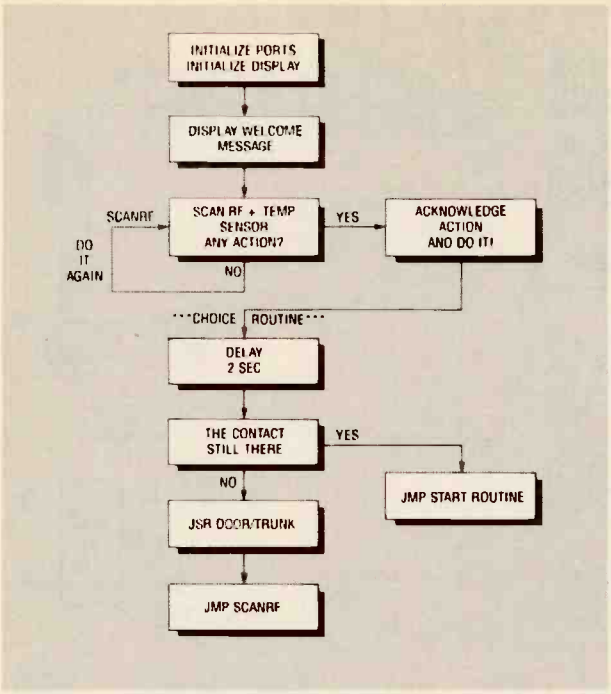


FIG. 2—THE MAIN PROGRAM. When the operator pushes the transmitter button once, the microcontroller unlocks the doors; if nobody opens them within 20 seconds, they automatically lock again.

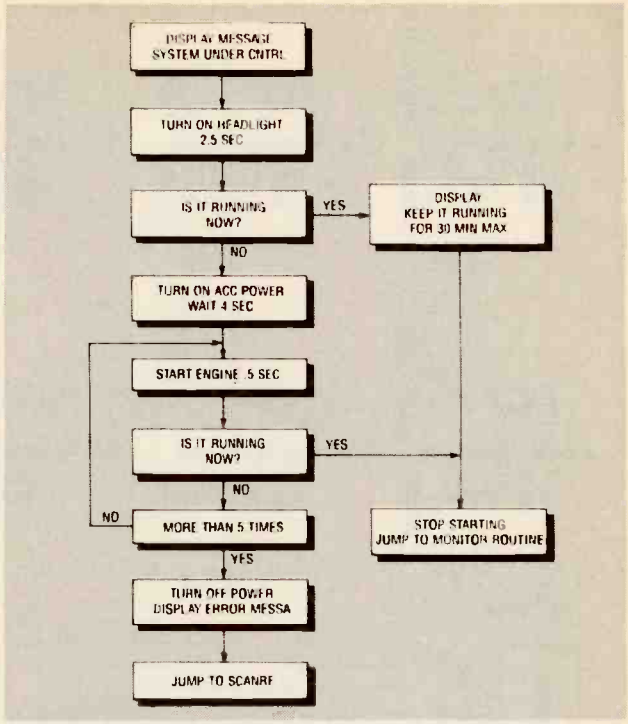
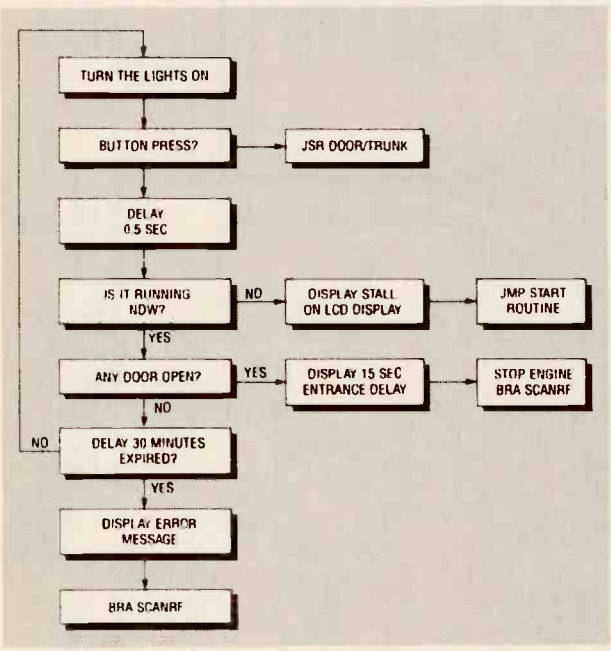


FIG. 3—THE START ROUTINE. The microcontroller turns on the accessory power of the car for 4 seconds, and then attempts to start the car.



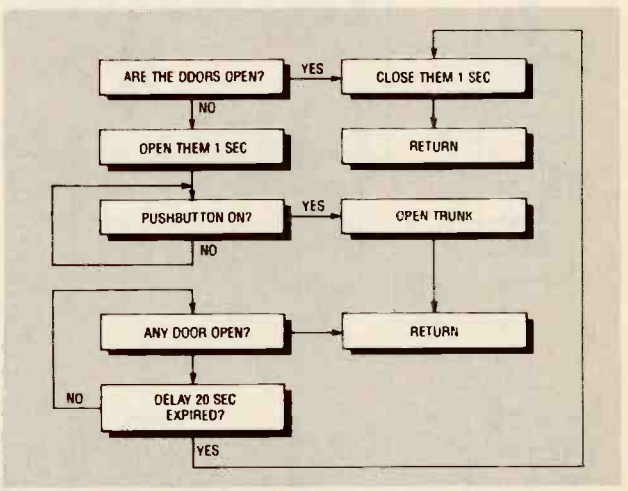


FIG. 5—DOOR/TRUNK ROUTINE. If the doors are open, the microcontroller locks them and waits for 5 seconds to see if the transmitter button is pressed.

◀ FIG. 4—THE MONITOR ROUTINE. If the engine is running and somebody presses the button for more than 3 seconds, this routine will start.

the car's distributor points. If it isn't, the start process will repeat a maximum of 5 times. If the engine is not running after 5 tries, an error message is displayed on the LCD and the microcontroller is ready for another request. If the engine is running and somebody presses the button for more than 3 seconds, the engine will stay on and the monitor routine, shown in Fig. 4, begins.

Because security is very important, if somebody opens any door when the car is in the monitor routine, they'll have only 15 seconds to put the keys into the ignition before the engine shuts off. Also, if the engine is still running and after 30 minutes, an error message will be displayed.

Note that the operator can lock or unlock the doors or open the trunk at any time. Figure 5 shows the door/trunk routine.

PARTS LIST

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

R1, R11—470 ohms
R2, R8, R12, R21, R26, R28, R29, R31, R32, R33, R36—10,000 ohms
R3, R9, R15–R20, R22—not used
R4—10 megohms
R5–R7, R10, R13, R14, R34—1000 ohms
R23—10,000 ohms, potentiometer
R24—10,000 ohms, SIP resistor
R25—4700 ohms
R27—100,000 ohms
R30—470,000 ohms
R35—51 ohms

Capacitors

C1, C7, C8, C10, C12, C22—0.1 μF filter
C2—0.22 μF
C3—0.023 μF
C4, C5, C6, C9, C11, C13, C14, C16, C21—not used
C15, C19, C20—10 μF, 12 volts, electrolytic
C17, C18—15 pF

Semiconductors

IC1—68705C8S microcontroller
IC2—ICL7660 voltage inverter (Signetics)
IC3—MC145041 A/D
IC4—LM7805 5-volt regulator
IC5—UA741 op-amp
IC6—MAX690 watchdog chip (Maxim)
IC7—not used
IC8, IC9, IC10—4N35 optoisolator (Signetics)
D1–D6—1N914 diode
D7, D8, D10, D11—1N4001 diode
D9—1N4739 9.1-volt Zener diode
D12—15-volt Transorb
D13—5-volt Transorb
Q1–Q6, Q9, Q10—2N2222 NPN transistor
Q7, Q8—not used
MOD1—Optrex 140-volt DC inverter (included with backlit display module)

Other components

DISP1—Optrex LCD module
RY1–RY6—12-volt relay (Omron)
XTAL1—4-MHz crystal
J1—RJ-11 telephone jack
J2—18-position terminal strip
S1—SPST on/off switch
L1—100 mH coil
Miscellaneous: Project case, Enforcer RF remote control system (or equivalent), PC board, ribbon cable, wire, etc.

Note: The following items are available from Les Controles Micro-Tech enr., 147 14th Ave, Dolbeau Quebec Canada, G8L-2L9, 418-276-2477 (leave message):

- **Remote starter, assembled and tested—$300**
- **Complete kit—$250**
- **PC board only—$40**
- **Programmed microcontroller—$25**
- **Case and hardware—$40**
- **LCD module with inverter—$60**

Write or call for quantity discounts.

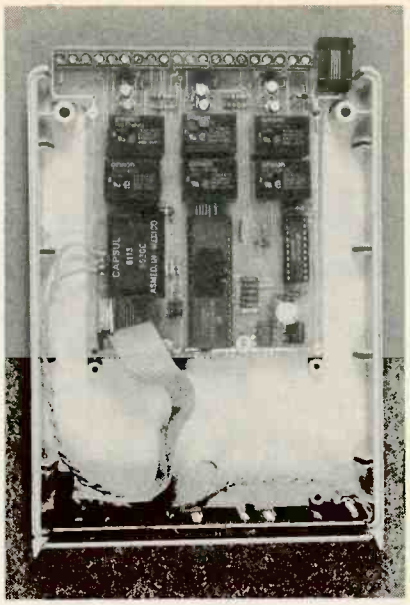


FIG. 7—THE FINISHED BOARD is shown here installed in its case.

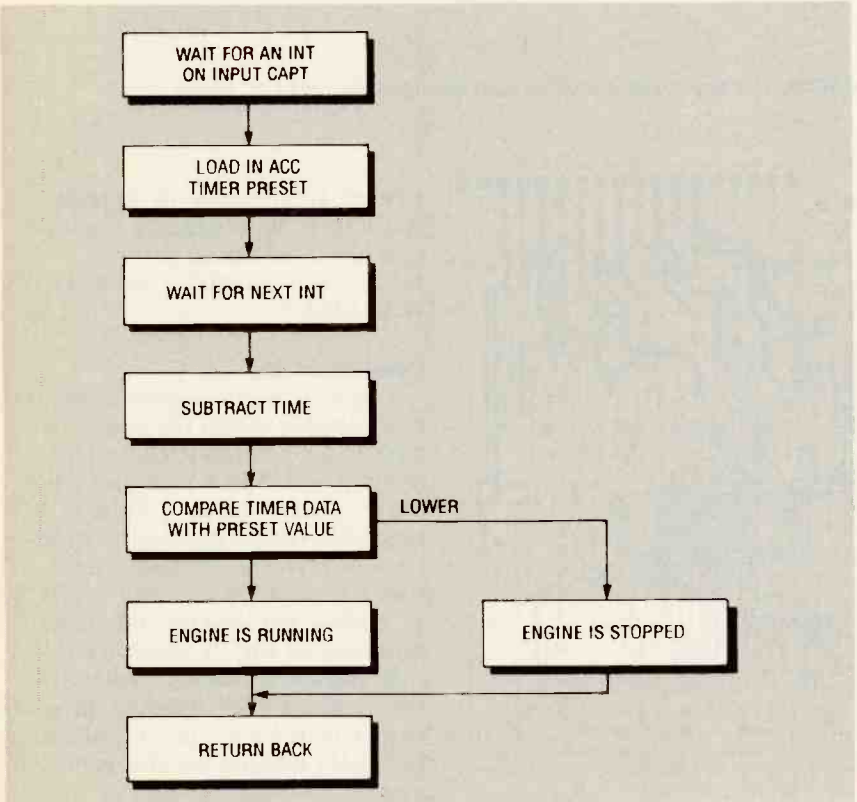


FIG. 6—ENGINE-RUN ROUTINE. The microcontroller waits for an input capture interrupt to determine if the engine is running.

When this routine is called, the program checks if the doors are open or not for 20 seconds. If the doors are open, the microcontroller locks them and waits for 5 seconds to see if the transmitter button is pressed. If it is, the processor opens the trunk and again checks to see if any doors are open and returns back to the main program. The 20-second delay is helpful in case you accidentally press the button once. The microcontroller will know that and will lock the doors if nobody opens them within 20 seconds.

The engine-run routine, shown in Fig. 6, waits for an input capture interrupt. After that the content of the timer is loaded in a memory location and the software waits again for another interrupt. When an interrupt occurs, the value of the timer is compared to a certain preset value to determine if the engine is running. A flag is set for engine running and clear for engine stop.

The engine-running feedback is taken from the breaker point of the car. Two jumpers, JMP1 and JMP2, are used to let the microprocessor know whether you have a 3-, 4-, 6-, or 8-cylinder engine. Note that information on setting those two jumpers is included in Fig. 1. The program will modify the

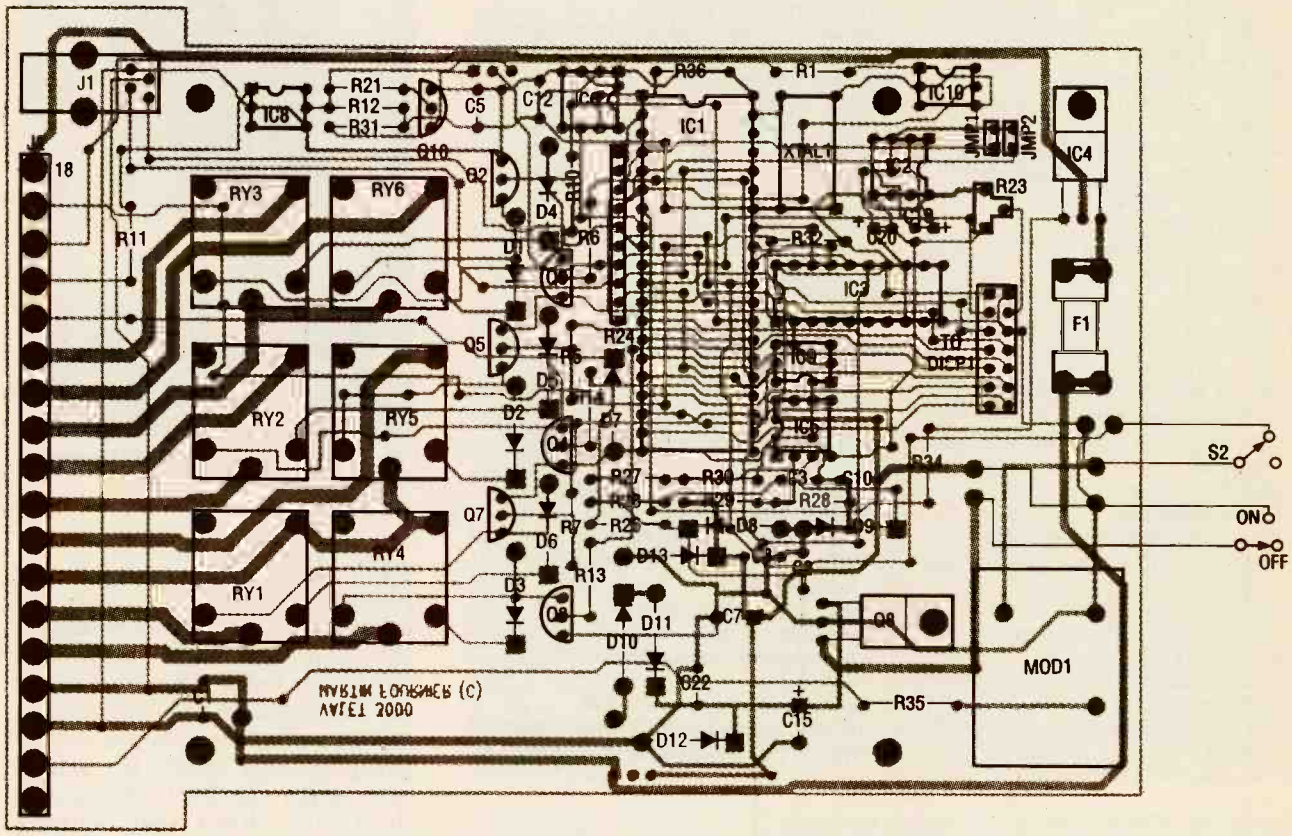
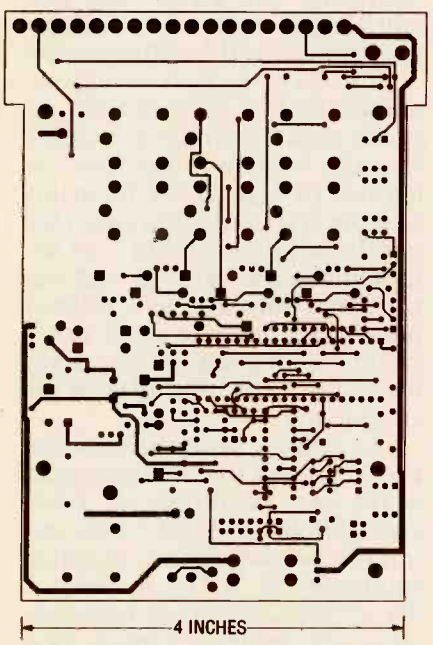
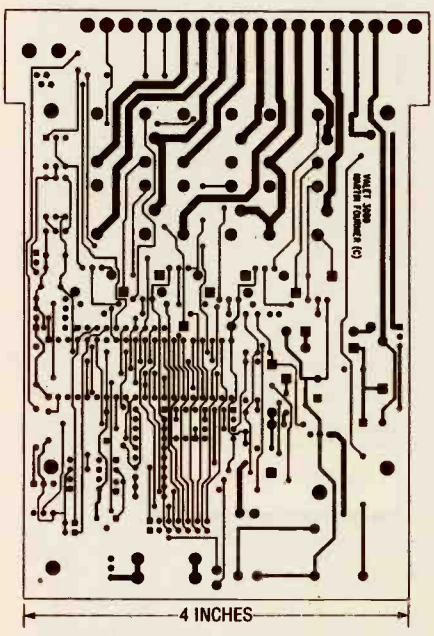


FIG. 8—PARTS-PLACEMENT DIAGRAM. The automatic starter is built on a double-sided PC board.



COMPONENT SIDE of the remote starter board, shown half-size.



SOLDER SIDE of the remote starter board, shown half-size.

preset frequency to adjust it with your car's engine. The frequency (f) is equal to:
RPM × (number of cylinders/120).

Construction

The automatic starter is built on a double-sided PC board, for which we've provided foil patterns if you'd like to make your own. Otherwise, a board is available from the source mentioned in the Parts List. The author's prototype is show in Fig. 7. Follow the Parts-Placement diagram in Fig. 3 when installing the components. Note that the Enforcer RF receiver plugs into the RJ-11-type telephone jack (J1) located on the remote starter PC board.

The finished board can be installed in any suitable case. Ω

Hone your musical skills with Perfect Pitch, the microprocessor-based instrument tuner, headphone amplifier, and metronome.

MUSICIAN'S FRIEND

FRED EADY

THERE ARE FOUR VERY IMPORTANT things that anyone who wants to be a good musician must do: practice, practice, practice, and play in tune. Perfect Pitch will help you do all four! Perfect Pitch, which is based on the 8751H microprocessor, is an inexpensive and easy-to-build instrument tuner/frequency counter with a built-in headphone amplifier and a visual metronome. Perfect Pitch converts the audio signal from your instrument to a digital signal, and displays the musical note you are playing and its frequency in real time on a 16-character liquid-crystal display. It also has an auxiliary audio input for radio, tape, or CD players so you can tune up and play along with your favorite artists.

The not-so-musically inclined can use the Perfect Pitch's 60-kHz frequency counter/period measurement system to get the most from other audio-based projects. Perfect Pitch not only processes audio signals; any TTL-compatible digital signal up to 60 kHz can also be measured. Building Perfect Pitch will demonstrate the concepts behind driving liquid-crystal displays (LCD's), performing mathematical calculations, sensing and reacting to switch closures, and digitally processing audio signals.

Operation

As previously stated, Perfect Pitch is based on the popular 8751-series microcontroller. The circuitry is not particularly complex when divided into five major areas: processor, LCD, signal processing/conditioning, audio amplifier, and power. Let's start by examining the 8751 and its directly associated components.

The 8751H

The 8751H is an 8-bit microcontroller that contains four 8-bit ports with 32 bidirectional and individually addressable I/O lines, 4 kilobytes of on-chip EPROM, 128 bytes of on-chip data RAM, two 16-bit timer/counters, and extensive Boolean processing (single-bit logic) capability. Its maximum clock speed is 12 MHz, with a corresponding instruction-cycle time of 1 microsecond. Figure 1 shows the 8751's block diagram.

Note that we're more interested in the processing power of the 8751H than the abundant I/O capabilities it contains. The complexity of the design is reduced because the 8751H instruction set and internal hardware structure is very efficient and powerful. Take a look at the Perfect Pitch schematic in Fig. 2.

Port 1 of the 8751H provides the ASCII display data used by the LCD, with bit 7 doing double-duty as an LCD BUSY input. Only five bits of Port 3 are in service as common I/O. Bits 5, 6, and 7 of Port 3 supply binary control sequences for LCD read/write operations. Bits 0 and 1 of Port 3 monitor the multipurpose switch, S1, which is used for scrolling through the menu selections as well as for pacing the visual metronome when the metronome function is invoked. The processor's external clock is connected to pins 18 and 19, and the processor-reset circuit, consisting of R1 and C3, is attached to pin 9 of IC1. A reset switch is not necessary, but if you think you might need one, place a normally open momentary switch across C3.

Port 3 can be configured as a bidirectional I/O port, or its pins, under software control,

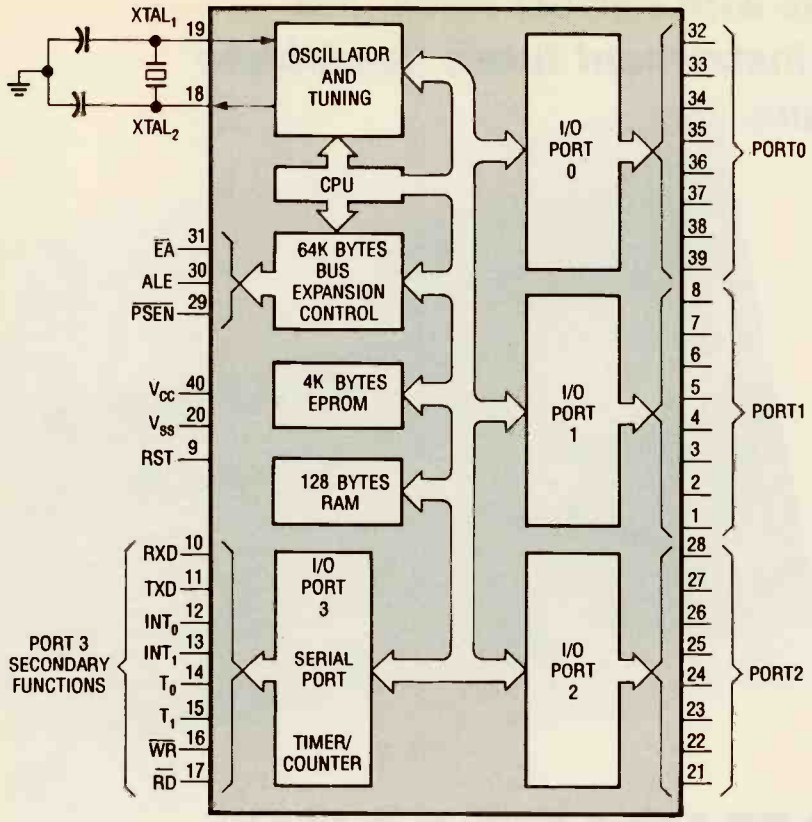


FIG. 1—THE 8751 BLOCK DIAGRAM: The 8-bit microcontroller contains four 8-bit I/O ports, 4K bytes of EPROM, 128 bytes of RAM, two 16-bit timer/counters, and Boolean processing.

can be used for timer/counter inputs and gates, serial communications, or control of external memory access. Perfect Pitch takes advantage of the timer/counter functions provided by bits 2 and 4 of Port 3. Bit 2 of Port 3 (INT_0) is organized by software to provide the gating function for timer/counter 0 for period measurement. which is used for tuning. Bit 4 of Port 3 (T_0) is the input for the frequency-counting function.

Period measurements are made while a TTL high state is present at INT_0. The program loads a bit pattern into the 8751H TMOD (Timer/Counter Mode Control) register to enable or gate Timer 0 when a high condition is detected on INT_0. (Both source code and executable code is available from the *Electronics Now BBS*, 516-293-2283, 1200/2400, 8N1, as a self-extracting compressed file called PERFECT.EXE. A preprogrammed microcontroller is available from the source mentioned in the Parts List.)

The resolution of Timer 0 is 1 microsecond. Thus, if 1000 microseconds were counted in Timer 0 during one complete cycle of a sampled signal, the frequency of the measured signal would be computed by Perfect Pitch to be 1 kHz. The frequency would be computed using the formula $f = 1/T$, where f is frequency in hertz and T is one cycle time in seconds (the period). This is a very fast and accurate way to determine the frequency of a signal that varies in amplitude over time, as guitar signals do. Perfect Pitch requires only 1 cycle of the incoming signal at proper amplitude to determine its frequency.

For frequency counting, the T_0 counter input detects 1-to-0 transitions of an incoming TTL signal on a timebase of 1 second. Those transistions provide the logical trigger that increments Timer/Counter 0 on each transition. Since the timer/counter registers are 16 bits wide, the maximum count is limited to 65.535 kHz maximum, with the usable resolution of our circuitry ending at just below 62 kHz. The 1-second timebase is implemented in software, which allows easy customization or fine tuning if it's necessary for your particular application.

The LCD

The Perfect Pitch display is a 16-character × 1-line dot-matrix LCD module that is based on the HD44780 controller and driver chip. The 8751H (IC1) provides ASCII data and associated control sequences to the HD44780, which controls the display of alphanumeric characters on the LCD. Contrast control is provided by potentiometer R2.

There are several advantages to using an LCD instead of LED's. For one, they are easier to interface to a microcontroller. They also have alphanumeric output capability, and are low in power consumption.

Processing/conditioning

If you were to take a snapshot of an electric-guitar signal on an oscilloscope, you would see that the base or fundamental frequency exhibits the maximum peak-to-peak amplitude, and all of its harmonics would be distributed around its center line at reduced amplitudes. To get an accurate frequency determination, only the fundamental frequency should be measured. And to get the most accurate readings, it is necessary to measure the desired signal peaks as many times as possible during the life of the signal.

Perfect Pitch begins at the first cycle and measures and displays the frequency of a signal until the amplified signal amplitude is too low to drive the input of IC4-d. If there is no signal, or if the amplified signal negative peaks cannot reach the 0.8-volt threshold of IC4-d, the software embedded in the 8751H provides an auto-zero function that automatically zeros the display. That allows multiple repetitive readings without manual intervention. The software also suppresses the display of leading zeros.

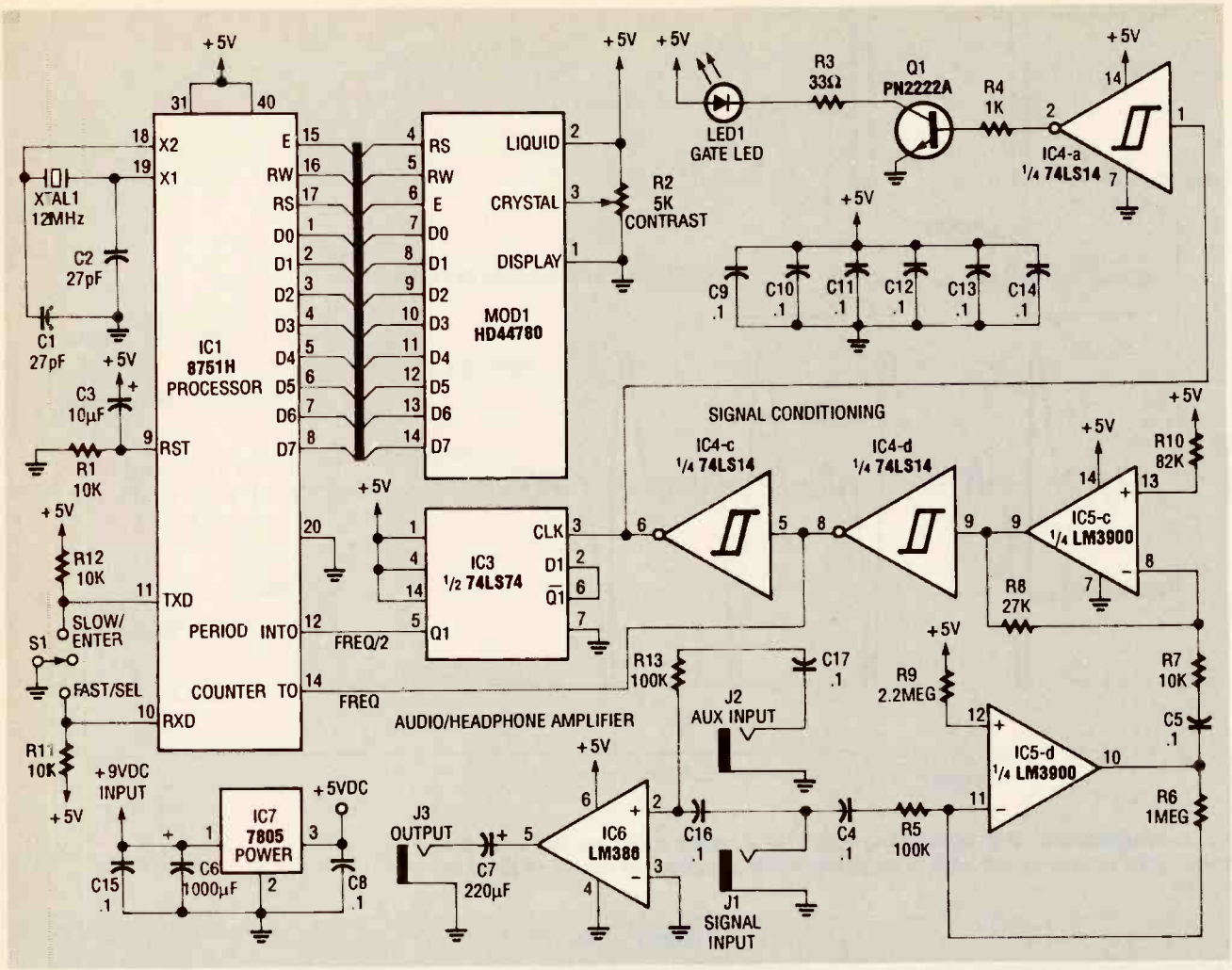


FIG. 2—PERFECT PITCH SCHEMATIC: The complexity of the design is reduced because the 8751H instruction set and internal hardware structure is efficient and powerful.

Most electronic instruments and microphones emit audio signals in the millivolt range. An average electric guitar produces a 65- to 100-millivolt signal into a high-impedance input. That is plenty of amplitude to drive an audio amplifier preamp circuit, but far below the level needed to drive a TTL gate (in our case, IC4-d, a Schmitt trigger). The incoming signal must be amplified so that it can be converted to a TTL-compatible waveform that the 8751H can interpret. A voltage gain of around 25 is the minimum required.

An LM3900 quad Norton amplifier (IC5) is configured as a two-stage audio amplifier with an overall voltage gain of 27. Given a sinewave with an amplitude of 65 millivolts or greater, an amplifier with a gain of 27, and the Schmitt trigger, you can produce clean TTL-compatible square waves that will be suitable as input to the 8751H processor.

Because musical instruments can generate many harmonics that will also be amplified, and possibly converted and analyzed, you have to get rid of the harmonics. "Filtering" is the first thing that comes to mind, but in this case that would be complicated and require additional circuitry. Amplifying the input signal enough to force signal clipping would be another solution, but that generates even more unwanted harmonics. You can solve the harmonic problem easily by using a feature inherent to the Schmitt trigger: hysteresis. As shown in Fig. 3, in effect, you will force the harmonics to reside in a "dead zone" where they cannot trigger IC4-d. Only the fundamental frequency will have enough amplitude to toggle the output of IC4-d. That enables you to use signal peaks as timing markers to calculate your results.

For the 74LS14 Schmitt trigger, the dead zone is nominally 0.8 volts wide with a minimum positive-going threshold of +1.6 volts and a minimum negative-going threshold of +0.8 volts. Audio amplifiers are normally designed to allow the output signal to swing symmetrically around a DC value of one half of the power-supply voltage. But since you want to convert your signal to a digital pulse with a Schmitt trigger, you can waive the symmetrical output rule.

Ideally the center line should be set at or above the +1.6-volt DC level because that will produce a TTL high level at the in-

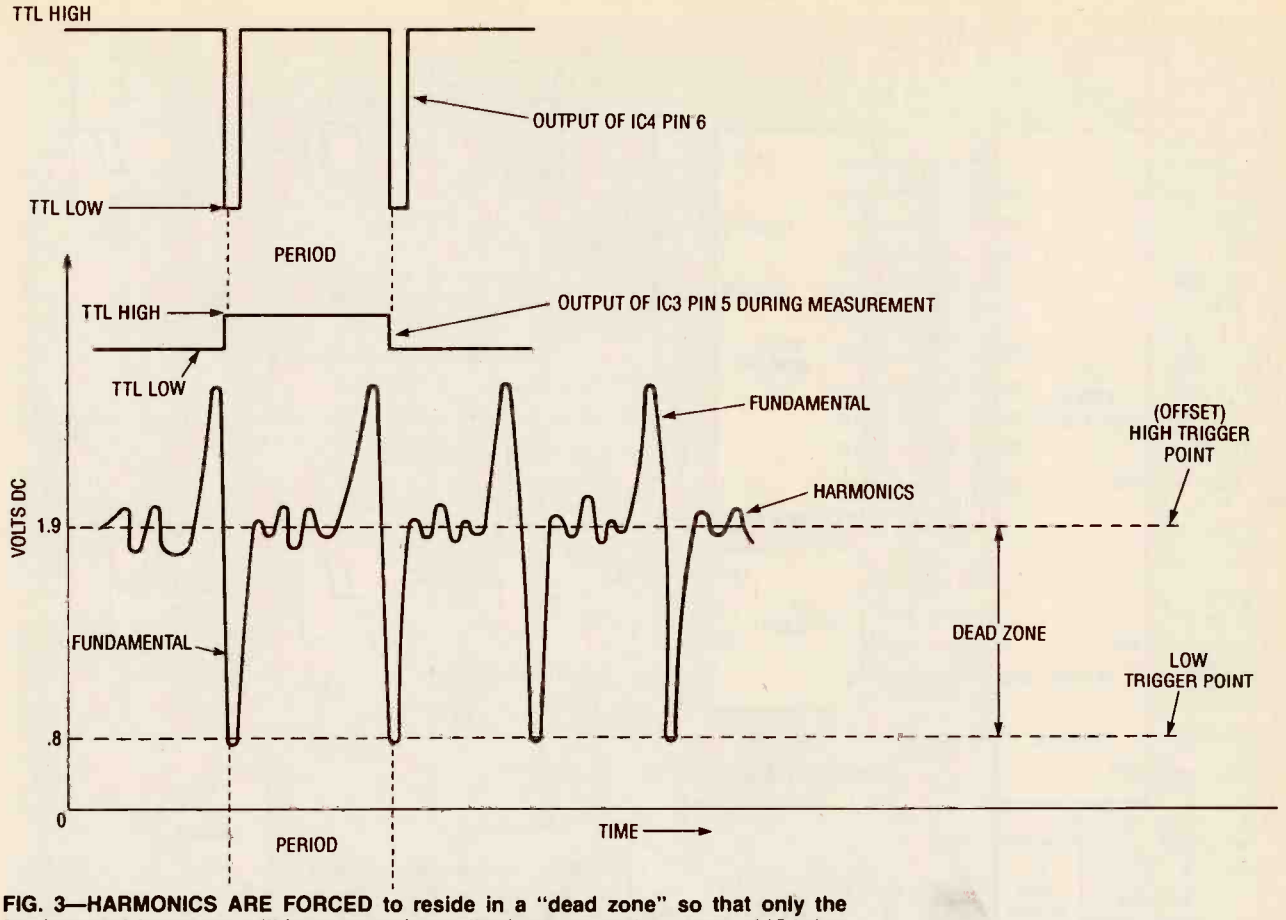


FIG. 3—HARMONICS ARE FORCED to reside in a "dead zone" so that only the fundamental frequency will have enough amplitude to cause the output of IC4-d to toggle.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted
R1—10,000 ohms
R2—5000 ohms, trimmer potentiometer
R3—33 ohms
R4—1000 ohms
R5, R13—100,000 ohms
R6—1 megohm
R7, R11, R12—10,000 ohms
R8—27,000 ohms
R9—2,200,000 ohms
R10—82,000 ohms
Capacitors
C1, C2—27 pF
C3—10 µF, 16 volts, Tantalum
C4, C5, C8–C17—0.1 µF
C6—1000 µF, 16 volts, electrolytic
C7—220 µF, 16 volts, electrolytic
Semiconductors
IC1—8751H microcontroller (must be programmed)
IC2—not used
IC3—74LS74 D flip-flop
IC4—74LS14 Schmitt trigger
IC5—LM3900 quad op-amp
IC6—LM386 audio amplifier
IC7—7805 5-volt regulator
LED1—light-emitting diode, any color
Q1—PN2222A NPN transistor
Other components
MOD1—Hitachi H2570 16-character × 1-line LCD module (uses HD44780 controller chip)
XTAL1—12-MHz crystal
S1—SPDT center-off momentary rocker switch
J1–J3—audio jacks and plugs of your choice
Miscellaneous: PC board, project case, ribbon cable, 9-volt DC power supply (500 mA), hardware, IC sockets, solder

Note: The following items are available from Fred Eady, PO Box 541222, Merritt Island, FL 32954:
- **Kit of parts with a programmed microcontroller and PC board (does not include batteries/power supply, case, plugs and jacks, ribbon cable, or rocker switch)—$59.00 + $5.00 S&H**
- **Programmed 8751H microcontroller—$25.00 + $2.50 S&H**
- **Blank 8751H microcontroller—$18.00 + $2.50 S&H**
- **PC board only—$20.00 + 2.50 S&H**
- **8751H source code on 5.25-inch diskette—$5.00 postpaid**
- **8751H modification plans for 874X programmer (includes source code, terminal program, and schematic)—$10.00 postpaid**
- **874X programmer kit and 8751H modification plans—$59.95 + $5.00 S&H**

Please send check or money order only
For technical assistance call (407) 454-9905

put of Schmitt trigger IC4-d. You can set that center line by adjusting the value of output offset resistor R10, which sets the output of IC5-c. The data sheet for the 74LS14 states that the minimum positive-going threshold value is +1.6 volts, and the maximum positive-go-

ing threshold value is +1.9 volts. To compensate for devices that toggle at the +1.9 volt value, the output of IC5-c is set at +1.9 volts. Note also that a TTL high threshold for most TTL devices is +2 volts DC, and the low threshold is +0.7 volts DC.

When referring to TTL levels in this discussion, we are speaking specifically about the 74LS14 Schmitt trigger, unless otherwise stated. With the output center line of IC5-c set at TTL high (+1.9 volts DC in our case), you will trigger and subsequently toggle the Schmitt-trigger chain when the output of IC5-c swings negative about the +1.9-volt DC line to +0.8 volts. Approximately 80 millivolts of incoming audio signal at IC5-d would be the minimum required to initiate a measurement when using the +1.9-volt reference.

When alternating high and low thresholds are reached at the input of IC4-d, its output is a clean TTL square wave that provides the input for the T_0 frequency counter. Schmitt trigger IC4-d also triggers IC4-c, which in turn triggers IC4-a. Schmitt trigger IC4-c also drives the clock input of IC3, a 74LS74 D flip-flop, which is configured to divide by two. The division is required because a period is the time required to complete one cycle. Also, the 8751H Timer 0 measures time only when INT_0 is presented with a TTL high.

Because one complete cycle consists of a high and low state of varying duty cycle that is not always 50%, the 8751H will measure time only for some fraction of a period that depends on a high percentage for the duty cycle. By dividing the incoming signal with a flip-flop, you produce a TTL signal with a 50% duty cycle that doubles the input signal's period. Since we measure time only at the TTL high level, and the TTL high level is one time period, the 8751H will log the period of the incoming signal. Note that the divide-by-two output of IC3 (pin 5) feeds the INT_0, or period input (pin 12) of IC1.

Once the period (T) has been measured, the algorithm contained in the 8751H EPROM performs the math necessary to solve the equation $f = 1/T$. The result of that equation (f) is then formatted and converted to ASCII and displayed for the user. A lookup table is used to determine the musical note associated with the frequency that has been calculated by perfect pitch.

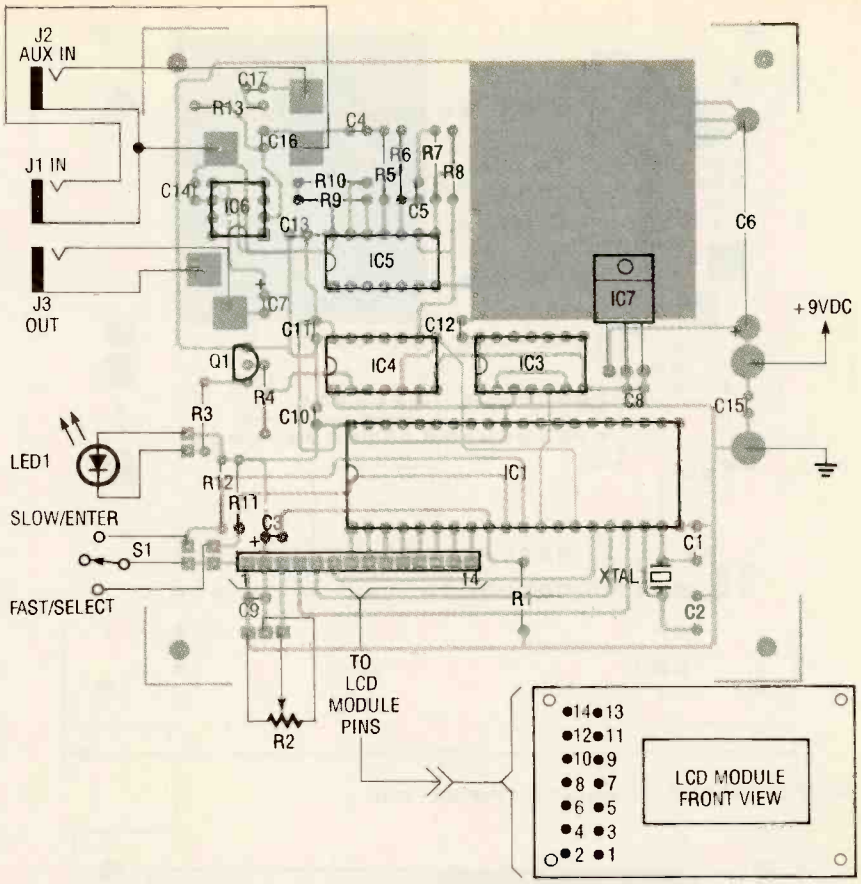


FIG. 4—PARTS-PLACEMENT DIAGRAM. The main board connects to the LCD module with a length of ribbon cable.

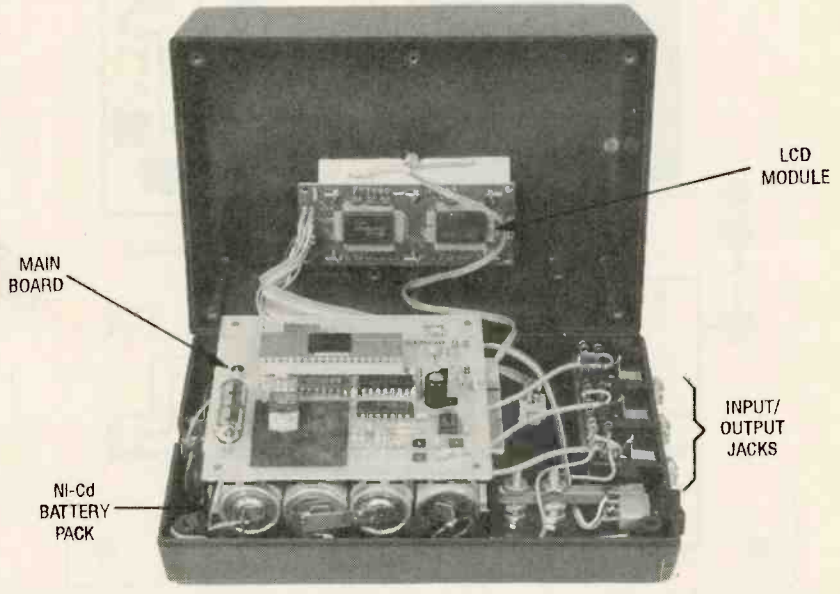
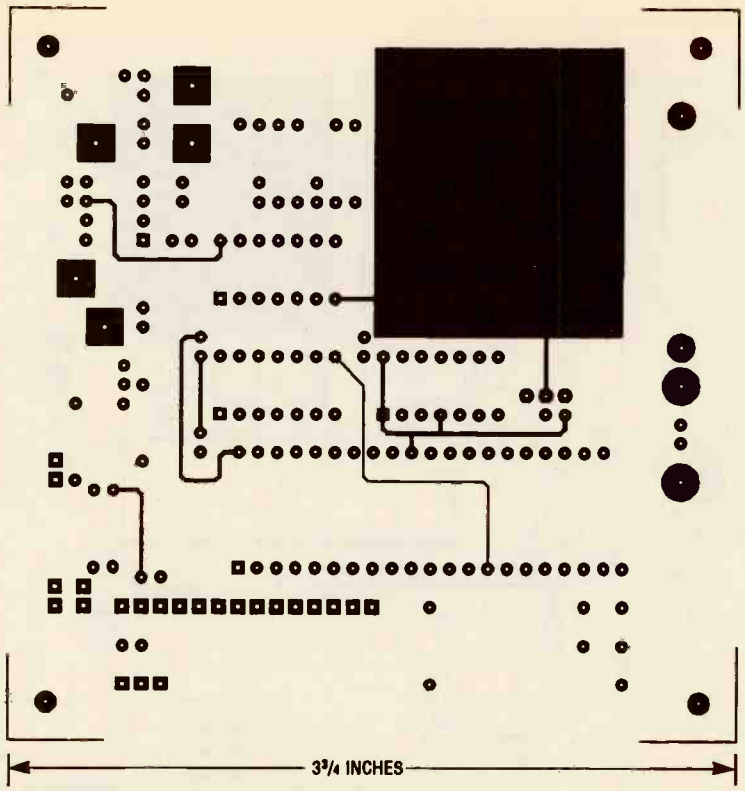
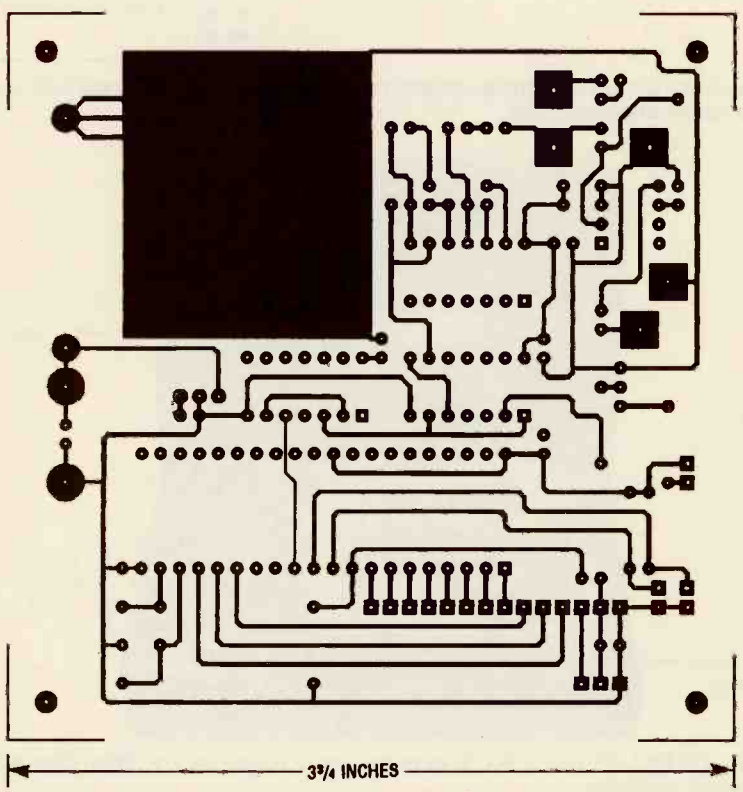


FIG. 5—INSTALL PERFECT PITCH in an enclosure of your choice. This is the author's completed prototype.



COMPONENT-SIDE foil pattern for Perfect Pitch.



SOLDER-SIDE foil pattern for Perfect Pitch.

Schmitt trigger IC4-a drives the base of transistor Q1 which provides a path to ground for LED1, the gate indicator; LED1 is illuminated when the amplified audio signal has sufficient amplitude to cross IC4-d's +0.8-volt threshold on negative peaks. Keep in mind that period and count measurements are made only when LED1 is illuminated.

Audio amplifier

So far we have discussed the signal-processing circuitry containing IC5, an LM3900 quad Norton amplifier, IC3, a 74LS74 D flip-flop, and IC4, a 74LS14 Schmitt trigger. Although Perfect Pitch displays the musical note and its frequency, the user still has to be able to hear the note. Therefore, headphone amplifier IC6 is included in the circuit. The amplifier also allows external audio to be mixed in at its noninverting input.

Note the absence of volume and tone controls. Most electronic instruments have their own volume and tone controls, so why not use them? The same goes for the auxiliary input: mix with the controls provided on the auxiliary device. If you require a volume control, put a 1K potentiometer in series with the output of IC6 pin 5.

Power

The Perfect Pitch prototype is battery powered, but any stable 9-volt DC source will work. A 7805 regulator, IC7, outputs 5-volts DC from the 9-volt input. Capacitors C8 and C15 perform bypass functions, while C6 provides some additional stability, and C9–C14 are standard TTL bypass capacitors.

The battery pack used in the prototype is composed of eight 1200-milliampere/hour sub-C rechargeable nickel-cadmium (Ni-Cd) cells. Perfect Pitch draws about 200 milliamps and battery life averages 4 to 5 hours. You can use smaller Ni-Cd cells but battery life will decrease accordingly.

Construction

Because we are combining audio and digital circuitry in close proximity, parts layout is critical. PC board construction is recommended. You can fabricate your own PC board or purchase a factory-made version from the source mentioned in the Parts List. If you decide to breadboard or wirewrap, the audio sections will be more susceptible to digital noise from the processor and the LCD. Use short lead lengths and shielded cable. Regardless of the method

you choose, you can mount all components in a case of your choice.

Figure 4 shows the Parts Placement diagram. Begin construction by installing the power components IC7, C6, C8 and C15. Mount IC7 with the metal heatsink tab against the heatsink pad on the PC board. Use No. 6-32 nuts and bolts to secure IC7 to the heatsink pad. Be careful with C6's polarity. Temporarily attach a 9-volt DC supply, and verify +5-volts DC at the output of IC7 (pin 3). Next, install all resistors and recheck your 5-volts DC. Install all capacitors, being careful to note the polarities of C3 and C7. Install Q1 and XTAL1, and again recheck the 5-volt DC line.

Install the IC sockets and verify that 5-volts DC is present at all pin locations shown in Fig. 2. Once you are sure the power distribution is correct, connect an appropriate length of 14-conductor ribbon cable between the LCD display module and PC board using the pin-connection information given in Fig. 4. Use a 3-conductor ribbon cable to connect contrast-potentiometer R2. If you expect to adjust the contrast often, mount R2 so it is accessible without having to open the enclosure. The lengths of the ribbon cable should not be excessive, but should allow for easy access to the PC board when you open the enclosure.

Install IC1, the 8751H, and apply power. "PERFECT PITCH" should appear on the display for a few seconds and then "TUNER" should appear and remain on the display.

Use a three-conductor ribbon cable to connect S1 to the PC board. Apply power and wait for "TUNER" display to appear. Center-off switch S1 will let you toggle through the menu selections "TUNER," "COUNTER," and "METRONOME," in one direction and select the displayed function in the other. If you select the Tuner function, expect to see "00000 Hz T" on the display. The same legend appears for the counter function except that "T" is replaced by "C." Selecting the Metronome function should reveal a pulsating display that can be made to oscillate faster or slower with "FASTER" and "SLOWER" appearing as you toggle and hold S1. If all is well at this point, remove power and install LED1 with an appropriate length of two-conductor ribbon cable.

Using shielded cable and the audio jacks and plugs of your choice, connect the input and headphone jacks to the PC board as shown. The prototype has standard ¼-inch phone jacks. The prototype has an input jack (J1) that contains a DPDT switch which applies power to Perfect Pitch when a ¼-inch phone plug is inserted. A recharge jack that disconnects power to Perfect Pitch when the charger is plugged in is also incorporated in the prototype.

Install IC6, the LM386 audio power amplifier. Plug a set of headphones into headphone-jack J3 and apply power. Touch the ungrounded input conductor of J1; you should hear a buzz or pop that corresponds to your touch. If not, recheck the work done in the audio-amplifier section. Install a jack for the auxiliary input (J2), and perform the touch test on it.

Install IC3, IC4, and IC5. Connect a signal source to J1 and headphones to J3 (the signal source can be a guitar, electronic keyboard, etc.) Apply power and select the Tuner function. When notes are struck, strummed, or keyed, you should see the gate LED illuminate and hear the audio in your headphones. The LCD should show a reading other than "00000" and possibly a note will appear at the far left of the LCD. If so, everything is OK and you can mount Perfect Pitch in a permanent enclosure. Figure 5 shows the inside of the author's completed prototype.

Using Perfect Pitch

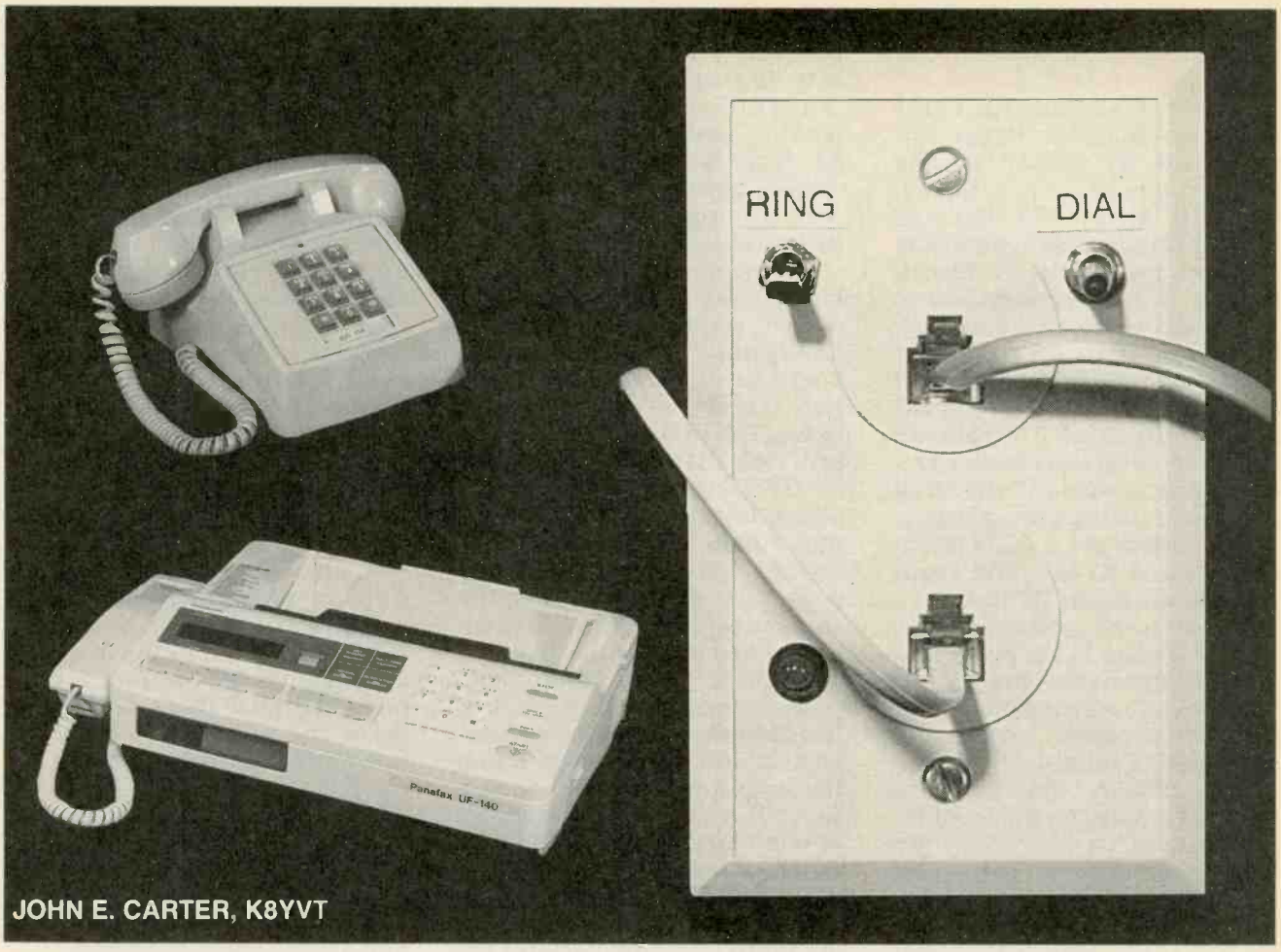
Perfect Pitch is as easy to use as it is to build. There are only one switch, two inputs, and one output to deal with. The contrast adjustment is usually made once and forgotten. Use your own judgement with regard to contrast.

When you turn on Perfect Pitch, the "PERFECT PITCH" banner is displayed, followed by the first menu selection, "TUNER." At this point you can scroll through the remaining two menu items (Counter and Metronome) or select any of the three when displayed using S1. As pointed out earlier in the construction section, "00000 Hz T" or "00000 Hz C" appears when the Tuner and Counter mode are selected, respectively. Connect the audio source and select Tuner or Counter and proceed. Only the Tuner mode will display notes on the musical scale along with frequencies. An added feature places a "+" or "−" immediately following the note to designate one cycle above (+) or below (−) the musical note shown in the display. For example, "A− 439 Hz T" denotes a signal that's one cycle below the universal A 440 Hz. Conversely, the display "A+ 441 Hz T" denotes 1 cycle above A 440 Hz. The Tuner mode's musical-note identification function spans from C 32 Hz to C 1046 Hz, or five musical octaves. Above a frequency of 1046 Hz, only frequency is displayed.

In the Counter mode, Perfect Pitch is a frequency counter. You can also bypass IC5 completely and feed TTL signals directly into pin 9 of IC4-d. You can also use the Tuner function if you bypass IC5 in favor of TTL inputs. Be sure to remove IC5 if you choose to run TTL only.

The Metronome function, which alternately turns on the left and right sides of the LCD, and is the only function that you can control in real time; S1 selects either "FASTER" or "SLOWER" while the function is invoked. A visual metronome allows you to keep time without having an audible tone or click mixed into the headphones with your music.

The auxiliary input (J2) is exclusively for mixing in headphone output from a radio, CD player, or tape player. Inputs at J2 will not reliably trigger the counting circuitry. By adding another output jack to the existing output jack, you and a friend can practice as a duet. Ω



JOHN E. CARTER, K8YVT

PHONE-LINE SIMULATOR

Build this low-cost telephone-line simulator that tests phone-based equipment without tying up two phone lines and perhaps an assistant's time.

A LOW-COST, EASY-TO-BUILD TELEphone-loop simulator will permit you to test telephone answering machines, fax machines, modems, electronic telephones, automatic dialers, and other telephone-related equipment. It includes a talk battery, ringing voltage, and simulated dial tone that are necessary for this testing.

Phone Helper 2, the telephone-loop simulator described here, makes the testing of telephone equipment as simple as plugging in RJ-11 plugs. It simulates a common-carrier telephone line, and permits you to test equipment without tying up several working telephone lines—and possibly damaging one of them if there is a fault in the equipment-under-test. It also permits you to perform tests without an assistant.

Figure 1 is the schematic, and Table 1 gives the unit's specifications. One switch is toggled on and off to obtain a simulated dial tone, and the other can be jogged to provide a simulated ring signal.

Commercial telephone-loop simulators capable of performing the same tests as Phone Helper 2 are priced at a several hundred dollars of more. Phone Helper 2 costs a lot less; just the parts cost less than $60, and you can purchase a completely assembled and tested unit with an AC-line adapter from the source given in the Parts List for less than $80.

FCC Requirements

Before discussing the loop simulator further, it will be useful to review the related telephone-ringing variables. The Federal Communications Commission's (FCC) Rule Section 68.312 defines the permissable AC voltages, frequencies, and impedances for ringing circuits. These are required guidelines for both domestic and foreign telephone equipment

manufacturers.

The FCC requires that manufacturers submit prototype equipment for testing by an approved laboratory, which runs many different tests on it. The test lab assigns a unitless ringer equivalency number (REN) that states the power required to actuate the ringing circuitry of the equipment. The manufacturer must stamp or print that number on all approved interconnect products sold.

The telephone operating companies require that no interconnect device shall have a REN greater than 5. In addition, the sum of all REN's on a particular loop must not exceed 5. A standard mechanical bell-type telephone typically has a REN of 1.0A. The "A" indicates that the device will respond to a ringing frequency between 17 and 33 Hz). Similarly a "B" indicates that the unit will respond to a ringing frequency between 15.3 Hz and 68 Hz.

A long list of REN suffixes from A to Z has been prepared to cover all combinations and permutations of ringing arrangements. Nevertheless, A and B type devices predominate, but today most answering machines, modems, fax machines, and electronic telephones are type B.

That equipment typically includes a bridge rectifier installed across the telephone line for receiving a large AC voltage which is rectified to obtain the signal for tripping the ring-detect circuitry. As a result, most of this equipment can be tested with a simulator that is based on a 60-Hz ringing-voltage source capable of operating only Class B ringers.

Versatile 20-Hz generator

The test unit in this article includes a true 20-Hz ringing generator rather than a 60-Hz ringing voltage source, so it can actuate both class B and class A ringers. The 20-Hz ringing generator provides about 85 volts at 20 Hz with enough power to drive up to five 1.0A or 1.0B REN numbered devices simultaneously. It is packaged as a potted module that can be directly mounted on a circuit board.

The module contains a 20-Hz multivibrator and amplifiers to obtain the power needed to actuate the ringers. It is available from the source given in the Parts List.

Telephone dial tone

Now it will be useful to review the basics of telephone dial tones. The telephone equipment industry has specified that the dial tone be composed of an equal mixture of 350-Hz and 440-Hz frequencies that leave the central office at a level of -13 dBm0 (measured at the zero transmission level point).

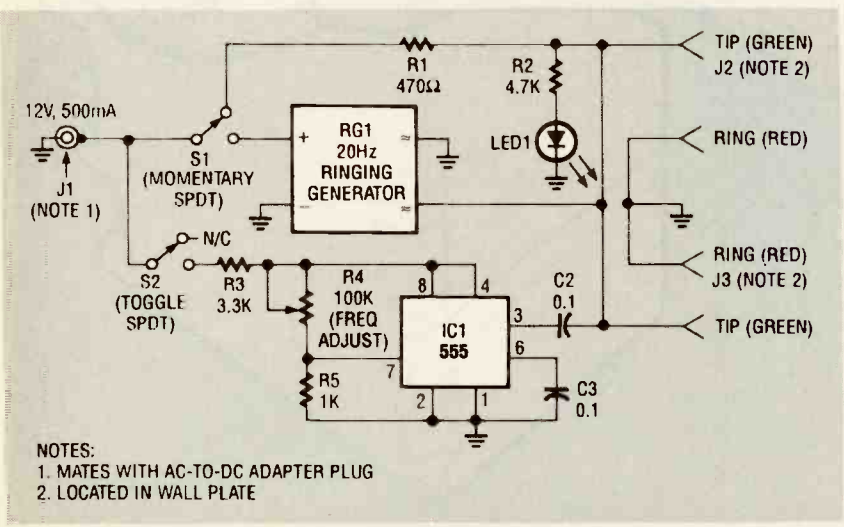


FIG. 1—SCHEMATIC FOR PHONE HELPER 2. The ringing generator is a proprietary device available from the source in the Parts List.

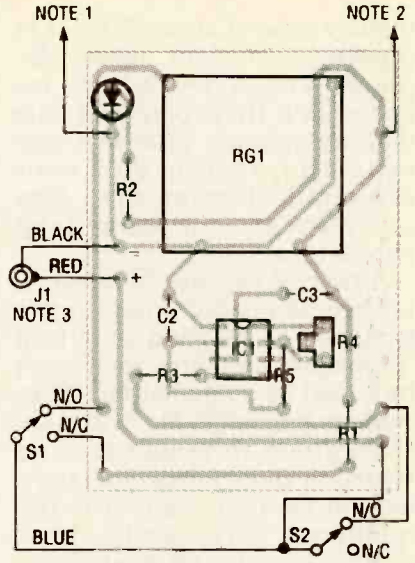


FIG 2.—PARTS PLACEMENT PROGRAM for Phone Helper 2 circuit board.

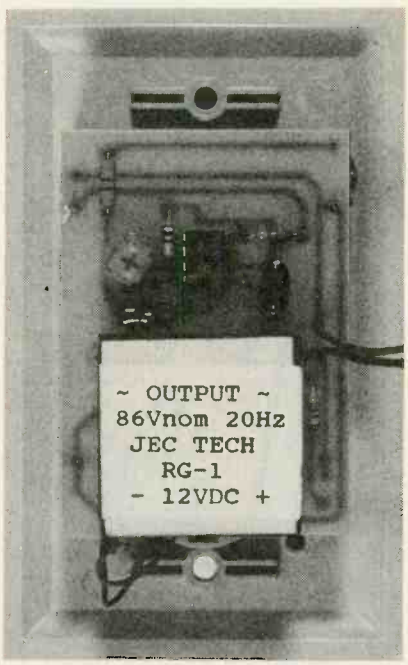


FIG 3.—PHOTOGRAPH OF PHONE Helper 2 circuit board showing external connections.

The signal could have dropped as much as 10 dBm0 lower (-23 dBm0) when it reaches the subscriber. However, tests have shown that most telephone interconnect devices will respond if they receive a steady tone that is close to either 350 Hz or 440 Hz.

For example, if a single-fre-

quency tone of about 500 Hz is presented to them, most telephone-related devices will respond as if they received a true dial-tone signal. This fact permits the design and construction of lower cost, less complicated telephone-loop simulators.

A note of caution here: some telephone-related products are designed to respond only to a "precision" dial tone; they won't be fooled by a single tone. They require both 350-Hz and 440-Hz signals to respond—and then only if the tones don't deviate too far from their true frequencies. Fortunately, these products are in the minority.

The single-tone generator in the simulator is included because some equipment, such as modems and fax machines, are designed to respond to a dial tone before they will dial out.

If a product does not "hear" a dial tone (when directed to dial out), it triggers the dreaded NO DIAL TONE message that can show up on your personal computer's display or your fax machine. In that case, a brief tone burst from a single-tone oscillator triggers the unit, causing it to dial the number.

Building Phone Helper 2

The construction of Phone Helper 2 is simple because it obtains its power from a wall-mounted AC-to-DC adapter rather than directly from the 120-volt line. A circuit board foil pattern has been included here for those who want to make the circuit board. Alternatively, you can purchase a completed board from the source given in the Parts List, or use a perforated phenolic board cut to the same size and wire the circuit components point-to-point.

A design objective for Phone Helper 2 was to package it in the smallest possible case without making it difficult to build. A basic requirement for the project was the availability of two RJ11/14 phone jacks, and this was met by a standard dual-jack wall plate, which also serves as the case cover. The nominal 2¾ × 4½-inch plate permits the use of a standard 3½ × 2⅛-inch × 2⅛-inch deep (inside di-

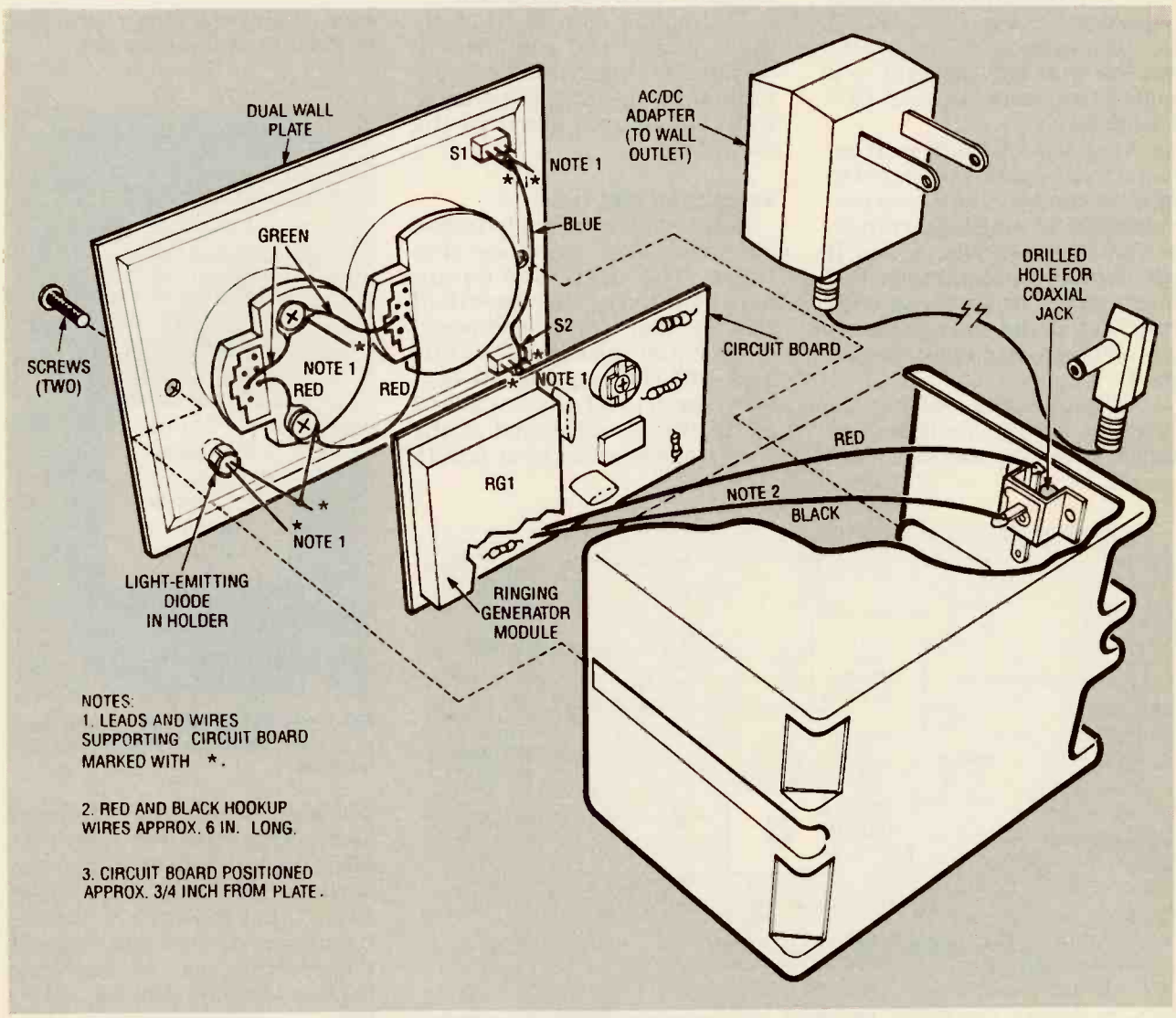


FIG. 4—EXPLODED VIEW OF PHONE HELPER 2 showing method of assembly and off-board wiring.

mensions) plastic outlet box as the case.

While referring to schematic Fig. 1 and parts placement diagram Fig. 2, begin construction by mounting all of the electronics components on the circuit board (or perforated board). There is nothing critical about the placement of components on the circuit board and the parts layout diagram shows a simple layout. Insert and solder all of the resistors, capacitors, trimmer potentiometer and timer IC1 before mounting the 20-Hz ringing generator module RG1.

Regardless of the construction option you select, follow accepted workmanship practice in soldering all component leads. Check carefully to be sure that all solder joints are shiny and clean, and that there are no unwanted solder "bridges" or cold-soldered joints, which are dull gray and lumpy. Figure 3 is a photograph of the completed circuit board showing some of its off-board wiring.

After completing the circuit board assembly, proceed with the mechanical construction. Prepare the wall outlet case by removing any small plastic tabs. Drill the ¼-inch hole in the case to admit the DC power jack in the location shown in exploded view Fig. 4. Then drill either one or two smaller holes adjacent to that hole for fastening the jack to the case with rivets or screws.

Prepare the wall plate by removing all but two of the screws that secure the associated wiring and clipping off the black and yellow wires. The red and green wires are for *line 1*, the pair found on all standard telephone-connected devices. Drill the three holes in the wall plate with the diameters necessary for mounting switches S1 and S2, and the panel-mounting clip for LED1 using the drilling template provided here as a guide.

Mount switches S1 and S2 on the back of the wall plate with their washers and locknuts. Then insert the snap-in-holder for the T-1¾ LED in the wall plate and insert LED1 in the holder. Solder two bare, solid hookup wires approximately one inch long to two of the terminals on switches S1 and S2 as shown in Fig. 4. Solder another short length of wire to the lug at the end of the red ring wire on the back of the wall plate. Then solder a short length of insulated hookup wire between the center terminals of switches S1 and S2. (It is shown as a blue wire in Fig. 4).

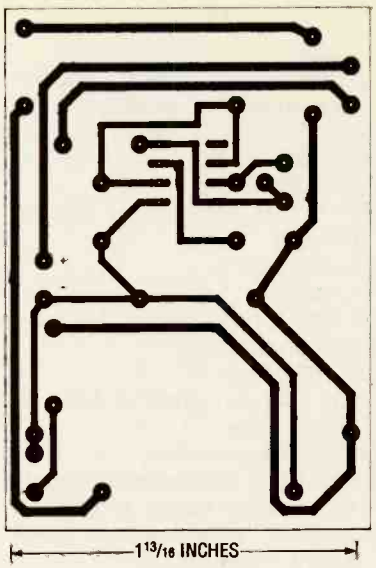
Cut two six-inch lengths of red and black insulated hookup wire, trim their ends, and solder them to coaxial jack J1 as shown in Fig. 4. Insert the other two ends in the circuit board from the component side as shown in Figs. 2 and 4, and solder them in position.

The circuit board assembly is light enough to permit it to be supported by the seven leads from switches S1 and S2, the green tip wire lug, and the leads of LED1. Insert those leads in the foil side of the circuit board assembly as shown in Figs. 2 and 4, and adjust the spacing of the loaded board so that it is parallel with the back of the wall plate and spaced about ⅞-inch away from it. Then solder the seven wires on the foil side of the board, and solder the jumper and the red ring terminal lug to the cathode of LED1.

Testing Phone Helper

When Phone Helper construction is complete, and before fastening the cover in position with two screws, verify that the DC power supply section is working properly. Plug the AC-to-DC adapter into a 120-volt AC outlet, and plug its power cord into the coaxial jack in the case. The LED should light normally during this test.

Plug a telephone known to be in proper working condition into RJ-11 jack J2 or J3 and make voltage measurement with a suitable voltmeter. Place the negative probe on the ring (red) terminal and the positive probe on the tip (green) terminal. With the attached telephone's handset on-hook, the reading should be 15 ±2 volts DC; with it off-hook the reading should be 4 to 12 volts DC.



FOIL PATTERN FOR PHONE HELPER 2 circuit board.

Testing with Phone Helper

To test a telephone-answering machine with Phone Helper, plug it into one of the RJ-11 jacks on Phone Helper and plug a telephone into the other jack, as shown in Fig. 5. Set the answering machine to receive calls, and jog the RING toggle switch S1 often enough to simulate a ring that makes the answering machine answer. When the answering machine answers, pick up the telephone handset and you will hear the outgoing message.

A plugged-in telephone, whose handset can be taken off-hook is necessary to make this test because most answering

TABLE 1
SPECIFICATIONS FOR PHONE HELPER 2

Ring Signal (1)	85 V, 20 Hz, 5 REN
Dialtone (2)	−20 dBm0 (min), 500Hz + 20%
Power Requirements	12 V DC, 500 mA.

Notes: 1. Momentary switch S1 jogged on and off
2. Switch S2 on or off

PARTS LIST

All resistors are ¼-watt, 10%, unless otherwise specified.
R1—470 ohms, ½ watt
R2—4.700 ohms
R3—3.300 ohms
R4—18,000 ohms trimmer potentiometer
R5—1000 ohms
Capacitors
C1, C2—0.1μF
Semiconductors
IC1—555 Timer IC
LED1—red light-emitting diode, T-1¾ package
Other components
S1—SPDT momentary toggle switch, panel mount, miniature
S2—SPDT toggle switch, panel mount, miniature
RG1—20-Hz ringing generator, (see text)
Miscellaneous: dual RJ-11 wall plate, plastic outlet box (see text), AC-to-DC adapter with 12-V, 500-mA output, coaxial power connector to mate with plug of 12-volt adapter, snap-in holder for a T-1¾ LED, insulated No. 18 AWG stranded hookup wire—(red, black, and blue), solid bare hookup wire, solder.

Note: Parts as well as an assembled and tested Phone Helper are available from JEC TECH, 13962 Olde Post Road, Pickerington, OH 43147.

- **Assembled and tested Phone Helper 1 with a 12-volt AC-to-DC adapter—$79.95**
- **Complete Phone Helper 1 kit with a 12-volt AC-to-DC adapter—$59.50**
- **Ringing generator module (RG1) and a complete circuit board— $44.00**
- **Assembled and tested**

Add $4.00 shipping and handling. Ohio residents add appropriate sales tax.

machines will reset if the telephone is on-hook—indicating that the calling party has hung up. You can then leave a message or retrieve stored messages, just as you would if you were calling in from the outside.

To test a facsimile machine, plug the unit-under-test into one of the jacks of Phone Helper 2, and then plug a jack from a known good fax machine (or fax card) into the other jack. The receive capabilities of the fax machine under test can be determined by placing a call on the known good unit with the simulated dial-tone function if needed.

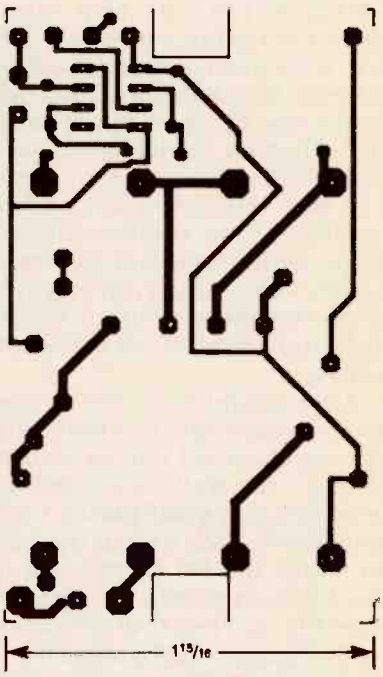
Once the fax machine known to be in good working condition has dialed out, jog the momentary RING toggle switch S1 often enough to signal the unit-under-test. It should answer, establishing a connection with the known good unit, which will then send your test fax.

If you have a fax card in your computer and a stand-alone fax machine. Phone Helper 2 will permit you to convert you fax machine into a full-page scanner. Insert a page of images and text that you want to enter into your computer into your stand-alone fax machine. Then "call" your fax card (any number will do) and send it the text of images. You can now modify your computer files with a graphics editor or run the text through an optical character recognition program to convert the scanned-in text into an ASCII file.

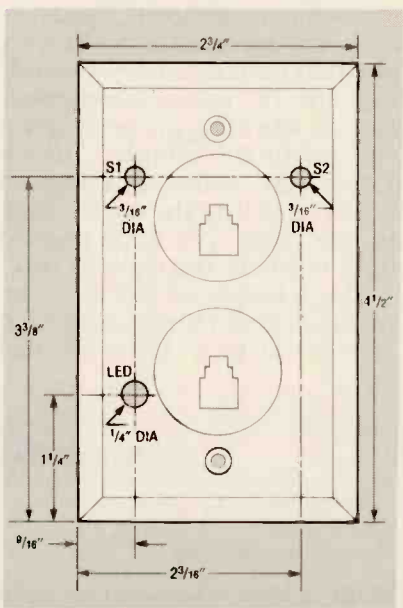
Modems can be tested in exactly the same way. The only difference will be in the frequencies of the tones that are used to communicate between them.

Several accessories will come in handy for making equipment test with Phone Helper 2. An inexpensive electronic telephone and a duplex adapter will permit you to monitor while testing. Ω

FIG. 5—SETUP FOR TESTING AN ANSWERING MACHINE with phone helper.



FOIL PATTERN FOR PHONE HELPER 2.



TEMPLATE FOR DRILLING HOLES.

DTMF DECODER

HAVE YOU EVER BEEN CURIOUS about the dual-tone multifrequency (DTMF) tones heard on your scanner or amateur-band receiver? The circuit discussed here will decode DTMF tones and display them on a liquid crystal display, so that you can get a better understanding of the action on the radio bands.

The unit has a memory capacity of 64 digits, yet the cost of building this project is one-third to one-half of comparable commercially available instruments.

Hardware

The circuit consists of three major components: a microcontroller, a DTMF decoder IC, and an LCD display module. The microcontroller, a Motorola 68705P3, is packaged in a 28-pin DIP, and contains 1804 bytes of EPROM, 112 bytes of RAM, 2 bi-directional 8-bit ports, and a bi-directional 4-bit port. Software for the microcontroller will be posted on the *Electronics Now BBS*. The 68705 microcontroller was discussed in the September and October 1989 issues of **Radio-Electronics**.

The DTMF receiver/decoder, a Silicon Systems 75T-202, requires a 5-volt power supply and a 3.579545-MHz colorburst crystal. It will decode all 16 Touch-Tone frequency pairs. The display, an Optrex DMC16101A sixteen-by-one LCD module, was covered in the June and July 1990 issues of **Radio-Electronics**. The module makes it very easy to display alphanumeric characters because it has a built-in controller that handles all conversion details.

How it works

The schematic for the DTMF decoder is shown in Fig. 1. Software configures all 8 bits of Port A (pins 20–27) of the microcontroller as outputs, which drive D0–D7 of the LCD module. Port B of the microcontroller has bits 5–7 configured as outputs that are the control signals for the LCD module. Bits 0–3 of Port B are inputs that accept data from the DTMF receiver/decoder IC, and bit 4 is unused in this project. Bits 0–2 of Port C are inputs that read the switches (S1–S3), and bit 3 of Port C is unused.

Within 40 milliseconds after receiving a valid tone pair, the decoded data (in 4-bit format) is latched onto the DTMF receiver/decoder's output lines and a DATA VALID (DV) signal is generated by the receiver at pin 14 to signal that data is ready to be picked up. Because the microcontroller's INTERRUPT input (INT) is active-low, the DV output from IC2 is inverted by Q1 for proper operation.

Upon receiving the INT signal, the microcontroller suspends other operations and jumps to a routine that deals with the interrupt. This routine accepts data from the receiver, looks up the corresponding character, and outputs it to the display, along with display-control codes. Approximately five seconds after the last valid tone is received, a blank space is sent to the display for aesthetic purposes. After 16 characters have been sent to the display, the microcontroller forces the display to scroll from right to left.

The microcontroller contains a 64-character memory, which

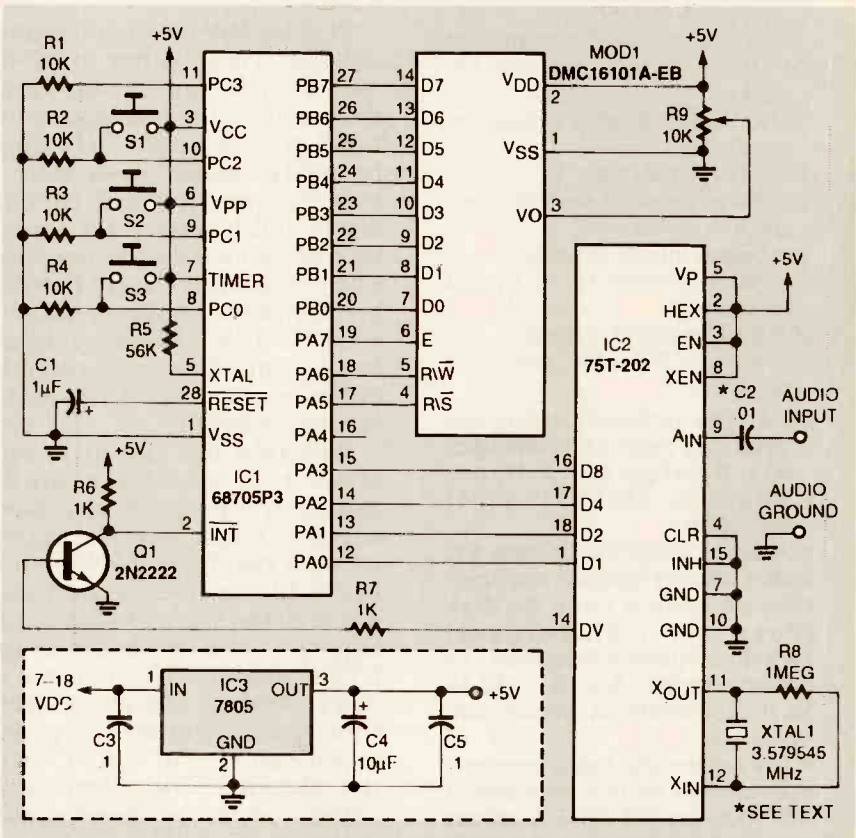


FIG. 1—DTMF DECODER SCHEMATIC. Port A of the microcontroller sends data to the LCD module. Bits 5–7 of Port B are the control signals for the LCD module. Bits 0–3 of Port B accept data from the DTMF decoder, and bit 4 is unused. Bits 0–2 of Port C are inputs that read the switches (S1–S3), and bit 3 is unused.

FRANK HAMPSHIRE

Here's an inexpensive way to decode DTMF tones that you hear.

PARTS LIST

All resistors are ¼-watt, 10%
R1–R4—10,000 ohms
R5—56,000 ohms
R6, R7—1000 ohms
R8—1 megohm
R9—10,000 ohms, PC-mount potentiometer
Capacitors
C1—1 µF, 35 volts, electrolytic
C2—0.01 µF, Mylar (see text)
Semiconductors
IC1—Motorola 68705P3 microcontroller (preprogrammed)
IC2—Silicon Systems 75T-202 DTMF receiver
Q1—2N2222 NPN transistor
Other components
MOD1—Optrex DMC16101A-EB 16 × 1 LCD module (available from Novus, 919-460-7771)
XTAL1—3.579545-MHz colorburst crystal
S1–S3—SPST pushbutton switch
Miscellaneous: PC board, suitable case, screws, spacers, wire, header pins
Power supply parts
IC3—7805 5-volt regulator
C3—0.1 µF disk or Mylar capacitor
C4—10 µF, 16 volts, tantalum capacitor
C5—0.1 µF, disk or polyester capacitor
9-volt DC transformer
TO-220 heatsink for the 7805 regulator
Telephone interface parts
T1—600-ohm:600-ohm hybrid transformer
MOV1—Metal-oxide varistor
C6—0.1 µF, 200 volts, metal-film capacitor

Note: The following items are available from ElectroMagiz, 511 Battleground Road, Chesnee, SC 29323 (803) 461-4664:

- **A kit of parts including a PC board, display module, and commented source code on disk (does not include case, switches, phone interface, or power supply)—$95.00 + $2.50 S&H. SC residents please add sales tax.**
- **The author also has a commercial version of this instrument that includes RS-232C, a printer port, and real-time clock for automated logging, complete with case and power supply. Contact the author at the address or phone number listed. He can also be reached via WISH @KI4FL.SC.**

can be displayed as four screens of 16 characters. Pressing S1 scrolls the pages. If more than 64 characters have been received, the characters are shifted out of memory.

Two other switch functions are included: S2 clears the display and S3 clears the memory. Resistors R1 through R4 are pull-down resistors for the switches. When any switch functions are used, the microcontroller disables the interrupt and refuses to accept any data from the 75T-202. The circuit must then be returned to a "ready" condition for further use.

The circuit requires a 5-volt DC power supply at approximately 125 milliamperes to operate. If you can't get the regulated 5 volts from some other circuit, such as your scanner, or don't want to open it up, the power supply shown in the dashed lines in Fig. 1 can be used.

The DTMF receiver/decoder chip (IC2) is sensitive to DC-biased signals, and if your audio source has a DC bias approaching 5 volts, capacitor C2 must be used to isolate the decoder. If your equipment has no DC bias on its audio output, C2 should be replaced with a jumper wire. The omission of C2 will noticeably increase the decoder's sensitivity. The 75T-202 has an input impedance of 100 kilohms, so loading of the audio line is negligible.

Note that the circuit is sensitive to over-voltage conditions, so a properly regulated supply is important. The author found a regulated 5-volt source inside his scanner, so he added a jack to the scanner that would supply 5 volts and audio to the DTMF decoder. If you can't or don't want to tap power from your scanner, build the power supply shown in Fig. 1 mentioned earlier. One advantage of using a separate power supply is that it allows the decoder to be transferred between scanners more easily.

As shown in Fig. 1, the DTMF decoder can accept an audio input—with or without a DC bias—directly from a pair of

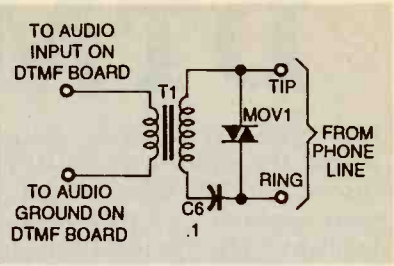


FIG. 2—THIS ISOLATION transformer is necessary to connect the DTMF decoder to a phone line.

speaker terminals, such as those of a scanner. To input audio from a telephone line, the isolation transformer circuit shown in Fig. 2 will be necessary to match signal levels properly. If the circuit is constructed as shown, there won't be enough DC load on the phone line to cause an off-hook condition, yet you will be able to continuously monitor Touch-Tone calls made on your telephone line.

Software

The operating software is an assembly-language program contained in the microcontroller's EPROM. Although the software listing is too long to print here, the commented source code is available on the *Electronics Now BBS* (516-293-2283, 1200/2400, 8N1) as filename DTMF.TXT. The file must be assembled and programmed into the microcontroller's EPROM; if you do not have the facilities for assembling the code and programming the EPROM, a preprogrammed EPROM is available from the source mentioned in the Parts List. A disk containing the commented source code is included with the kit available from that same source.

Construction

The DTMF decoder can be built on a piece of perforated circuit board using point-to-point wiring, or on a PC board. Foil patterns are provided here if you'd like to make your own board, or you can purchase one from the source given in the Parts List. A parts-placement diagram is shown in Fig. 3.

(Continued on page 104)

Enjoy video programming throughout your house with the Video Master video distribution system.

RUDOLF F. GRAF and WILLIAM SHEETS

EXOTIC HOME-ENTERTAINMENT containing VCR's, satellite receivers, laserdisc players, video games, security cameras, and more are certainly enjoyable. However, they often fall short in convenience. The Video Master adds that missing convenience; it lets you set up your own video network and watch any video source on any TV in your home.

The Video Master, described in this article, consists of a series of converters that place all your video sources on unused UHF channels and then combines them with normal TV channels (terrestrial or cable) into one cable. That one cable can then feed several TV sets for whole-house coverage. The desired video source is selected with the TV set's tuner. All of the TV's remote-control features are retained, and you'll be able to switch between any of the sources simply by changing the channel!

Keep in mind that it's illegal to insert unauthorized signals into any public cable system. An isolation amplifier, incorporated in the Video Master's design, prevents signals from feeding back into the cable system. *Do not omit the amplifier portion of the system for any reason.*

Figure 1 shows a block diagram of a typical system setup with the Video Master. It shows a TV antenna (or cable system), satellite TV receiver, VCR, security camera, video game, and laserdisc player, all feeding the Video Master. Notice that all inputs (except cable or antenna) are on Channel 3. There are five upconverters (1 through 5) and a buffer amplifier/power supply module, which supplies +12-volts DC to the upconverters.

The six outputs are combined with a splitter in reverse so that it acts as a signal combiner. The splitter feeds the combined output to all the TV sets in the sys-

tem. The combined output contains all terrestrial or cable channels (VHF 2–13, MID-BAND, UHF, etc.) in the original locations, plus five new channels—36, 39, 42, 59, and 61. Those five new channels carry the signals from the satellite TV, VCR, security camera, video game, and laserdisc player. Any TV on the system can select any signal source by tuning to its new channel.

A buffer amplifier and power supply module inputs the broadcast or cable channels into the system and prevents signals from being fed back to the antenna or cable system. The amplifier also provides about a 7-dB gain to overcome unavoidable losses in the combiner network at the output of the system. The power supply is fed by either 12–14 volts AC or 15–20 volts DC; it supplies +12 volts DC at up to 180 milliamperes to power as many as five upconverters. (The amplifier/power supply module requires about 30 milliamperes, and each upconverter module requires about 35 milliamperes.)

Block diagrams of the upconverter and amplifier modules are shown in Fig. 2. The upconverters consist of a preamplifier operating at 60–66 MHz, with 23-dB gain, and a two-pole bandpass filter between the amplifier and mixer. A double-balanced mixer combines the 60–66 MHz (Channel 3) TV signal with a local oscillator (LO). The LO is set to operate at a frequency 60 MHz below the low end of the desired output signal. For example, to obtain an output on Channel 39 (620–626 MHz), the LO must be at 560 MHz.

Several outputs appear at the mixer output: the original Channel 3 signal, the LO signal, and their sum and difference frequencies. A three-pole bandpass filter selects the desired output (the sum of LO + Channel 3) and rejects the difference frequency. (Theoretically, a double-balanced mixer produces no LO or Channel 3 output, but the mixer used here is not a perfect device, and those frequencies still appear.) The Channel 3 signal is severely attenuated, but the LO signal is suppressed by only 25 dB. Because the LO level must be about +7 dBm (decibels above one milliwatt) or about 0.3 to 0.5 volts rms at the mixer input, the LO appearing at the mixer output is still −18 dBm (about 30 millivolts rms). The desired Channel 39 signal is at about −34 dBm (approximately 4 millivolts rms). Therefore, the LO signal is about 16dB stronger than the desired Channel 39 signal, even using a balanced mixer and keeping the input signal level as high as possible (10 millivolts) to avoid generating excessive spurious signals. The LO signal can interfere with another channel 60 to 66 MHz lower (in this case, Channel 28).

If the LO signal is suppressed to less than half a millivolt, it causes no problems as long as it is placed outside an existing UHF channel. Because typically ten or fewer UHF channels can be received in any given area, ten or fewer new channels—or upconverters—will be needed. The upconverter channel outputs must be selected so as to

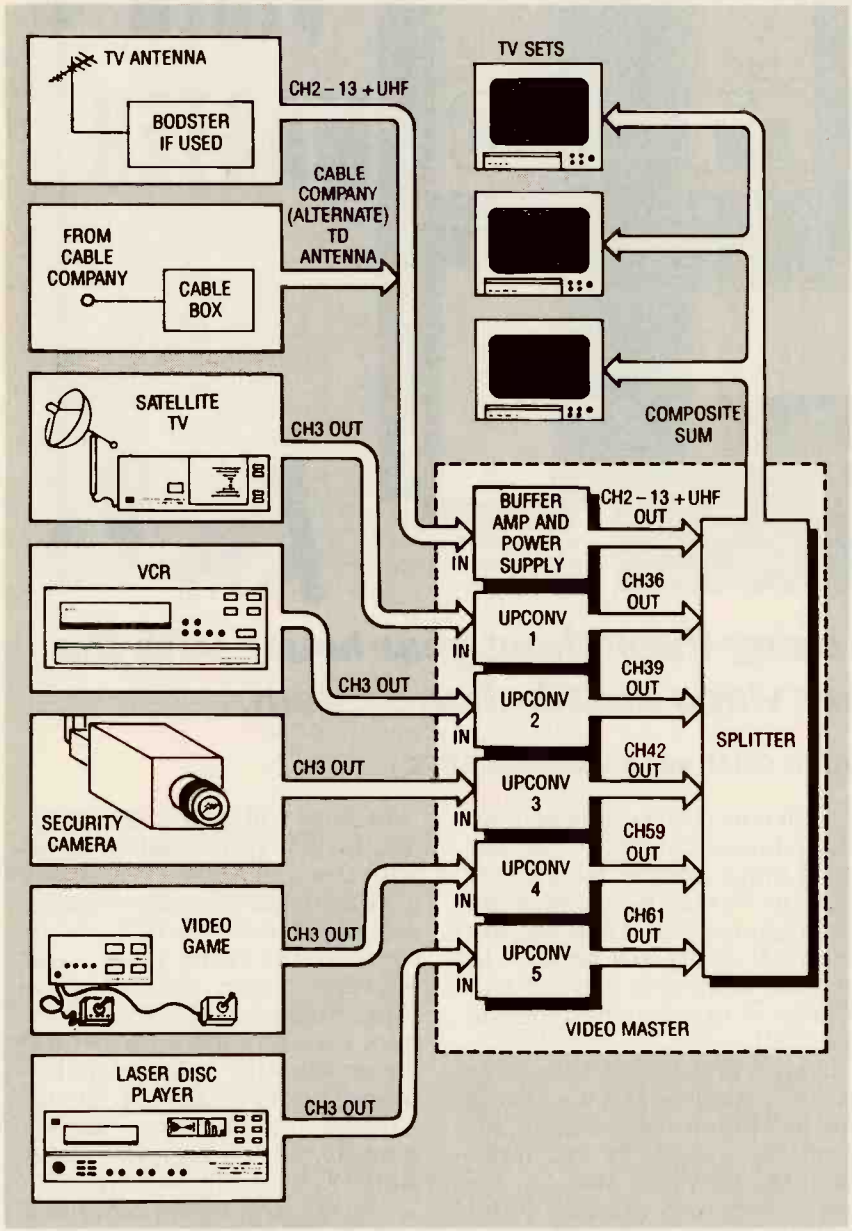


FIG. 1—THE VIDEO MASTER lets you convert Channel-3 outputs from many video devices to unused cable channels, combine them with your normal channels, and view them from any cable-ready set in your house, simply by tuning to the proper channel.

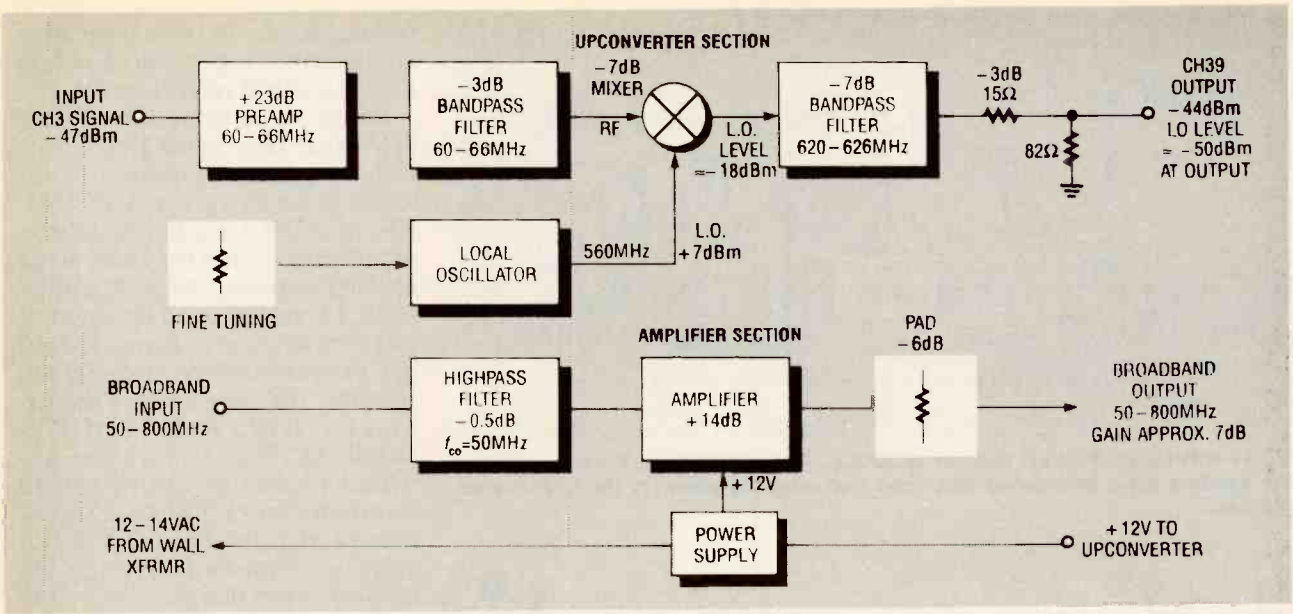


FIG. 2—BLOCK DIAGRAMS of an upconverter module and an amplifier/power supply module.

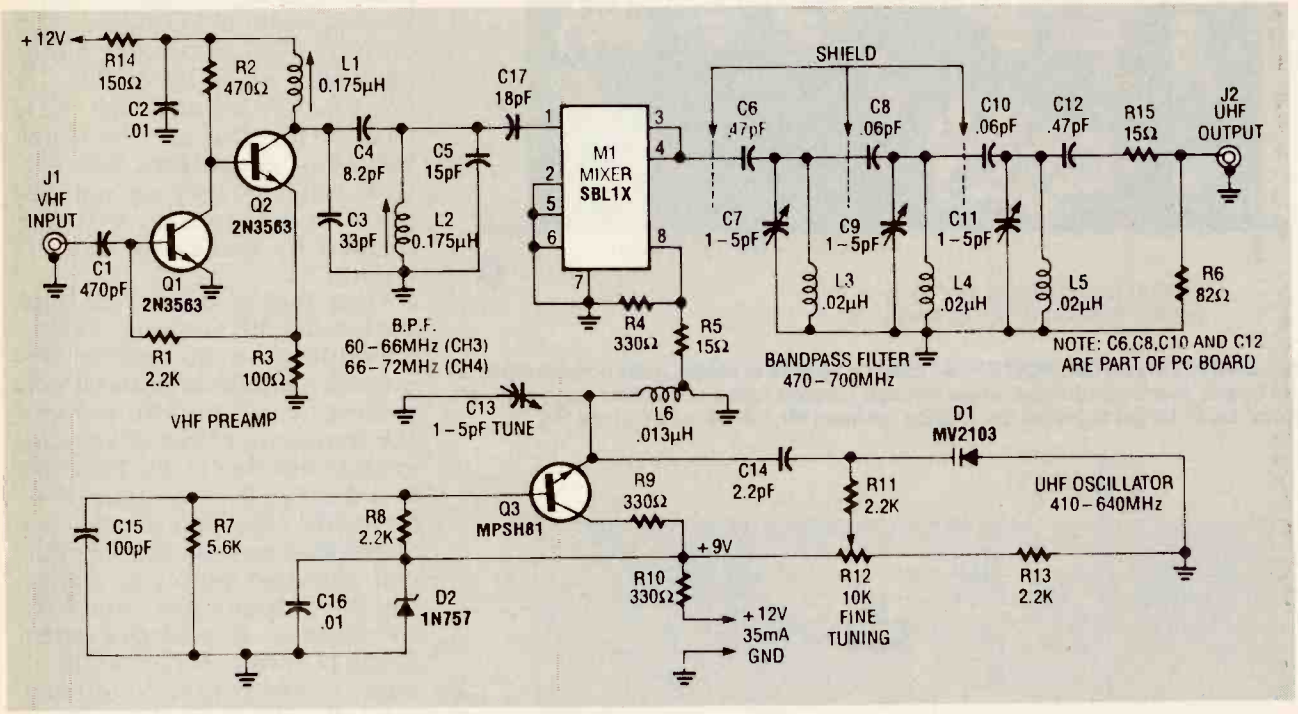


FIG. 3—VIDEO MASTER SCHEMATIC. This circuit inputs a VHF signal at J1 and converts and outputs it as a UHF signal at J2.

avoid placing the LO signal on top of an existing UHF channel. In our example, a Channel 39 upconverter output would have its LO at 560 MHz, and therefore it could interfere with Channel 28 and Channel 29. In an area where a UHF station exists on those channels, the upconverter should be moved up to Channel 41 or down to Channel 37 to avoid interference with Channel 28 or Channel 29. In general, do not select an output frequency 10 or 11 channels higher than our existing UHF channel or any UHF channel to be used by another upconverter in the system.

To reduce stray signal pickup and interference problems in general, individual upconverter and amplifier/power supply modules are used. That eliminates crosstalk problems, and simplifies shielding and circuit layout. The modular approach also lets you build only what you need, yet still allows future upgrades and expansion.

Circuitry

A schematic diagram of the upconverter is shown in Fig. 3, and its companion amplifier and power supply is shown in

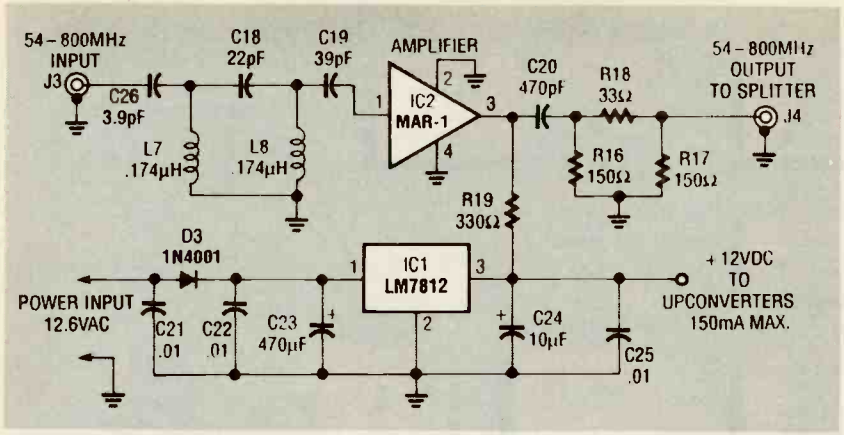
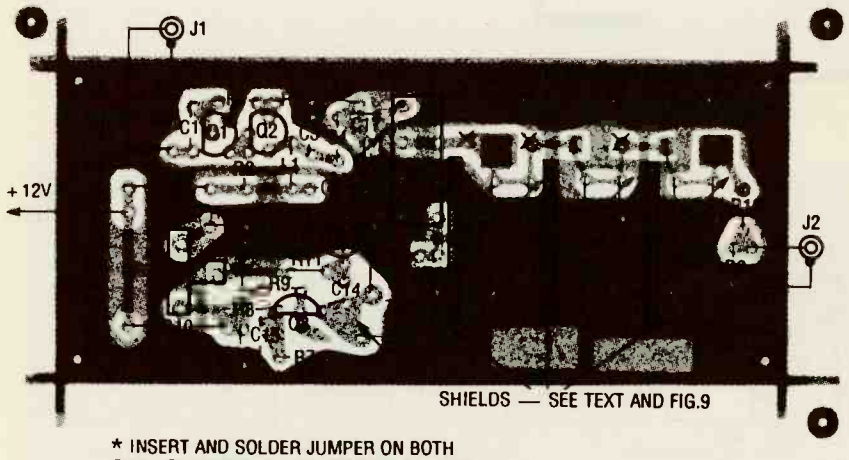


FIG. 4—AMPLIFIER/POWER SUPPLY MODULE. This circuit buffers and conditions your existing cable or antenna input and also supplies power to the upconverter modules.



* INSERT AND SOLDER JUMPER ON BOTH SIDES OF BOARD AT LOCATIONS MARKED "X"

FIG. 5—UPCONVERTER PARTS PLACEMENT. Be sure to solder leads on both sides of the board, and insert jumper wires through unused holes and solder them on both sides. Don't forget to install the shields between M1, L3, L4, and L5 (see Fig. 9).

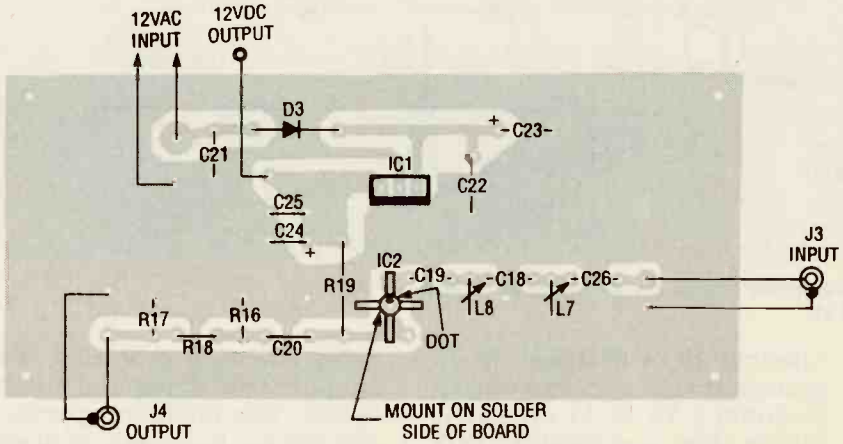


FIG. 6—PARTS-PLACEMENT DIAGRAM for the amplifier/power supply board.

Fig. 4. Channel 3 (VHF) input from a video device such as a VCR is supplied to J1. The signal level is assumed to be −47 dBm (about 1 to 2 millivolts). Capacitor C1 couples the input to an amplifier consisting of Q1 and Q2. The collector of Q2 feeds a filter with a 60–66 MHz passband. The filter components are L1, C3, coupling capacitor C4, L2, C5, and matching capacitor C6. The total gain at the mixer input (pin 1 of M1) is about 20dB referenced to J1.

Mixer M1 is driven by a UHF LO signal that is 60 MHz lower than the desired channel. Transistor Q3 is in the oscillator; R7, R8, and R9 are bias resistors, and C15 grounds the base of Q3 for UHF signals. Variable capacitor C13, coil L6, and the capacitance of the series combination of C14 and varactor diode D1 determine the frequency. Potentiometer R12, R13, and R11 supply DC bias to varactor D1, which allows fine tuning of Q1's frequency by ±3 MHz. The oscillator signal (about 0.3 to 0.5 volts) is supplied through R5 and R4 to pin 8 of M1. The mixer output appears at pins 3 and 4 of M1, where about 4 millivolts of desired signal (the output) is present, along with 25–30 millivolts of residual LO signal. The output is fed to tunable bandpass filter made up of C6, C7, L3, C8, C9, L4 and C10, C11, C12 and L5. (Due to the very low values of capacitors C6, C8, C10, and C12, they are not discrete components, but are formed by traces on the PC board.)

Filter loss is about 7dB, and the bandwidth is about 10 MHz, depending on the center frequency. A simple attenuator pad formed by R15 and R6 reduces the detuning effect of varying loads connected to J2. The filter is a three-pole zero-ripple (Butterworth) type that allows easy alignment. In practice, the filter can be tuned simply by watching the output signal on a UHF TV receiver. It provides up to 50dB LO suppression with respect to the center frequency. Overall gain from J1 to J2 is about +3 to +6dB. That allows for loss in combining the output of J2 with the outputs of additional converters.

Figure 4, the amplifier-section schematic, shows that the antenna or CATV input is applied to J3. A high-pass filter formed by C26, C18, C19, L7, and L8 attenuates unwanted signals (such as shortwave, CB, amateur, and AM) below 50 MHz. A monolithic microwave integrated circuit (MMIC) am-

plifier, IC2, has a broadband gain of about 14dB. Resistor R19 provides DC bias to IC2, and C20 couples the amplified output to resistors R16, R17, and R18 (which sets the total gain to about +7 to 8dB) and to J4. The amplifier compensates for the inevitable loss in the signal-combining network connected to J4.

A 12.6-volt AC wall-mounted transformer feeds components C21, D3, C22, and C23. Those components supply approximately 16-volts DC to the input of an LM7812 regulator (IC1), which supplies 12-volts DC to the rest of the circuit. (If desired, +15 to +20 volts DC can also be introduced to the supply. In that case, D3 would guard against reversed DC power-input polarity.)

Construction

The PC board for the upconverter is double-sided, and the board for the amplifier and power supply is single-sided; foil patterns are provided for both. Parts-placement diagrams for the two boards are shown in Figs. 5 and 6, respectively. Do not change the PC layout, because filter characteristics are dependent on it. PC boards and complete parts kits are available from the source given in the Parts List.

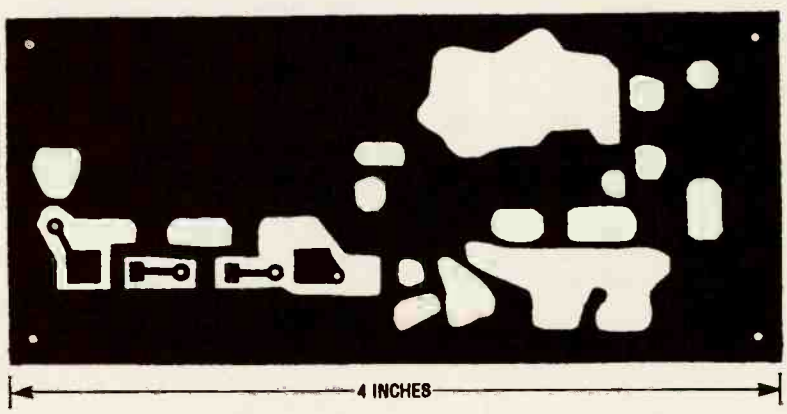
Although the upconverter boards are double-sided, they are not through-hole plated. Therefore, solder all component leads on both sides of the board wherever there is copper foil on both sides. In addition, you must place grounding jumpers in all holes marked with an "X," and solder them on both sides of the board to connect the top and bottom foils. Short lead lengths are important in RF projects because long leads can act as antennas. Also, mount all components snugly against the circuit board and clip their leads close to the board.

Although it would be possible to integrate inductors L3, L4, L5, and L6 into the PC board, the resulting printed inductors would have Q values that are too low, and there could be stray coupling and shielding difficulties. A high value of Q is necessary for L3, L4, and L5 to achieve narrow filter bandwidth, and for L6 to stabilize the oscillator. Those coils are made from lengths of No. 18 AWG wire as shown in Fig. 7.

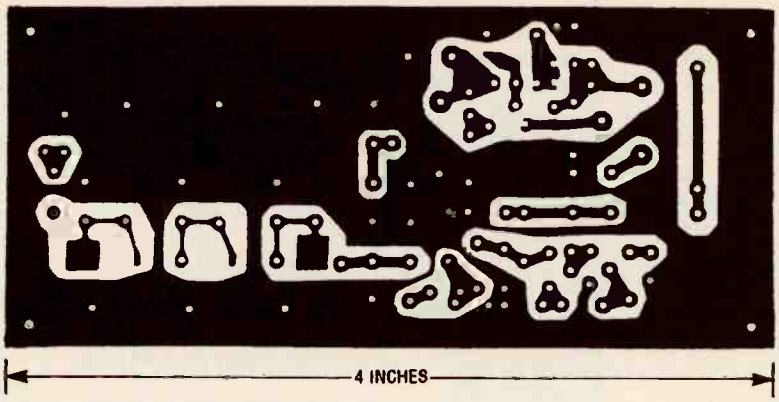
Note that shields—small scraps of G-10 double-sided PC-board material from 0.020- to 0.062-inch thick—must be soldered after standing them on

PART #	INDUCTANCE	CONSTRUCTION
L1,L2 65MHz FILTER COILS	.105–.230µH	SLUG, COIL: 6½ TURNS OF 22-GAUGE ENAMELED WIRE WIND WIRE IN THREADS OF 8–32 SCREW, FORM LEADS TO FIT PC BOARD, TIN LEADS, REMOVE SCREW, AND INSTALL SLUG
L3,L4,L5 UHF FILTER RESONATORS	0.02µH	18-GAUGE WIRE BENT TO FIT PC BOARD; SOLDER ON BOTH SIDES OF BOARD AT GROUND END; 1/8"; ≈3/4"; PC BOARD
L6 OSCILLATOR INDUCTANCE	0.013µH	18-GAUGE WIRE BENT TO FIT PC BOARD; MAKE TAP FOR R5 CLOSEST TO GROUND END OF L6. POSITION CAN BE ADJUSTED TO VARY L.O. DRIVE; SOLDER ON BOTH SIDES OF BOARD AT GROUND END; ≈3/8"; PC BOARD; R5; 0.15"; TO M1
L7,L8 HIGH-PASS FILTER COILS AMP/POWER SUPPLY	0.174µH	9-½ TURNS OF 22-GAUGE ENAMELED WIRE WIND WIRE IN THREADS OF 8–32 SCREW, FORM LEADS TO FIT PC BOARD, TIN LEADS, AND REMOVE SCREW (NO SLUG USED)

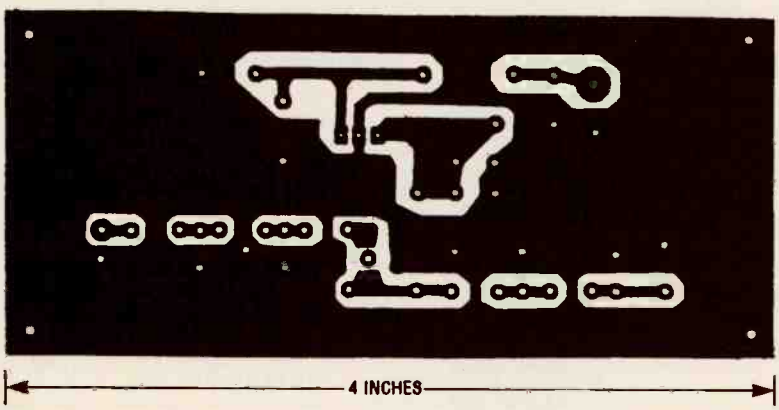
FIG. 7—COILS L1–L7 are made according to these instructions.



COMPONENT SIDE of the upconverter board.



SOLDER SIDE of the upconverter board.



SOLDER SIDE of the amplifier/power supply board.

edge on the top ground plane of the upconverter PC board between M1, L3, L4, and L5 in the locations shown in Fig. 5. The shields are necessary for proper filter performance because they keep down spurious outputs—especially the LO residual leakage. The shields must be well soldered to the top of the PC board.

Mount each converter in its own enclosure. A suitable case is included with the previously mentioned upconverter kits. Suitable connectors are F, BNC, TNC, or SMA—do not use UHF or RCA connectors. Figure 8 shows a suitable packaging scheme for the upconverter board and the amplifier board. Do not omit the three shields in the upconverter filter section, as shown in the photo of the board in Fig. 9. Figure 10 is a photograph of the amplifier/power supply board.

Figure 11 shows one way to mount several modules together to make up a system. The module outputs all connect to the "outputs" of a passive split-

PARTS LIST

All resistors are ⅛ watt, 5%, unless otherwise noted.
R1, R8, R11, R13—2200 ohms
R2—470 ohms
R3—100 ohms
R4, R9—330 ohms
R5, R15—15 ohms
R6—82 ohms
R7—5600 ohms
R10, R19—330 ohms, ¼-watt
R12—10,000 ohms, potentiometer
R14—150 ohms, ¼-watt
R16, R17—150 ohms
R18—33 ohms

Capacitors
C1, C20—470 pF, ceramic disc
C2, C16, C21, C22, C25—0.01 μF, ceramic disc
C3—33 pF, 5%, NPO
C4—8.2 pF, 5%, NPO
C5—15 pF, 5%, NPO
C6, C8, C10, C12—Part of PC board
C7, C9, C11, C13—1–5 pF trimmer
C14—2.2 pF ±0.5 pF, NPO
C15—100 pF, 10%, NPO
C17—18 pF, 5%, NPO
C18—22 pF, 5%, NPO
C19, C26—39 pF, 5%, NPO
C23—470 μF, 25 volts, electrolytic
C24—10 μF, 16 volts, electrolytic

Semiconductors
IC1—LM7812 12-volt regulator
IC2—MAR1 MMIC
D1—MV2103 varactor diode
D2—1N757 9-volt Zener diode
D3—1N4001 diode
Q1, Q2—2N3563 NPN transistor
Q3—MPS H81 NPN transistor

Other components
L1, L2—6½ turns No. 22 AWG enameled wire wound on 8-32 screw with 8-32 ferrite slug (see Fig. 7)
L3–L5—0.02 μH (¾-inch No. 18 AWG wire, see Fig. 7)
L6—0.013 μH (½-inch No. 18 AWG wire, see Fig. 7)
L7, L8—0.174 μH (9½ turns No. 22 AWG enameled wire wound on 8-32 screw)
M1—SBL1X mixer
J1–J4—chassis-mount F-connector
Miscellaneous: PC boards, one shielded enclosure per module, hardware, feedthroughs or bushings for power inputs and outputs, 12.6-volt AC wall transformer, two feet of 22-gauge enameled copper wire, two feet of 18-gauge tinned copper wire, 2- or 4-way splitter, 75-ohm cable, solder

Note: The following items are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804:
- **Amplifier/power supply kit (includes case, hardware, connectors, PC board, and all parts)—$29.50**
- **Upconverter kit (includes case, hardware, connectors, PC board, and all parts)—$34.50**
- **Four-way splitter—$5.50**
- **12.6-volt AC wall transformer—$ 9.50**

Please add $3.50 S&H (foreign orders $5.00) to any order. NY residents must add sales tax. For a catalog of other kits, please send $1 (refundable on next order) or SASE (52 cents postage) to North Country Radio at the above address.

ter. A passive splitter can be used as a combiner simply by running it backwards. That won't work for an active, amplified splitter.

The upconverter modules have a 3-dB gain, which is adequate for compensating for splitter loss. Because most video devices have an RF output of about 3dB above 1 millivolt, approximately 1 millivolt of UHF signal will appear at the system output for each channel, assuming the use of a four-way splitter and three upconverters. The cable level should be around 1 millivolt per channel, which will give about 50dB or better signal-to-noise ratio for the average TV receiver. Levels lower than 200 microvolts might yield a snowy picture. If necessary, the system output can be run through a distribution amplifier. Remember to terminate all unused splitter ports with 75-ohm terminating resistors.

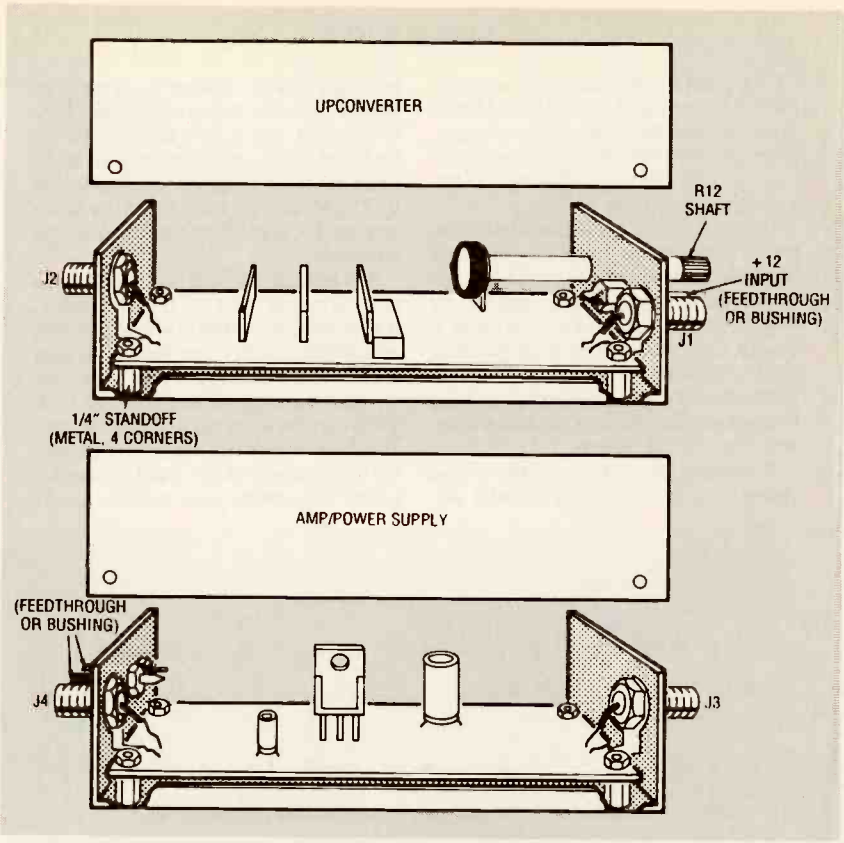


FIG. 8—SUGGESTED PACKAGING SCHEMES for the upconverter and amplifier/power supply boards.

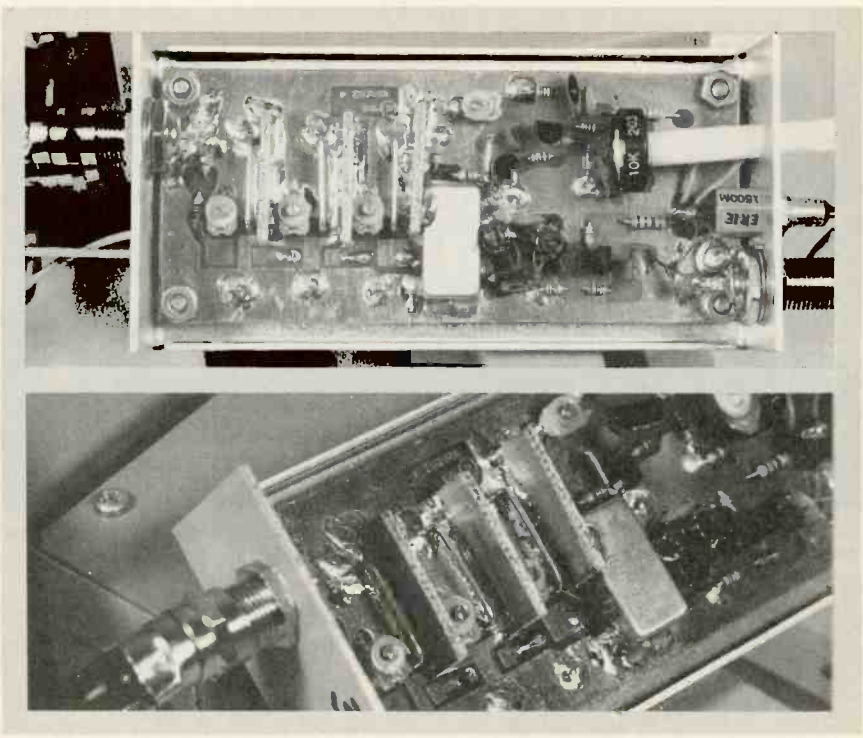


FIG. 9—UPCONVERTER BOARD. Note the shields, made from scraps of double-sided PC board material, that are placed between M1, L3, L4, and L5.

Test and alignment

Alignment of the completed unit requires a video source on Channel 3 (your VCR will do) and a digitally tuned TV set. A frequency counter will also be helpful in this procedure.

First check out the amplifier/power supply. Connect a source of 12 to 14 volts AC, of at least 250 milliamperes to the junction of C21 and D3, and connect the remaining lead to ground—a plug-in wall transformer is recommended. Alternatively, a DC source of 15 to 20 volts can be used, with the positive lead to the C21-D3 junction, and negative lead to ground. Regardless of the supply you use, verify that there is 15 to 20 volts DC across C23.

Next check for +12 volts at the junction of IC1, C24, C25, and R15. If there is less than 11.5 volts or more than 12.6 volts, check to see if IC1 is defective or improperly inserted in the PC board. Check to be sure that IC1 does not get hot. If all tests are passed so far, check for +4 to +7 volts at pin 3 of IC2. Next check for infinite resistance from the center pin of J3 to ground. Next, check the resistance from J4's center conductor to ground; it should be about 80 ohms. Mount the board in a case, apply power, and connect a TV receiver to J4, and the antenna to J3. Normal

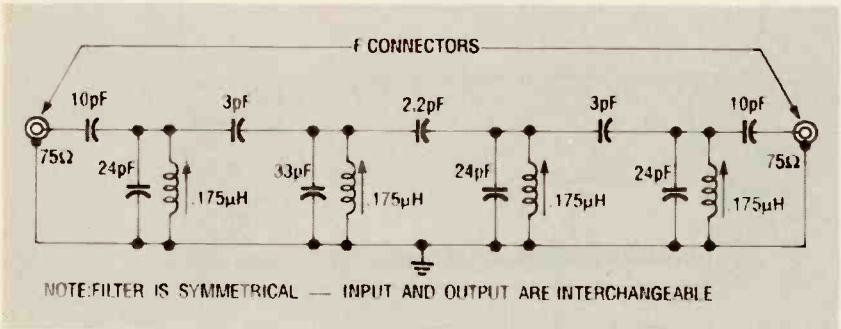
CABLE BOXES

There are many different types of cable boxes, but as far as the Video Master is concerned, there are only two types. One type contains a built-in video modulator and its output is spectrally clean enough for the Video Master.

However, many cable boxes are simply RF converters, and there are other frequencies mixed in with the Channel-3 or -4 output. You can easily test this by changing channels on the TV's tuner. If the TV can receive any channels other than Channel 3 (or 4), you could have problems with the upconverter modules that will show up as lines, ripples, noise, and beats in the picture.

If you have any of those problems and you're sure that no stray signals are leaking into your system, build the filter shown here. It's designed to pass only Channel 3, but it can be retuned for Channel 4. Its capacitors are all silver mica or NPO ceramic. The coils are 0.175 μH, and can be made in the same way as L1 and L2 in the upconverter modules.

The filter can be built on a scrap piece of G-10 copper-clad PC board material. It should be mounted in a shielded box and provided with F connectors for best results. It is aligned by peaking the coils for maximum signal on Channel 3. A VCR can be used as a signal source. The filter should be inserted between the cable box and the input connector on the appropriate upconverter. Ω



This filter will remove all signals except Channel 3 (or 4) from the output of your cable box.

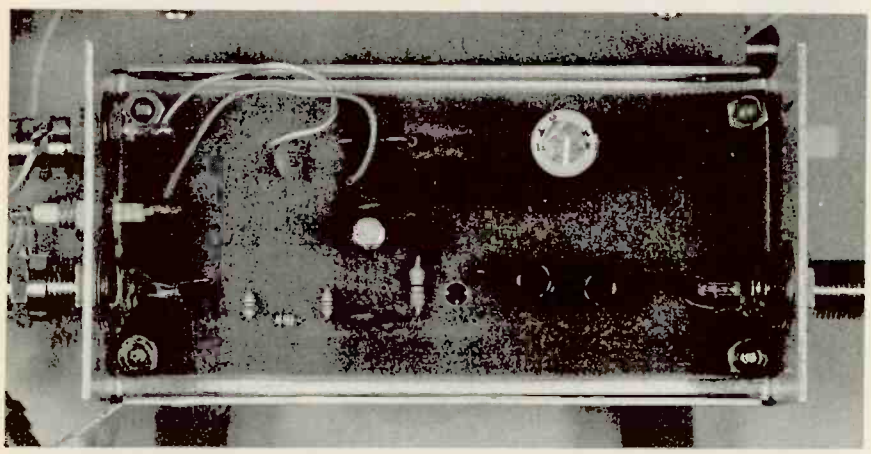


FIG. 10—AMPLIFIER/POWER SUPPLY. This board is mounted in the same type of case as the upconverter modules.

TV reception should result, with no loss of picture quality. If RF test equipment is available, measure the gain from J3 to J4. About 7 to 8dB should be obtained at 450 MHz (UHF), and slightly more on VHF (100 MHz). That completes the amplifier/power supply tests.

The upconverter board is tested as follows: After the board has been visually checked for shorts, solder bridges, and correct component placement, install the board in its case. Connect a Channel-3 source to J1 and connect a TV receiver to J2. Use 75-ohm cable. Apply power to the 12-volt input (the junction of R10 and R14), and check for the following voltages:

- Junction of D2 and R10—+8.4 to 9.5 volts
- Wiper of R12—+3 to 9 volts depending on setting of R12
- Junction of R11 and D1—+3 to 9 volts depending on setting of R12
- Emitter of Q3—+6 to 7.5 volts (adjusting C13 should vary the voltage by ±0.1 volt—this verifies that Q3 is oscillating)
- Base of Q3—+6 to 7.5 volts (adjusting C13 should vary the voltage by ±0.1 volt—this verifies that Q3 is oscillating)
- Emitter of Q2—+1 to 1.2 volts
- Base of Q2—+1.8 to 2.1 volts
- Collector of Q2—+8.5 volts (typical)
- Pin 8 of M1—0.3 to 0.5 volts RMS (this test is optional, and can only be done with an RF voltmeter)

Tune the TV receiver to the UHF channel on which you would like the upconverter to produce a signal. Set the slugs in L1 and L2 halfway in the coil winding. Set C7, C9, and C11 so that their plates are halfway engaged, and C13 fully engaged. Set R12 to mid-position. Turn on the source connected to J1. Slowly rotate C13 with a plastic alignment tool; at several points the TV set should exhibit a response of some kind. (If you have a frequency counter, connect it to pin 8 of M1 and set C13 for the correct oscillator frequency.) When you get a response, you might see a very weak picture, but at first you will probably only hear audio. Note the position of C13. Now look for other responses; the correct one will be where C13 is set at greater capacitance (more of the plates engaged).

The oscillator can produce an output either on the high or low side of the desired channel—you want the low side, otherwise the converter output will have picture and sound frequencies inverted from the usual positions. Next, slowly adjust C7, C9, and C11 for best picture and sound. Now go back to L1 and L2 and adjust for best picture quality as well as sound quality. Readjust C7, C9, and C11 for the best picture and sound. Repeat any alignment as needed.

The adjustment of trimmer

(Continued on page 107)

STATIC ROM

Build your own EPROM emulator for less than $60.00!

FRED EADY

THIS ARTICLE IS DEDICATED TO ALL electronics experimenters who have discovered the microcontroller. Developing a new microcontroller-based project is rewarding, but it can be difficult even with the aid of a microcontroller simulator. After all, you can't flash an LED or write to an LCD with a simulator because programs don't energize relays—hardware under program control does. Our inexpensive Static-ROM project is designed to be an alternative to the expensive professional microcontroller emulation systems. The Static-ROM in combination with an assembled 8048 board (discussed in greater detail later on) is the perfect learning tool for the beginner, and the perfect debugging tool for the experienced microcontroller user.

Designing projects that use EPROM (Erasable Programmable Read Only Memory) technology without reliable and helpful hardware tools can be an iterative and painful process. Each time you change the firmware embedded in the EPROM for your project, you must remove, erase, reprogram, and remount the EPROM. Even if you have dozens of EPROM's, and cycle through them as you change your firmware, it is still very time consuming. An alternative to development with EPROM's is the use of battery-backed RAM modules. But they are expensive, require special programming tools and techniques, and you still have to remove and remount them. Wouldn't it be nice to be able to emulate the EPROM in your project and eliminate the vicious erase/program cycle? Wouldn't it be nice to be able to build your own EPROM emulator in an evening for less than $60.00?

Our Static ROM project is named for its ability to emulate ROM (Read-Only Memory) with static RAM (Random-Access Memory). It plugs in directly where the EPROM would go, and eliminates the hassle of EPROM swapping. An average program change and load to Static-ROM takes less than a minute; it takes a minimum of 15 minutes to erase an EPROM!

Static ROM can be made to emulate the EPROM family from 2716 to 27256 simply by switching EPROM emulator cables. In addition, Static-ROM provides an automatic processor-reset pulse (active-high or active-low) after your program download that can be used to restart your target processor.

Operation

The Static-ROM is built around the PIC16C55 CMOS microcontroller (IC3 in Fig. 1). The 28-pin PIC16C55 provides one 4-bit and two 8-bit bi-directional I/O ports, as well as a timer/counter input, clock input, and clear input. The PIC16C55 contains 512 bytes of EPROM and 32 bytes of RAM. That doesn't seem to be much, but good things come in small packages. The EPROM bus is 12 bits wide, while the RAM bus is standard 8 bits wide. The 12-bit EPROM bus allows the use of a simple and powerful instruction set with emphasis on high-speed bit, byte, and register operations. There are only 33 12-bit instructions for the PIC16C55. With a 4-MHz clock, each instruction is executed in 1 microsecond. Its beauty lies in the power and simplicity of the PIC16C55 instruction set, as it takes less than 60 instructions to implement the entire algorithm for Static ROM.

The algorithm programmed into IC3 reads the STROBE line of parallel port 1 or 2, responds on the BUSY line of the respective parallel port, and supplies control line signals and sequential address information to the 43256 static RAM, IC4. Terminal software controls the selected parallel port, and communicates with the PIC16C55 and the user while routing binary user-written data to IC4. The PIC16C55, as implemented in the Static-ROM, is essentially an intelligent 15-bit up-counter triggered by the parallel port STROBE line and synchronized with the parallel port BUSY and END lines. The END input on the PIC16C55 serves as an end-of-download indicator, and also supplies the reset pulse for the target system's processor. Resistor SIP's R4 and R5 perform the necessary pull-up functions for the PIC16C55 output lines.

Static RAM chip IC4 (a 43256) holds all of the downloaded user-generated binary EPROM image data. If your application does not use raw binary data, Static-ROM does not care—it downloads whatever the terminal program sends. Therefore, special tables and unique characters can also be downloaded and used during emulation. The 43256 has the equivalent storage capacity (32K) of the 27256 EPROM. Only the amount of storage necessary to emulate a particular EPROM is used during actual emulation. In the program-download mode, the address lines of IC4 are controlled by the PIC16C55. In the EPROM-emulation mode, the 43256 is con-

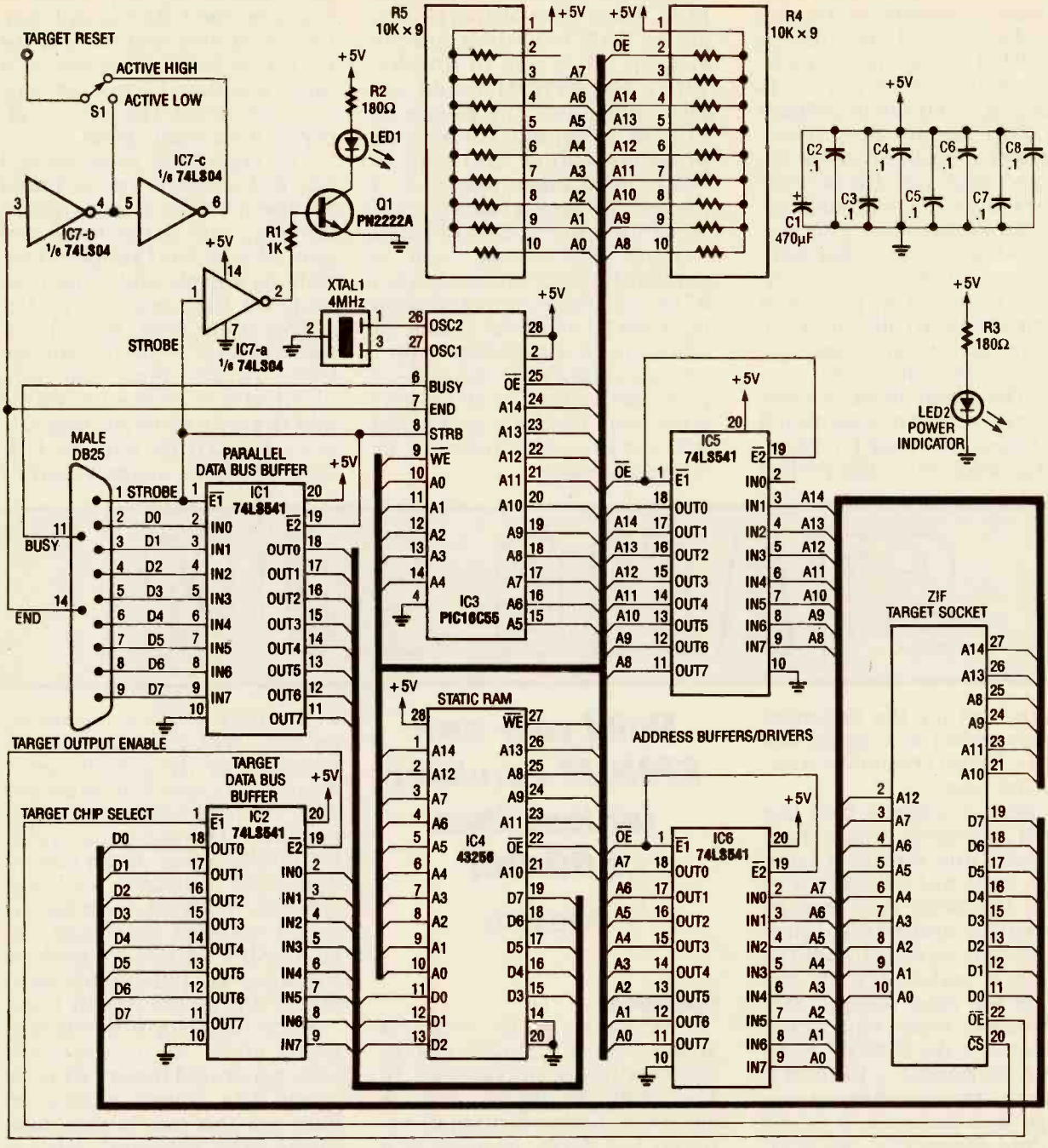


FIG. 1—THE STATIC-ROM is built around IC3, a PIC16C55 CMOS microcontroller that has one 4-bit, and two 8-bit bi-directional I/O ports, 512 bytes of EPROM, and 32 bytes of RAM.

nected via address and data buffers to the target system exactly as an EPROM would be. The target system does not know the difference.

While the PIC16C55 is generating address information for the static RAM, the static RAM address and data lines must be isolated from the target system's address and data lines to eliminate any conflict, and the static RAM data lines must be gated to the data lines of the parallel port. IC1, a 74LS541, provides the gate for incoming data from the parallel port. The chip passes data to the 43256 static RAM when the STROBE line is active (TTL low). When the STROBE line is inactive, IC1 isolates the parallel port data bus from the static RAM data bus.

When in the EPROM-emulation mode, the STROBE line is in the inactive state, which allows the static RAM data bus to be used exclusively by the target system. During the download cycle, the PIC16C55 emits a BUSY signal to the parallel port, and generates the WRITE ENABLE ($\overline{WE}$) signal required to store data in the 43256. During the BUSY time, the PIC16C55 generates the $\overline{WE}$ signal that writes the incoming data to RAM, increments the address counter,

updates the address lines to RAM, and checks for the END signal. Before dropping the BUSY line, the PIC16C55 also verifies that STROBE has gone from an active to an inactive state. The terminal program senses an active BUSY line and stops data transfer until the BUSY line is made inactive or cleared by the PIC16C55.

Another 74LS541 octal buffer, IC2, has its ENABLE lines tied directly to the target system EPROM CHIP SELECT ($\overline{CS}$) and OUTPUT ENABLE ($\overline{OE}$) lines. When the target system processor is fetching data from the Static-ROM (which it thinks is an EPROM), IC2 gates IC4's data bus to the target processor's data bus. When the target EPROM's select lines are inactive, the outputs of IC2 float, thus isolating the RAM's data bus. That allows the processor data bus to be used by other devices requiring its services.

The incoming address lines are buffered by IC5 and IC6 from the target system. The enable lines for IC5 and IC6 are tied directly to the PIC16C55 OUTPUT ENABLE ($\overline{OE}$) pin. The PIC16C55 disables IC5 and IC6 during program download and enables the line after target processor reset. Those two IC's provide isolation from the target system address lines during program download, and act as target-system address-line drivers during EPROM emulation. That allows the Static-ROM to download a new software image regardless of the state of the target system.

Inverters IC7-b and IC7-c provide an active-high or active-low RESET pulse in synchronization with the END input from the parallel port. Gate IC7-a, driven by the parallel port STROBE signal, drives the base of switching transistor Q1 via R1 to indicate program download activity with LED1 and R2. Upon sensing an active END signal, the PIC16C55 resets its internal address counter to zero, refreshes the address bus to RAM, floats the address lines to RAM, enables the address buffers (IC5 and IC6), and waits for the next active STROBE signal from the parallel

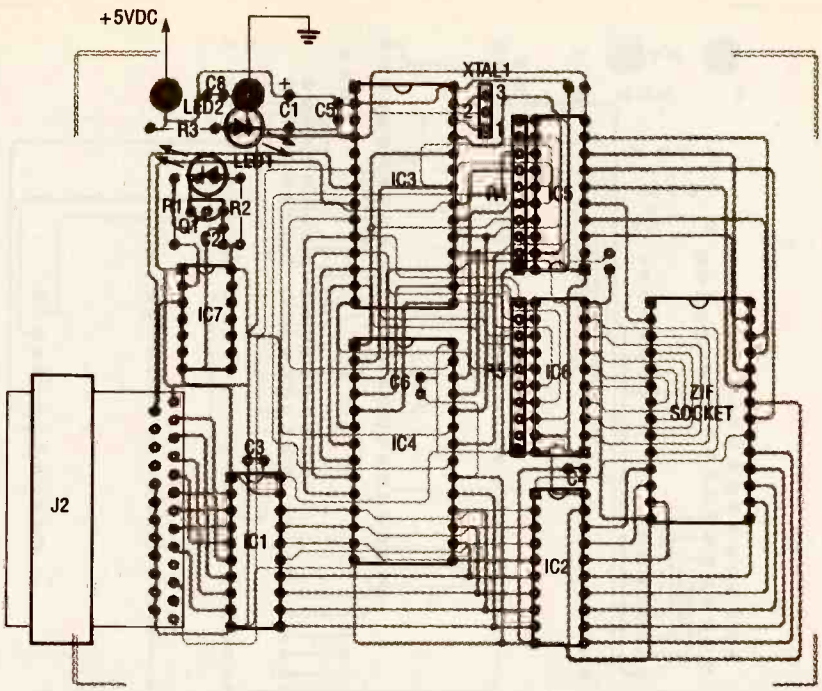


FIG. 2—INSTALL ALL PARTS as shown here. Note that IC5 and IC6 are mounted in a direction opposite that of the other IC's, and that C6 mounts within the confines of IC4's socket.

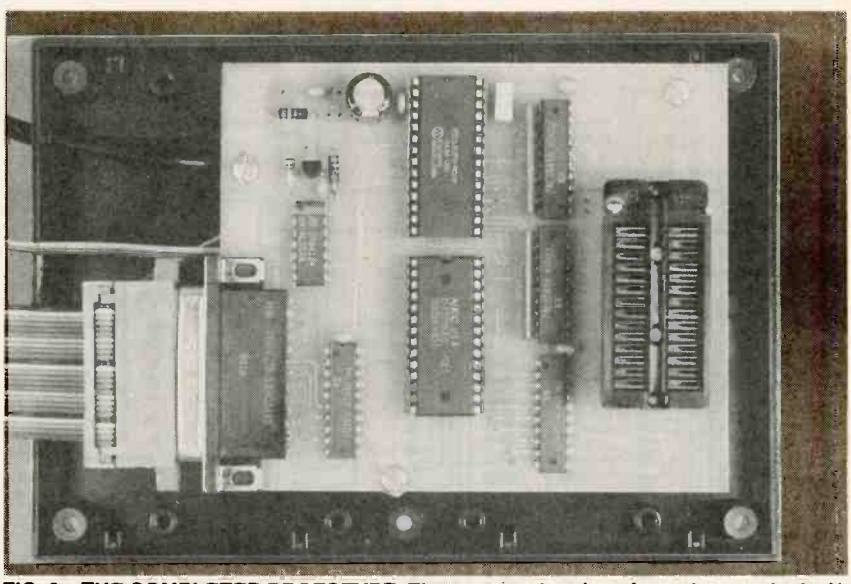
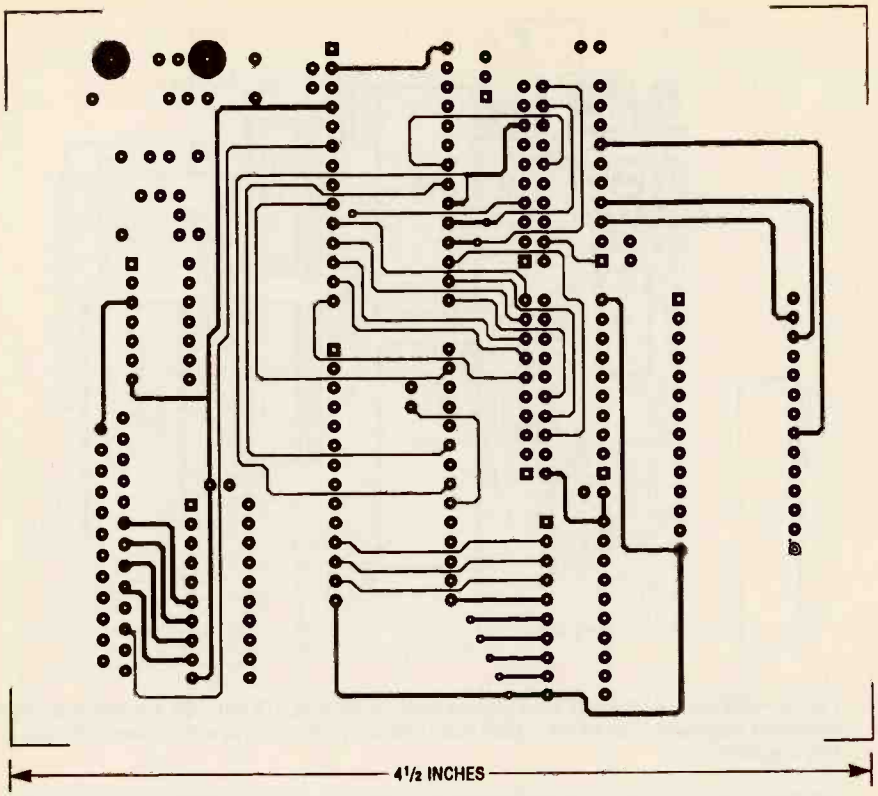


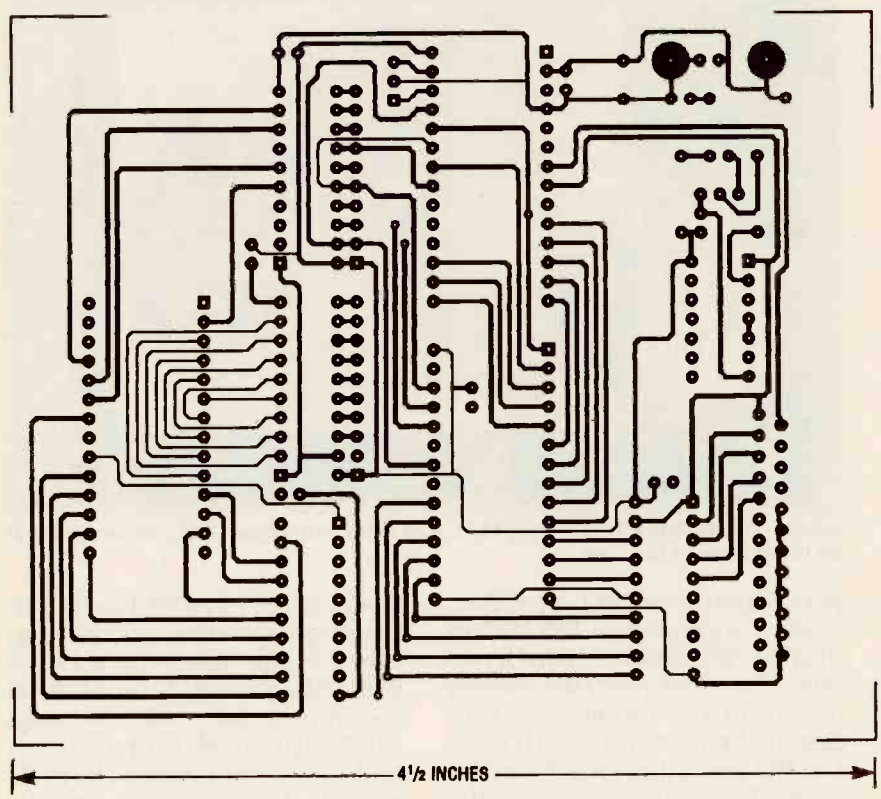
FIG. 3—THE COMPLETED PROTOTYPE. The reset probe plugs into a banana jack, J1, on the outside of the case.

port. Upon receiving an active STROBE signal, the PIC16C55 disables IC5 and IC6, which isolates the Static-ROM address bus from the target. The processor then proceeds with loading the incoming data from the parallel port into RAM. Once the download is complete, the cycle repeats.

Static-ROM doesn't require personality modules, jumpers, and software to define the EPROM being emulated. Instead, each EPROM has a particular cable wiring scheme that allows the user to switch EPROM's simply by installing the appropriate cable between the Static-ROM target socket and the target system's EPROM socket. An advantage to this scheme is that you need only make the cables you will actually use.

Capacitors C1 through C8 filter and bypass the 5-volt DC power bus. LED2 along with re-





sistor R3 serve as a POWER-ON indicator. An external 5-volt DC regulated power supply is required to power the Static ROM.

The software for the Static-ROM consists of a terminal program that transports user-generated data, and controls the selected parallel port. It has an intelligent address generation algorithm that resides within the PIC16C55. If you own a PIC16C55 programmer, the PIC16C55 source listing is available, so you can program your own. Source listings of the software for both the PIC16C55 and terminal program are available on the RE-BBS or from the address in the Parts List.

Construction

A PC board is recommended, but not necessary. If you choose to make one, use the supplied foil patterns; otherwise you can obtain one from the address in the the Parts List. Placement of the DB25 parallel-port connector is critical, so follow the

PARTS LIST

Resistors
R1—1000 ohms
R2, R3—180 ohms
R4, R5—10,000 ohms × 9, SIP
Capacitors
C1—10 µf, 16 volts, electrolytic
C2–C8—0.1 µF, Mylar
Semiconductors
LED1, LED2—light-emitting diode, any color
Q1—PN2222A NPN transistor
IC1, IC2, IC5, IC6—74LS541 octal buffer/line driver
IC3—PIC16C55 CMOS microcontroller (programmed)
IC4—43256 static RAM
IC7—74LS04 hex inverter
Other components
XTAL1—4-MHz ceramic oscillator
S1—SPDT switch
J1—banana jack
Miscellaneous: 5-volt DC power supply (500 mA), 28-pin ZIF socket (optional, for the target socket), IC sockets, 25-pin right-angle D shell connector, EPROM cables, serial cable, PC board, wire, solder, mounting hardware, etc.

Note: The following items are available from Fred Eady, PO box 541222, Merritt Island, FL 32954:

- **A complete kit of parts including PC board, 25-pin connector, SPDT switch, and IC sockets (not including 8048 target board, power supply, ZIF socket, and cables)—59.95 + 5.00 S&H**
- **Assembled 8048 microcontroller target board and software routines on diskette—$20.00 + 5.00 S&H**
- **Programmed PIC16C55—$25.00 + 5.00 S&H**
- **PC board only—$15.00 + 5.00 S&H**
- **Static-ROM software on diskette—$5.00 postpaid**

Check or money orders only. For technical assistance and inquires call 407-454-9905

component layout if you choose to handwire the Static-ROM.

It's a good idea to socket all of the IC's. Install all IC sockets as shown in the parts-placement diagram of Fig. 2, paying particular attention to the pin-1 positions of IC5 and IC6, which are mounted in the opposite direction from the other IC's. Capacitor C6 mounts within the confines of the socket for IC4. The dot on SIP resistors R4 and R5 indicates pin 1, as do the square pads on the printed circuit board. The Static-ROM does not require a case, but if you decide to use one, remember to mount the LED's and switches in the appropriate locations.

At this point you should have all of the components except the IC's and the DB25 shell connector mounted on the printed-circuit board. Apply power (the POWER LED should illuminate) and check for power and ground on all of the IC's. If the specified voltages are not present, recheck your work. When you are satisfied with the voltages, install the DB25 connector.

Depending on your choice of target processor, solder a length of wire with a microclip on one end to either pin 5 or pin 6 of IC7 to act as a target-system reset probe. Remember, you will be attaching this lead directly to the pin of the target processor, so be sure to select the appropriate microclip. The prototype was built with SPDT switch S1 supplying either an active-high or active-low reset pulse to a banana jack, J1, on the outside of the case. The prototype's reset probe consists of a multimeter test lead with banana plugs on both ends. That makes connecting the probe to the Static-ROM painless and allows for different types of clips at the opposite end of the reset cable. Incorporating switch S1 not only makes switching between active-high and active-low reset outputs simple, but also provides a way for manually resetting the target processor by simply toggling the switch. Figure 3 shows the completed prototype.

Referring to Table 1 and Fig. 4 as a guide, assemble the EPROM cables of your choice. Use wirewrap wire and insulation-displacement ribbon-cable headers to make the EPROM cables. Use needle-nose pliers to insert the wirewrap wire into the required insulation-displacement header pins, and then insert the ribbon cable on top of the wirewrap jumpers, and then complete the assembly of the header. Maximum EPROM cable length should not exceed 36 inches for reliable operation. The data cable from the parallel port has a 25-pin, pin-to-pin male connector on the parallel-port end and female connector on the Static-ROM end. That cable can have a maximum length of 6 feet. For ease in making the data cable, use insulation-displacement DB25 shell connectors on both ends. When you are satisfied that all is correct, install the IC's.

TABLE 1—EPROM CABLE WIRING CHART

EPROM Type	Ground to Pin 14 (Emulator Side)	No Connection (Emulator Side)
2716	2, 23, 26, 27	1, 2, 23, 26, 27, 28
2732	2, 26, 27	1, 2, 26, 27, 28
2764	26, 27	1, 26, 27, 28
27128	27	1, 27, 28
27256	None	1, 28

Notes:
- No connection means that no ribbon cable should be connected to the emulator-side pins listed.
- If you eliminate the connections on the emulator side, you can install the full cable on the target side.
- You can eliminate the ribbon cable for pins 1 and 28 from all EPROM types.
- See text and Fig. 4

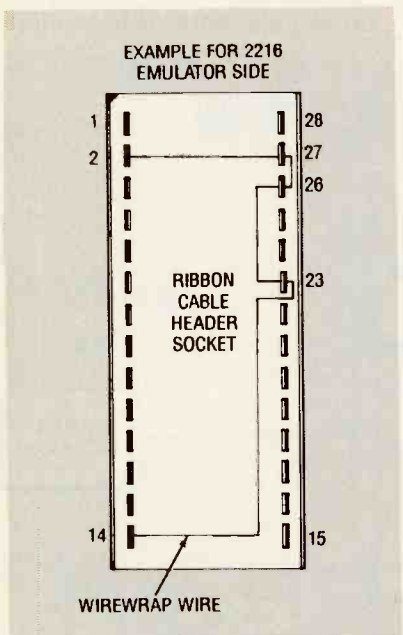


FIG. 4—USE NEEDLE-NOSE PLIERS to insert the wirewrap wire into the insulation-displacement header pins, and then insert the ribbon cable on top of the wirewrap jumpers (see text). Table 1 shows the connections for different EPROM's.

Initial testing and use

The best test for Static-ROM is to write some simple routines for controlling a small microcontroller system and execute them with it. If you do not have an EPROM-based target system, the author will provide an assembled 8048-based microcontroller system that contains a microcontroller, UART (Universal Asynchronous Receiver Transmitter), I/O ports, RAM and EPROM. A schematic diagram and software routines to exercise the assembled 8048 board are also included. The author-provided fully commented software routines consisting of an LCD driver, I/O drivers, and a serial I/O routine using the on-board UART. The serial routine is written to talk to an ASCII terminal. A feature of the assembled 8048 board is that you can replace the 8048 and EPROM on the assembled board with a programmed 8748. This feature permits you to eliminate the EPROM if you decide to ded-

(Continued on page 111)

DINESH BHATIA

WIRELESS GUITAR TRANSMIT

TRANSMIT YOUR GUITAR CHORDS through the air to a nearby FM receiver, and get rid of those cords on the floor. Your FM receiver can feed one or more amplifiers if you really want to boost the sound and fill the room with music. Simply plug this transmitter into your guitar's output jack, make a few adjustments, and start playing "wireless" through your FM stereo tuner or a portable FM receiver.

With this Guitar Transmitter, you won't have to plug in cables, hook up guitar-effects pedals, and turn on a lot of different power sources. Moreover, you can build your own transmitter for a lot less money than you would pay for a factory-built unit—and you'll end up with a better product. The parts for the Guitar Transmitter described here cost less than $40. This transmitter has a built-in distortion effects unit, so you won't have to fumble with an effects pedals every time you play your guitar.

Today many professional guitar players have their own wireless guitar transmitters. Why doesn't every guitar player have one? Probably because of price. Until now it has just been a lot less expensive to plug your guitar into your amplifier with a patch cord.

Commercial wireless guitar transmitters have been available since the late 1900's, but those early units were either too noisy or too expensive for most amateurs. It seemed that only rock stars could afford them. However, integrated circuitry cut the cost of transmitters and led to significant improvements in signal-to-noise (S/N) ratio over the earlier models.

Recent "affordable" IC-based transmitters have usually included some form of *companding* to reduce background noise. Companding is a technique for compressing the signal's dynamic range at the transmitter and then expanding it back to its original range at the receiver. Dynamic range is the difference in volume between the lowest and highest audio levels.

Companding usually works well as a noise-reduction technique, but it has drawbacks: the most common of these is a response known as "breathing"—the background noise gets softer and louder as

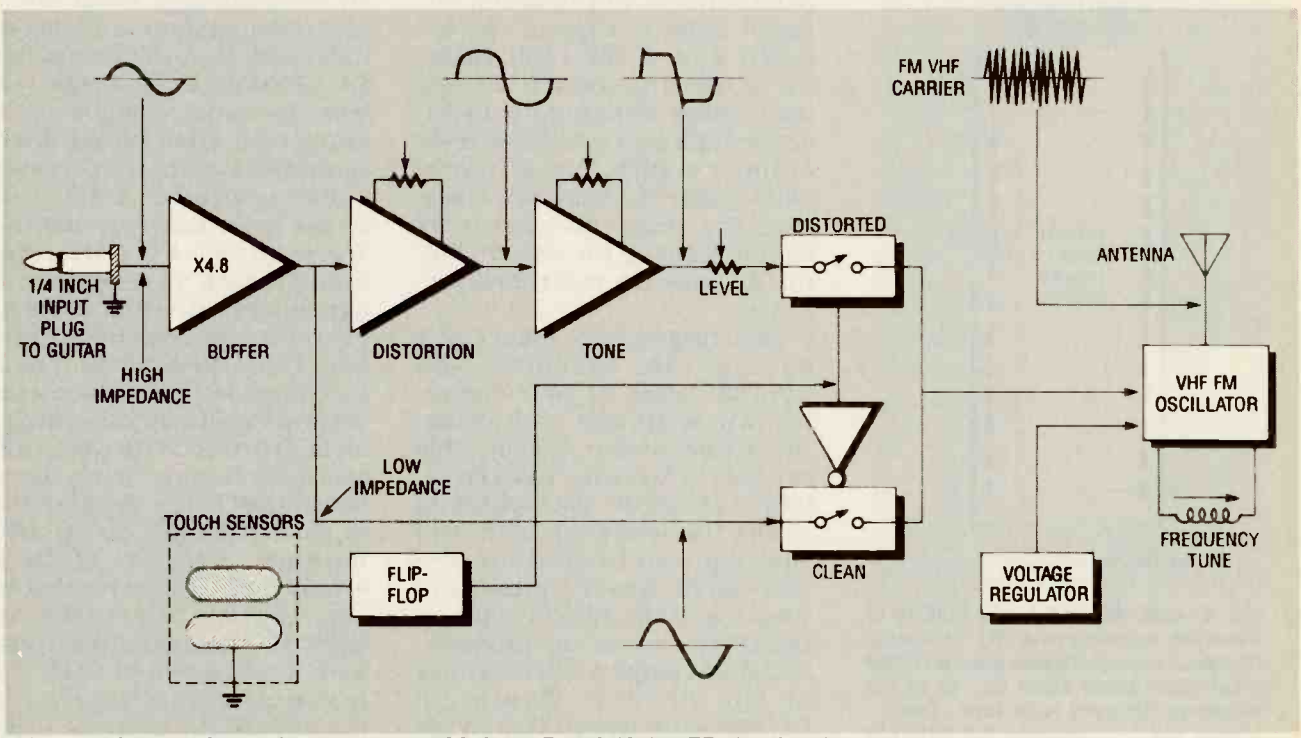


FIG. 1—BLOCK DIAGRAM OF THE WIRELESS GUITAR TRANSMITTER showing the separate channels for the distorted and clean sound and the VHF FM oscillator.

Build a wireless FM guitar transmitter that is better than what you can purchase —and save money.

TER

the guitar is played. The latest commercial wireless guitar transmitters include modifications of companding that reduce background noise and suppress "breathing," but that improvement has increased their price.

A transmitter must have a high signal-to-noise ratio (S/N) if it is to be used with a distortion-effect unit because the distortion unit is essentially a high-gain audio amplifier. Therefore, if the distortion effect is inserted after the receiver (as in typical wireless guitar transmitters), *all* sound including background noise will be amplified. The result is a lower overall S/N ratio.

Typical S/N ratios for wireless transmitters rarely exceed 70 dB unless some form of companding is present. However, if you assume that a commercial wireless transmission system has an S/N of 100 dB and a distortion effects unit is inserted between the receiver and amplifier, the overall S/N will drop to about 54 dB. This is based on the assumption that voltage gain is 200, therefore:
S/N reduction = 20 log (200) = 46 dB

The Guitar Transmitter differs from the latest commercial products because it has a distortion-effects unit which precedes its transmitter. As a result, the effects unit amplifies *only* the pure guitar signal and not the background transmission noise. Therefore, noise is reduced, component cost is lower because no companding circuity is required, and you can expect a consistent 60-dB overall S/N.

Figure 1 is a block diagram of the Guitar Transmitter with typical waveforms shown at various stages of signal processing. Notice that the complete transmitter has three functional circuits: distortion, touch switch, and a VHF FM voltage-controlled oscillator (VCO).

How it works

Figure 2 is the schematic diagram for the Guitar Transmitter. The plus and minus signs on the schematic near the potentiometer symbols indicate that clockwise rotation is from the minus sign towards the plus sign.

This circuit will produce both undistorted and distorted audio output. The undistorted output is produced by non-inverting amplifier IC1-*d* with a gain of:
R4/R5 + 1 = 68K/18K + 1 = 4.8.

Capacitor C1 blocks the DC components of the input signal, and resistors R2 and R3 form a voltage divider to bias the input of an LM324 operational amplifier IC1 at about half of its supply voltage of 9 volts. Resistor R1 sets the input impedance of the circuit to 1 megohm.

Capacitor C2 attenuates unwanted ultrasonic frequencies, while capacitor C3 lowers the impedance of the bias voltage at audio frequencies to yield a cleaner bias-voltage supply. Capacitor C4 performs the same function on the supply voltage for IC1.

The clean signal is then routed to IC2, a CD4066 CMOS quad bilateral switch, and is also amplified from 1 to 214 times by IC1-*a*, depending on the setting of DISTORTION control potentiometer R7. Resistor R6 and capacitor C5 establish a low-frequency roll-off (i.e., attenuation of low frequencies) of approximately 160 Hz.

To produce a distorted signal from IC1-*a*, three 1N4148 diodes, D1, D2, and D3 clip the amplified voltage at asymmetric levels of about Ø.7 volt and -1.4 volts, producing a distortion similar to that obtained with an overdriven vacuum-tube amplifier.

The distorted signal is then sent to the tone-control section centered around IC1-*b* where frequencies above about 1KHz are attenuated when TONE control potentiometer R10 is set full counter-clockwise (i.e., the wiper is at the non-inverting input of IC1-*b*. This stage amplifies frequencies above 1KHz when R10 is fully clockwise.

Resistor R8 and capacitor C6 form a low-pass filter that attenuates the high-frequency components of the clipped

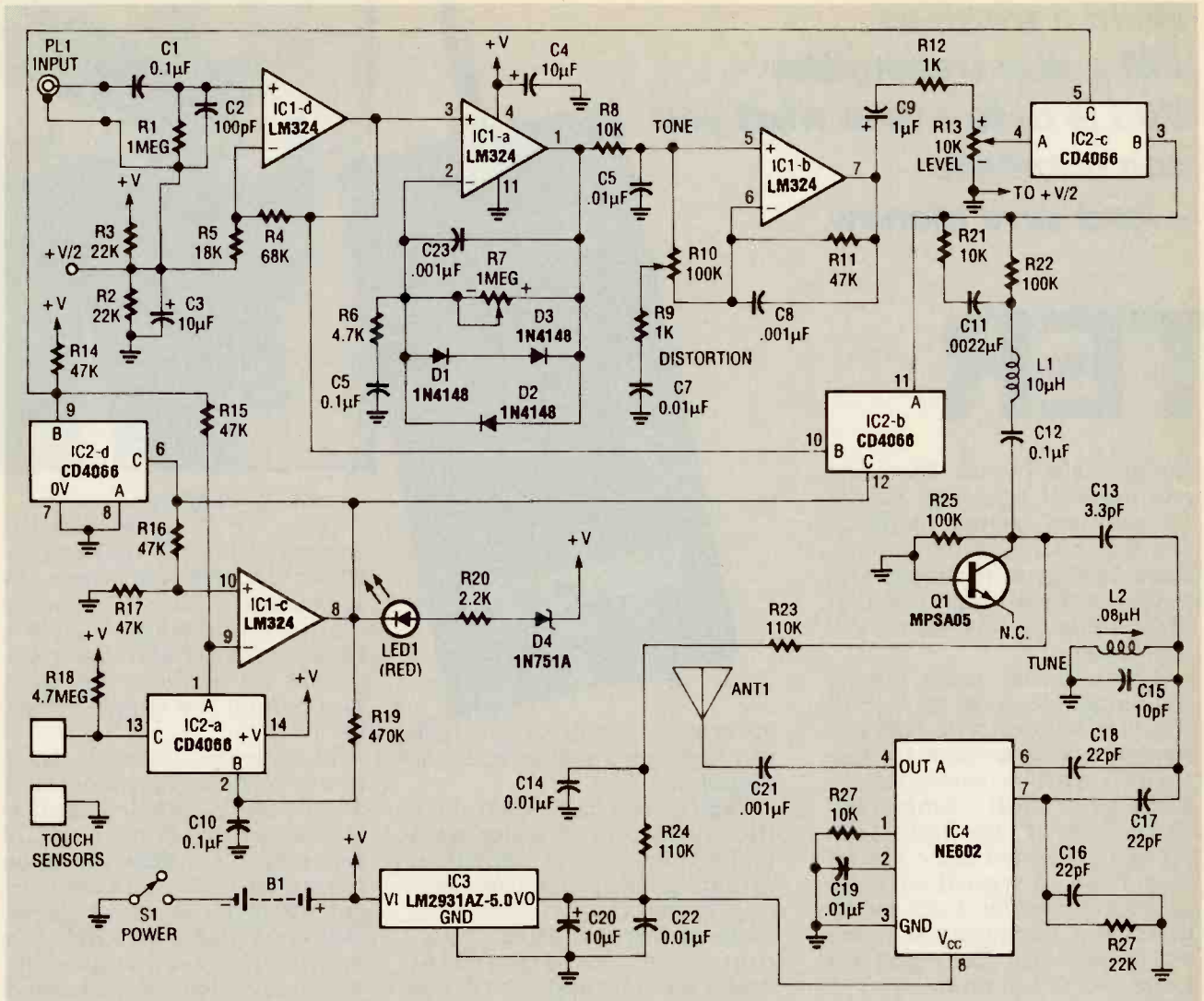


FIG. 2—SCHEMATIC FOR THE WIRELESS GUITAR TRANSMITTER. The touch sensors permit fingertip control of the sound.

waveform produced by IC-*a*. High-frequency roll-off for IC1-*b* is set by C8 and R11. The AC voltage gain is determined by resistors R9, R10 and R11.

The output level from IC1*b* is controlled by LEVEL control potentiometer R13. Capacitor C9 AC-couples R13 from the output of IC-*b*. Resistor R12 limits the maximum output voltage to prevent overmodulation of the transmitted carrier.

Touch control:

Two sections of IC2 switch between the clean and distorted signals. Sections *b* and *c* of IC2 are operated as complementary switches by the touch-control section of the transmitter. Operational amplifier IC1-*c* forms a voltage comparator with hysteresis produced by positive feedback resistor R16. The reference for this voltage comparator is set slightly higher than half the supply voltage by R16 and R17.

The entire comparator circuit performs a flip-flop function by combining an inverter IC2-*d* and R14 with low-pass filter R19 and C10. That filter has a time constant of 47 milliseconds to prevent false triggering and high- frequency oscillations.

To understand the operation of this flip-flop, assume that C10 is initially discharged, IC2-*a* is open, and IC1-*c* is in its true state (the voltage at the inverting input is less than at the non-inverting input; thus its output is at supply-voltage level). Capacitor C10 charges through R19 to a value higher than the reference voltage.

Now, if IC2-*a* were closed momentarily (pins 1 and 2 shorted), IC1-*c* would change state (i.e., output drops to zero volts). Resistor R15 provides the inverse of the output level of IC1-*c* from IC2-*d*, keeping IC1-*c* in static equilibrium. Then C10 discharges through R19 and once discharged, IC2-*a* closes momentarily, causing IC1-*c* to change state again.

This process causes a "push-pull" action, thus forming a "touch-on/touch-off" switch. In practice, the touch sensors will be shorted by a finger tip, causing control input pin 13 of IC2-*a* to be grounded, opening the switch.

The EFFECT/BATTERY LED1 lights only when the distorted sound channel is selected. Zener diode D4, resistor R20, and LED1 form a measuring cir-

cuit to indicate when battery voltage falls below about 7 volts. Replace the 9-volt battery if the *effect/battery* LED dims when the distorted sound channel is selected.

VHF FM oscillator:

The clean or distorted audio signal is fed into the VHF FM oscillator section of the transmitter. Resistors R21 and R22 and capacitor C11 form a pre-emphasis network to complement the de-emphasis network found in most FM receivers. The values chosen for this network attenuate frequencies below about 700 Hz to produce a "brighter" sound with a lot of "edge."

Low-power VHF mixer/oscillator forms an oscillator with an operating frequency of about 100 MHz, a frequency that can be adjusted across most of the FM broadcast band of 88 to 108 MHz by tuning variable coil L2.

Caution: It is unlawful to broadcast above or below the FM band with this transmitter. The oscillator is frequency modulated by using transistor Q1 as a varactor diode. The transistor's collector-to-base junction capacitance varies directly with the applied audio voltage.

The output of voltage regulator IC3 powers IC4 and supplies a stable DC bias for transistor Q1 through resistors R23, R24, and R25. Capacitor C14 and resistors R23 and R24 form a low-pass filter that prevents unwanted RF from affecting the DC bias supply. Capacitor C13 limits the capacitance change of transistor Q1 as seen by the inductor-capacitor tank tuning section made up of variable coil inductor L2 and capacitor C15.

Hence, C13 limits the frequency deviation of the FM carrier to a maximum of ±75 kHz in accordance with the Canadian Department of Communications (DOC) and the U.S. Federal Communication Commission (FCC) regulations. The VHF FM sinewave is generated by the inductive-capacitance tank section, and amplified and buffered by IC4. This signal is then AC coupled to the antenna by capacitor C21, which also helps to minimize antenna loading effect on IC4.

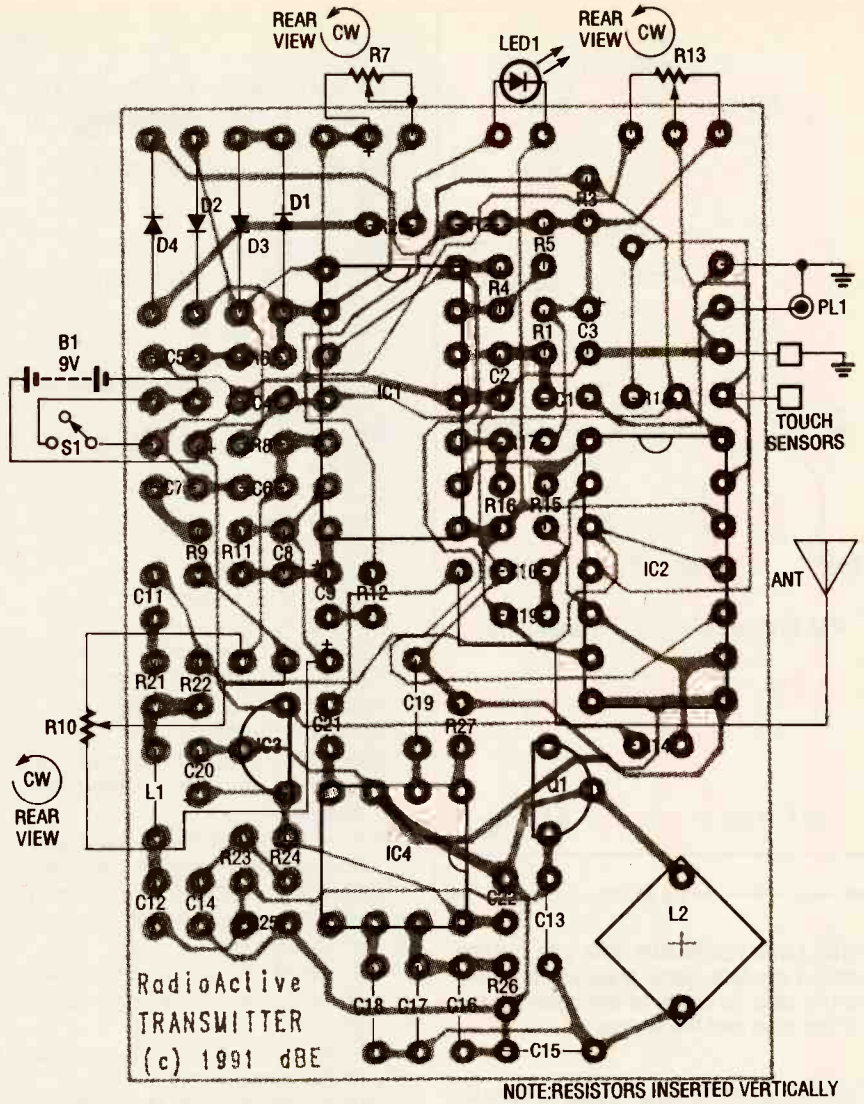
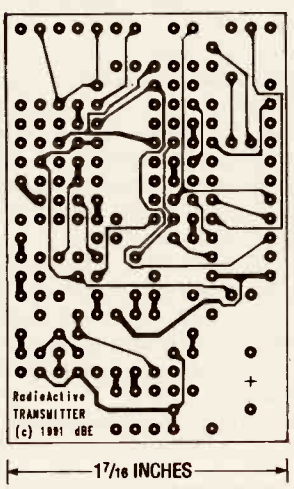
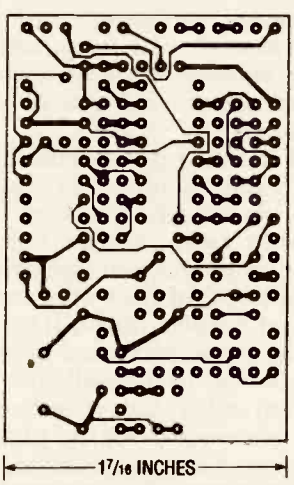


FIG. 3—PARTS PLACEMENT DIAGRAM for the wireless guitar transmitter. Three control potentiometers, the LED, and touch sensors are located on the case cover.



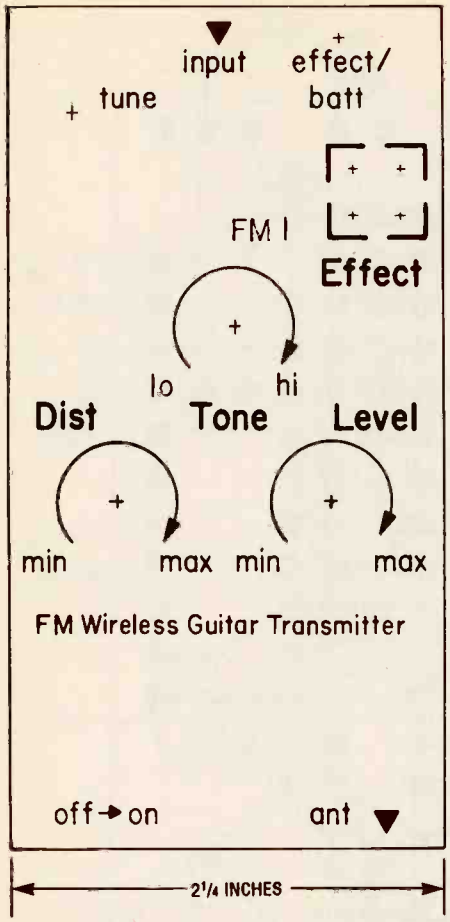
COMPONENT-SIDE FOIL PATTERN for the two-sided circuit board of the guitar transmitter.



SOLDER-SIDE FOIL PATTERN for the two-sided circuit board of the guitar transmitter.

Building the transmitter

Most of the components in the Guitar Transmitter are stan-



DRILLING TEMPLATE FOR THE COVER of the wireless guitar transmitter. Holes must also be made in the case for the input plug and the switch.

dard, off-the-shelf parts available from electronics retail stores and mail-order distributors. Although not surface-mount, the components were selected to conserve PC board space and miniaturize the circuitry.

All resistors are specified as ⅛-watt, metal-film units because they generally produce less noise in audio circuits than carbon-composition or carbon-film resistors, and they are smaller. Radial-leaded monolithic ceramic capacitors were selected because of their small size, and dipped solid tantalum capacitors were specified in place of aluminum electrolytics for 1-microfarad and 10-microfarad values to save space. Moreover, since tantalum capacitors retain their rated capacitance values at higher frequencies better than aluminum electolytics, they do a better job of filtering out stray radio frequency (RF) noise from the power supply.

PARTS LIST

All resistors are ⅛-watt, 5%, unless otherwise specified.
R1—1 megohm
R2, R3, R26—22,000 ohms
R4—68,000 ohms
R5—18,000 ohms
R6—4,700 ohms
R7—1 megohm miniature potentiometer
R8—10,000 ohms
R9—1000 ohms
R10—100,000 ohms miniature potentiometer
R11, R14, R15, R16, R17—47,000 ohms
R13—10,000 ohms miniature potentiometer
R12—1000 ohms
R18—4.7 megohms
R19—470,000 ohms
R20—2,200 ohms
R21, R27—10,000 ohms
R22, R25—100,000 ohms
R23, R24—110,000 ohms

Semiconductors
IC1—LM324N quad low-power operational amplifiers, Motorola or equivalent
IC2—CD4066BCMOS quad bilateral switch, Harris or equivalent
IC3—LM2931Z-5.0 low-dropout voltage regulator, 5-volt, Motorola or equivalent
IC4—NE602Nlow-power VHF mixer/oscillator, Signetics or equivalent
Q1—MPSA05 NPN transistor National or equivalent
D1, D2, D3—1N4148 fast-switching diode
D4—1N751A Zener diode, 5.1-volt, 500 mW
LED1—light-emitting diode, general purpose, T1 case size, red

Capacitors
C1, C5, C10, C12—0.1 µF ceramic monolithic , radial-leaded, 10%
C2—100 pF, ceramic disc, 10%
C3, C4, C20—10 µF, tantalum, solid dip, 10%, 10 volts
C6, C7, C14, C19, C22—0.01 µF ceramic monolithic, 10%,
C8, C21, C23—0.001 µF ceramic monolithic, radial leaded, 10%
C9—1 µF tantalum, solid dip, 10%, 10 volts
C11—0.0022 µF, polyester film, 5%
C13—3.3 pF ceramic Philips 09338 or equivalent
C15—10 pf ceramic, Philips 10109 or equivalent
C16, C17, C18—22 pF ceramic, Philips 10229 or equivalent

Inductors
L1—10 µH, fixed, 5% Toko FL-4 or equivalent
L2—0.08 µH variable molded, Q = 130 @ 100 MHz, Toko MC-120 or equivalent

Other components
B1—battery, 9-volt, alkaline transistor
S1—switch, subminiature slide, SDPDT
PL1—input plug, ¼-inch, mono phone

Miscellaneous: double-sided printed circuit board, 9-volt battery clip, plastic project case with cover with inside dimensions of 4 ¼ × 2⅛ × 1⁹⁄₁₆-inch deep, three miniature black knobs, 28 AWG stranded, black-insulated hookup wire, multicolored ribbon cable, plastic coil alignment tool, solder, epoxy cement, RTV silicone adhesive.

Note:The following parts are available from RadioActive Transmissions, P.O. Box 6714, Station "A", Toronto, Ontario, M5W 1X5 Canada, Sales Office: Axxon, (519) 974-0163, Fax (519) 974-0165.

- **Kit 1 for FMI—complete kit of all parts including double-sided PC board, plastic coil alignment tool, and screened predrilled case—$39.95 plus $5.00 shipping and handling.**

- **Assembled and tested unit $54.95 plus $5.00 shipping and handling. Please send U.S. money order only. Canadian residents please call for prices. Other countries add additional $5.00 for shipping. All prices in U.S. funds.**

Assembled and tested RAFMII $64.95, Kit 2 for RAMFMII (higher power professional use, beltpack model) $49.95.

Board assembly:

The Guitar Transmitter will perform better if it is built on the double-sided printed-circuit board designed for it. Both component- and solder-side foils are included in this article if you want to make your own boards. Notice, however, that plated-through holes are recommended so that you do not have

to solder leads on both sides of the board to assure a sound solder joint. If you do not want to make the board yourself you can purchase a finished circuit board from the source listed in the Parts List or build the circuit on perforated board.

You can obtain the full performance capabilities of the circuit with perforated board if you are aware of the possible pitfalls in building an RF circuit on that substrate—and take extra care in placing components and dressing wires. Nevertheless, the use of perforated circuit board stock is not recommended.

When building the transmitter, refer to schematic Fig. 2 and Parts Placement diagram Fig. 3. Follow standard practice in inserting the components and soldering them in place. Use a grounded, 15- to 30-watt, pencil-type soldering iron, especially for soldering the semiconductor devices to avoid damaging or destroying the devices with excess heat or electrostatic discharge (ESD).

There is a choice of three different values for capacitor C15 because the tuning coil L2 for this transmitter has a high Q (130 at 100 MHz). The letter Q stands for quality factor—a reference to the ability of the circuit to present a well defined oscillator frequency. The higher the resolution, the smaller the tuning range if the range of the tuning slug is limited to the length of the coil body.

Variable coil L2 specified in the Parts List has a tunable frequency limit of about 15 MHz. Because the FM broadcast band spectrum is 20 MHz wide (from 88 to 108 MHz), select one of three standard values for C15:

- 10 picofarads gives a tuning range 15 MHz wide centered at approximately 98 MHz. (The ends of the FM broadcast band can be obtained with slightly higher or lower values for C15.)
- 12 picofarads permits tuning in the lower end of the band.
- 8.2 picofarads permits tuning in the upper end.

The exact tuning range obtained will vary with each transmitter because of the parasitic capacitance and inductance introduced by the interconnecting wires.

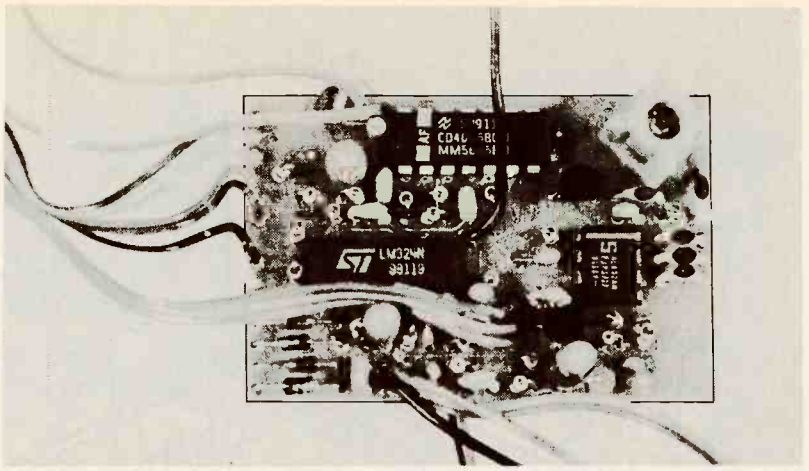


FIG. 4—PHOTO OF THE COMPLETED guitar transmitter circuit board showing wiring to off-board components. Note the star-shaped tuner body.

Do not use IC sockets for any of the ICs because all lead lengths must be kept as short as possible. The components can be inserted and soldered in any order, but it is a good idea to check off each part on the Parts List after you insert and solder it.

Observe all polarities shown on the schematic for the diodes and tantalum capacitors. Mount all resistors vertically, and mount all capacitors flush against the circuit board. After soldering, trim all lead lengths as short as possible to reduce stray noise pick-up in the audio-frequency section of the transmitter.

Antenna length

Cut a 38.2 centimeter (15.3-inch) length of black stranded 28 AWG insulated hookup wire for the antenna. Trim one end and solder that end in position as shown in Fig. 3. The Guitar Transmitter operates at 98.00 MHz, so one wavelength equals 3.0612 meters.

Transmitted signal strength is generally proportional to antenna length up to one wavelength, but if its length is more than 76 centimeters (30 inches) the transmitted carrier will exceed the maximum allowable signal strength level specified by the DOC and FCC regulations. That's why the 38.2 centimeter antenna length was selected for this transmitter.

Mechanical assembly

After all of the components are inserted and soldered on the PC board, refer to exploded assembly drawing Fig. 4 as well as the Parts Placement diagram Fig. 3 for the location and orientation of off-board components. If you purchase the case and cover from the source given in the Parts list, all holes will be drilled.

If you elect to provide your own case, use the cover template provided to drill:

- Three control potentiometer mounting holes.
- Four 3/32-inch holes for the touch sensor.
- One 1/16-inch hole for access to tuner L2.
- One 3/32-inch hole for LED1.

Then drill a 0.39-inch diameter hole centered in the end wall of the case for plug PL1, taking care that the plug fits snugly. (The plug will be the sole support for the completed transmitter when it is plugged into the guitar, so it is important that it be rigidly mounted.)

Finally, cut a slot in the opposite end wall of the case for switch S1, and drill one or two holes beside the slot, as necessary, for fastening the switch to the case. With a hacksaw, cut a slot about 1/16-inch deep in the end wall of the case near the switch slot for the antenna wire to permit it to pass under the cover without interference when the cover is closed.

Assemble the touch sensor from four 1/4 inch, No. 4-40 Phillips-head screws with match-

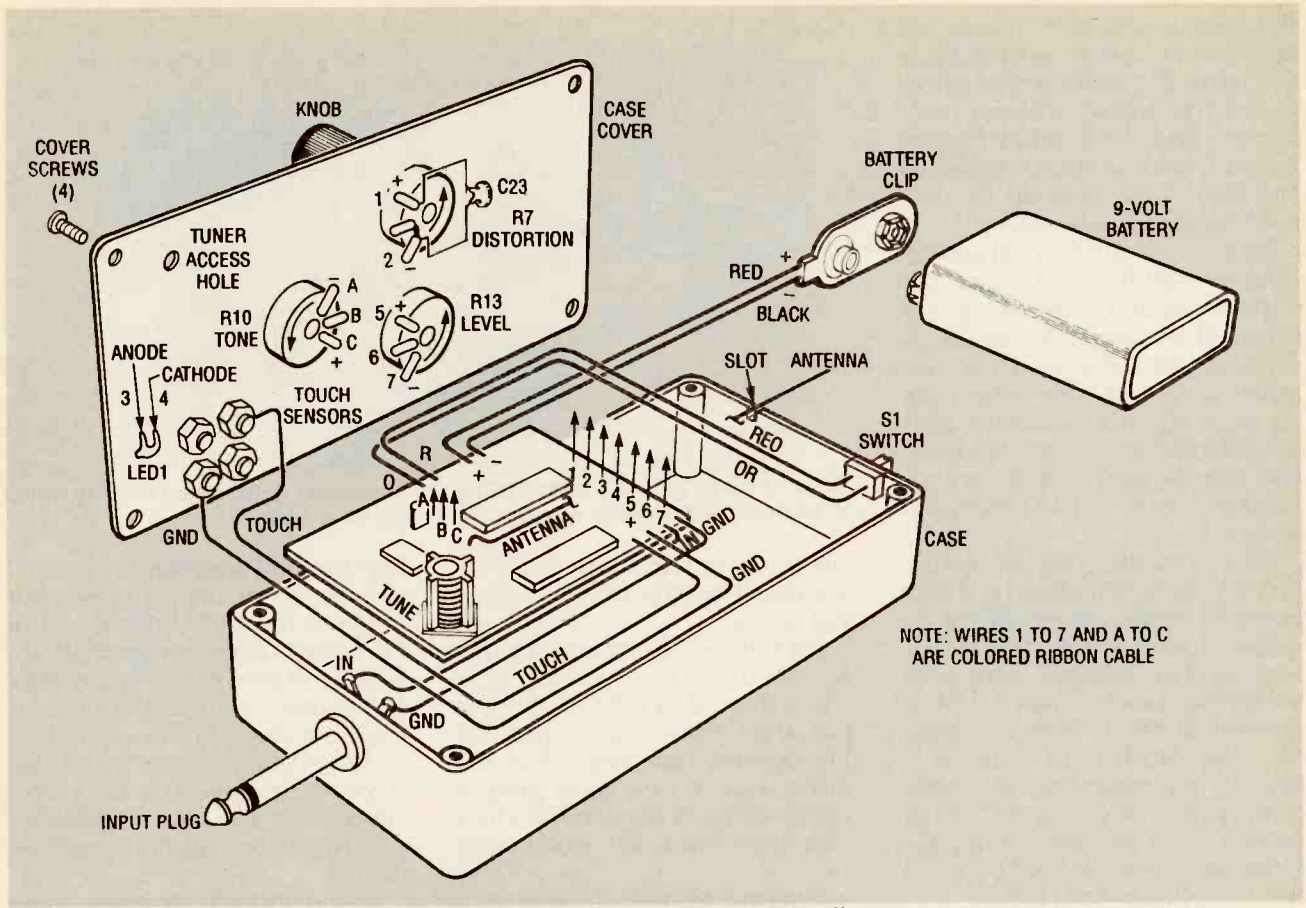


FIG. 5—EXPLODED VIEW OF THE TRANSMITTER showing the locations of the off-board components and wiring. The input plug attaches the transmitter to the guitar.

ing nuts. (Two of the four nut-bolt combinations will be non-functional.) However, be sure that the two to be wired as active sensor elements are electrically isolated.

Assemble the three miniature control potentiometers R7, R10 and R13 to the underside of the cover with the ring nuts provided, orient their terminals as shown as shown in Fig. 4, and tighten the nuts. Insert plug PL1 and secure it in position with its nut. Insert switch S1 in the case and fasten it with one or two rivets or self-tapping screws.

Off-board wiring

Cut 6- to 7-inch lengths of standard multicolored ribbon cable (28 AWG 7×36 stranded tinned copper), strip about 1/16-inch of insulation from the ends, and insert one set of wires in the board and solder them in position. (As many as ten wires can remain bonded together for most of their length if they are separated only near top and bottom to permit making the connections.) Then crimp the bared ends of the off-board wires around the lugs of the potentiometers, and the leads of the LED and plug before soldering:

- The terminal lugs of potentiometers R7, R10, and R13 (as shown in Figs. 3 and 4): 8 wires.
- Light-emitting diode (LED1): 2 wires.
- Input plug PL1: 2 wires.

Insert capacitor C23 between the terminals of potentiometer R7. (It reduces the possibility of audible feedback in the high-gain distortion stage.) Solder all wires to the potentiometer lugs and the leads of LED1.

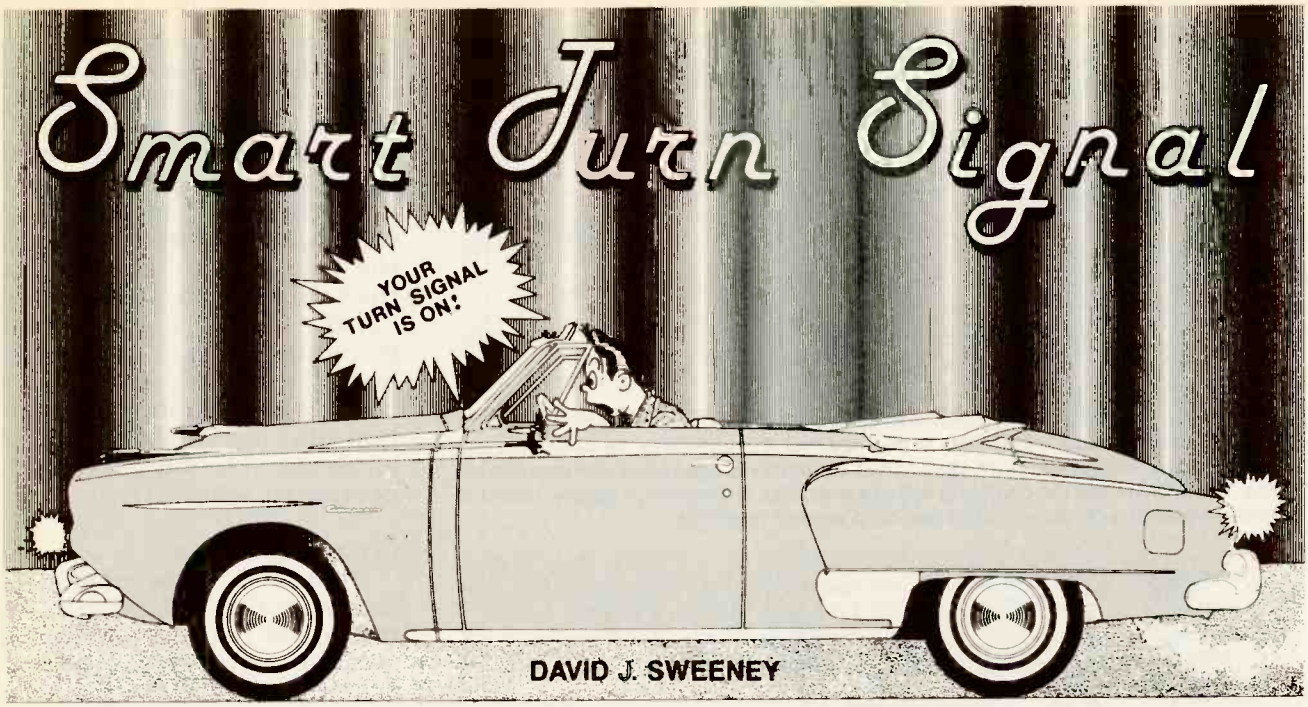
Loosen two of the touch -sensor nut-bolt combinations, and wind one turn of the bare end of the "ground" wire around one of the screws and one turn of the bare end of the "touch" wire around the other screw. Then tighten both nuts to clamp the wire ends securely in place.

Cut, and strip the ends of about 3-inch lengths of the red and black battery-clip wires. and solder them to the PC board. Bend the leads of LED1 90°, insert the LED in the drilled hole in the cover, and cement it in position with epoxy cement. Carefully check all wiring to be sure that you have made no mistakes, and make any corrections necessary.

Position the circuit board as shown in Fig. 4, being certain that the top of inductor L2 is aligned under the access hole drilled in the cover. Apply one drop of RTV silicone (or other appropriate adhesive) to each of the four corners of the circuit board on the solder side, and position the board correctly in the bottom of the case. Also place a drop of adhesive in the slot for the antenna wire cut in the edge of the case, and position the wire in the slot to keep it in position. Allow time for all adhesives to set.

Snap a fresh 9-volt alkaline transistor battery to the battery clip. Check to see that the EFFECT/BATTERY LED lights when you bridge the screw

(Continued on page 108)



Avoid potential road hazards, as well as potential embarrassment, with the Smart Turn Signal.

EVERYONE WHO DRIVES A CAR OCcasionally forgets to shut off the turn signal. That sends the wrong message to other vehicles and could cause an accident. At the very least, other drivers will assume that there's an idiot at the wheel of a car whose turn signal continues flashing long after the turn has been made. An electronic turn-signal alert, able to remind the driver that his turn signal is continuing to flash, could prevent an accident or at least save the driver some embarrassment.

We have a circuit that is sure to be welcomed by drivers worldwide. It sounds a warning signal whenever a blinker has been left on for more than 15 seconds. If, however, a blinker is left on while the driver is waiting to make a turn, that warning signal would become more annoying than helpful. In that case the Smart Turn Signal remains silent. Also, when the warning signal sounds, it starts off softly, and then gets louder, in the event that road noise prevents the driver from hearing the alarm.

The Smart Turn Signal, or STS, is easy to install in any car because it connects only to the contacts on a typical automotive flasher and to the brake-pedal switch—one need not interfere with the car's wiring.

A typical flasher

Figure 1 shows a representative schematic for a typical automotive flasher. When you operate the turn signal, the heating element and 50-ohm resistance wire are connected in series with the turn-signal lamps. With a 50-ohms resistor in series, the lamps will not light. As current passes through the heater element it warms up, heating the bimetallic contacts which then close (the clicks you normally hear from a flasher), bypassing the resistance wire and heater. That's when the turn signal lamps are lit. The bypassed heater element then cools, allowing the bimetallic contacts to open, reconnecting the heater and resistor wire in series with the bulbs. The process repeats as long as the flasher remains connected in the circuit through the driver's turn-signal control switch. To add delayed, dynamically varying sound to the turn signals, you can add the Smart Turn Signal circuit to a standard flasher circuit.

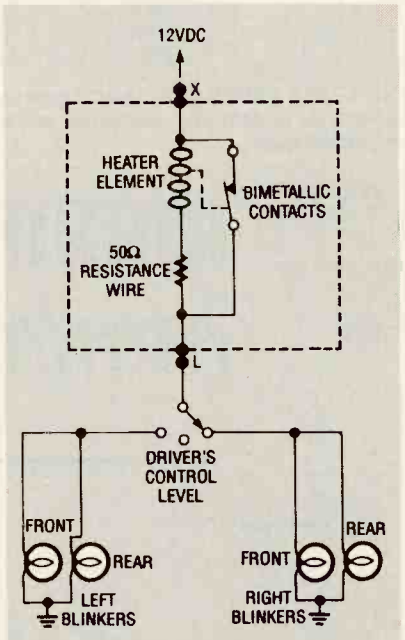


FIG. 1—A TYPICAL AUTOMOTIVE flasher. Initially the heating element and a 50-ohm resistance wire are in series with the turn signal lamps so they do not light. When the heater element warms up, the bimetallic contacts close and bypass the resistance wire and heater, allowing the lamps to light. The bypassed heater element then cools, allowing the bimetallic contacts to open.

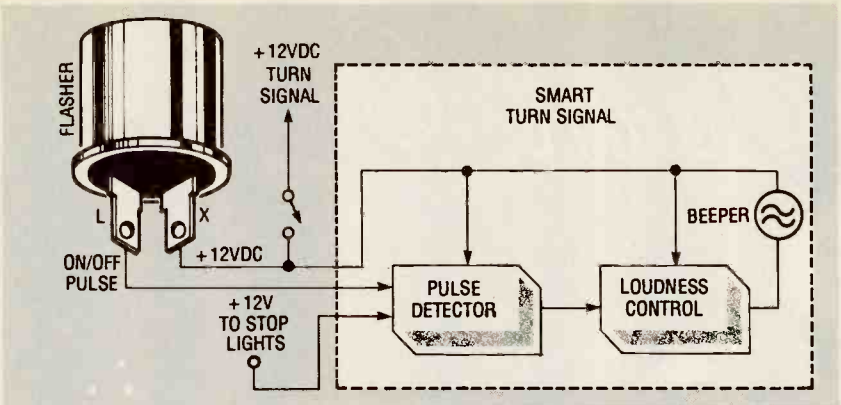


FIG. 2—Flasher terminal L connects to the load and X connects to the 12-volt supply. When the driver engages the turn signal, the L terminal voltage varies with the blinking lights. The STS senses the changing voltage and, after 15 seconds, it applies power to a buzzer through a current-limiting device to control loudness.

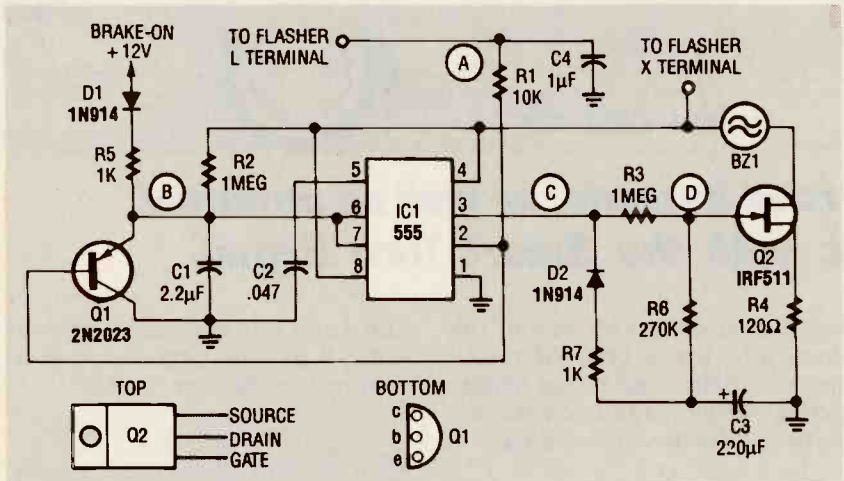


FIG. 3—STS SCHEMATIC. The Q2 gate voltage increases with the charge on C3. After 15 seconds of charging, the buzzer will warble. As the charging continues, the sound will grow louder.

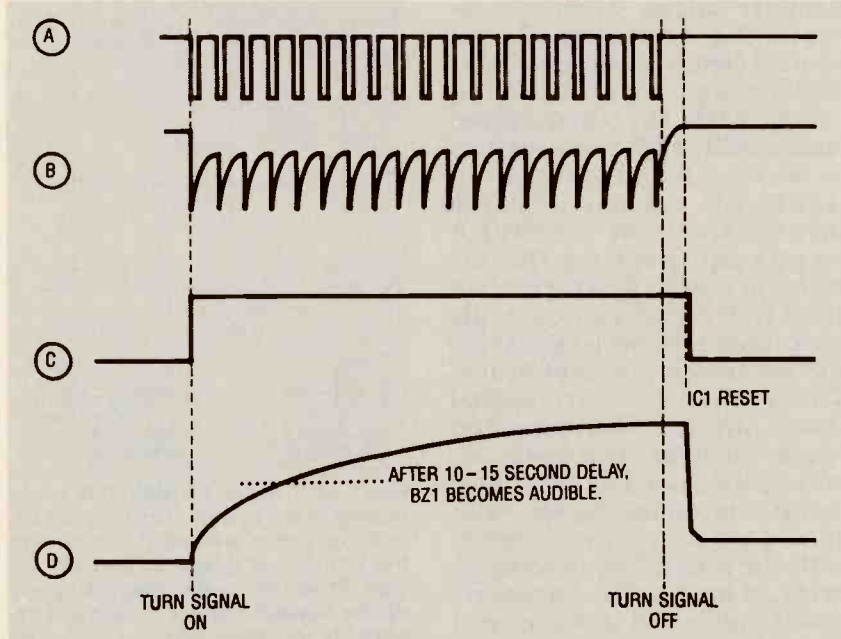


FIG. 4—CIRCUIT WAVEFORMS. Point A shows the signal from the flasher. The voltage at point D will increase as long as the pin-3 output of IC1 (point C) remains high. The C1-R2 time constant (point B) determines how long the output will be high.

Figure 2 shows how the STS and flasher work together. Flasher connections are usually labeled L and X, where L connects to the load and X connects to the vehicle's 12-volt supply. The L connection remains at 12 volts until the driver engages the turn signal. The voltage then varies with the blinking lights. The STS senses that changing voltage, unless the brake is applied, and applies power to a buzzer through a current-limiting device to control loudness. The buzzer's loudness varies with current.

Circuit operation

Figure 3 is the schematic diagram for the STS. In order for the buzzer (BZ1) to sound, Q2 must be turned on. As the voltage at point D (Q2's gate) increases, the current through BZ1 increases, with a resulting increase in loudness. The Q2 gate voltage increases with the charge on C3. To charge C3, pin 3 of IC1, a 555 timer, switches from low to high when the first pulse from the turn signal is applied to pin 2 of IC1. With the values shown for R3 and R6, the initial voltage at Q2's gate will be nearly sufficient to sound the buzzer. After C3 charges for 15 seconds, the voltage will be high enough for the buzzer to warble and, as the charging continues, the sound will grow louder.

Figure 4 shows some of the waveforms at various points in the circuit. Notice that the voltage at point D continues to increase as long as the pin-3 output of IC1 remains high. When the output goes low, C3 rapidly discharges through D2. The 555 timer (IC1) operates as a one-shot multivibrator, where a negative going input to pin 2 causes pin 3 to go high, until C1 charges through R2. The C1-R2 time constant determines how long the output would be high, and is set to about 2 seconds with the values shown. To keep the 555 output high, transistor Q1 operates as a missing-pulse detector (see **Electronics Now**, November, 1992). While the first negative pulse from the flasher sets pin 3 of IC1 high, later pulses turn on Q1, which shorts

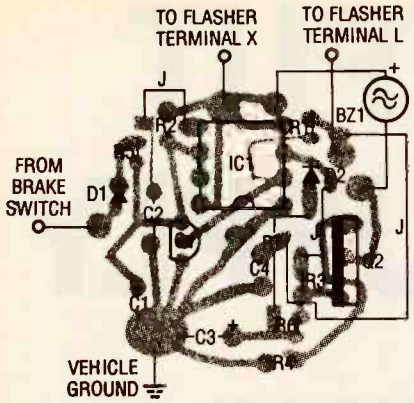
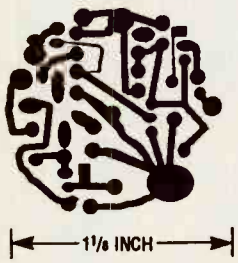


FIG. 5—PARTS-PLACEMENT DIAGRAM. You must make your own circuit board if you want to use one, as they are not for sale. Otherwise use perforated construction board.



STS FOIL PATTERN.

C1 and restarts the charging cycle. As long as the turn signal operates, the pulses continue to keep C1 discharged and pin 3 high.

When the driver's foot is on the brake pedal, 12 volts is applied to the anode of D1. Capacitor C1 then quickly charges through R5, resetting IC1 after every turn-signal pulse, and the buzzer does not sound.

Packaging

The STS circuit can be assembled on one small PC board. We've provided the foil pattern in case you want to make your own. See the parts-placement diagram in Fig. 5. All parts are mounted vertically on the board. Also note that a few jumpers, marked "J," must also be installed on the component side of the circuit board; use insulated wire for the jumpers to avoid any possible shorting on the small board.

Because this project will be operating in your motor vehicle, extreme care should be taken to produce a reliable, quality device. A failure could result in annoying beeping or in a short circuit to the turn-signal flasher. To package the unit, use a solid, weather-tight case, such as the 35 mm film canister shown in Fig. 6. The cylindrical packaging takes advantage of the size and shape of standard turn-signal flashers, which fit snugly in plastic 35 mm canisters. The STS PC board is also circular, and sized to fit inside a film canister. The buzzer is mounted on the base of the film can.

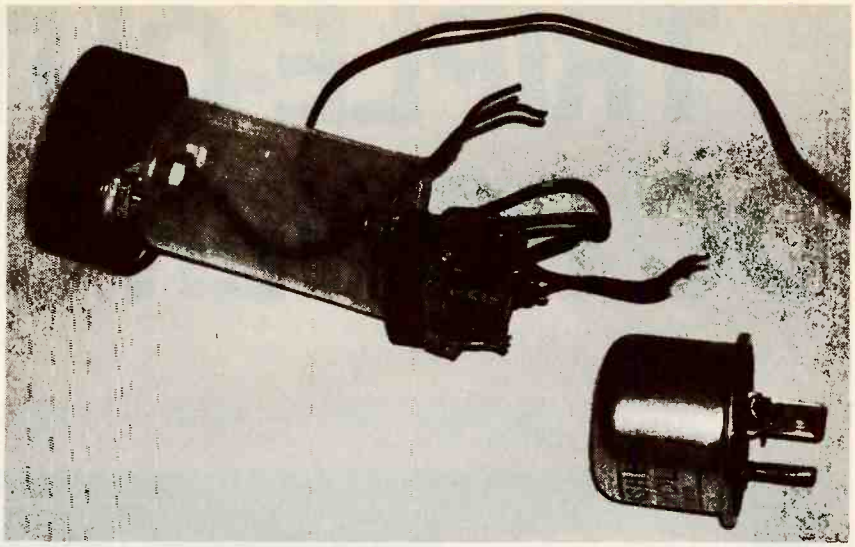


FIG. 6—YOU CAN PACKAGE THE UNIT in a 35 mm film canister which takes advantage of the size and shape of standard turn-signal flashers, as well as the STS PC board.

FIG. 7—THE STS FLASHER plugs into the original flasher socket.

PARTS LIST

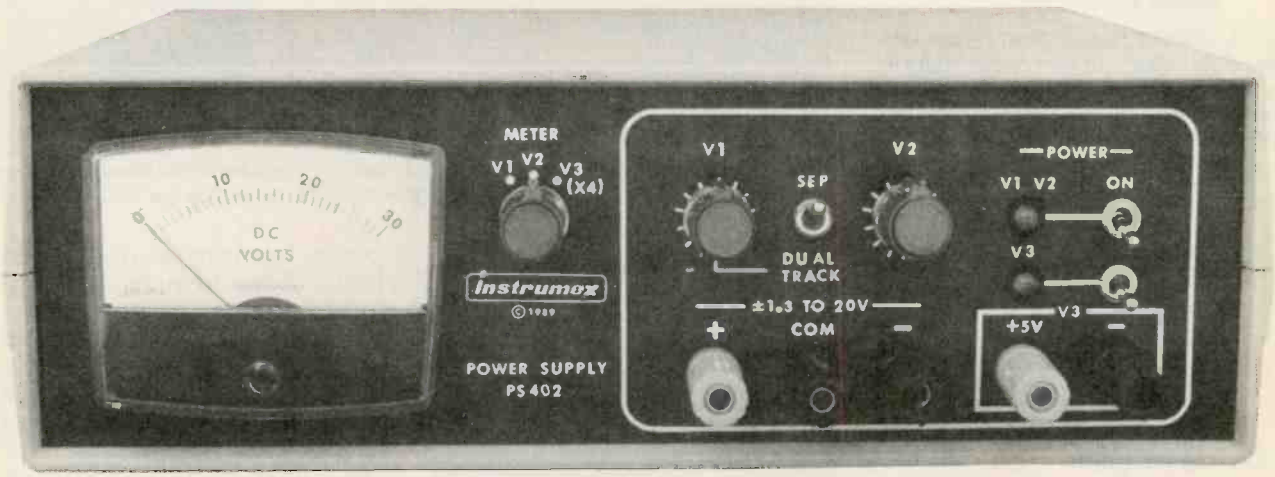
All resistors are ¼-watt, 5%.
R1—10,000 ohms
R2, R3—1 megohm
R4—120 ohms
R5, R7—1000 ohms
R6—270,000 ohms
Capacitors
C1—2.2 µF, electrolytic
C2—0.047 µF
C3—220 µF, electrolytic
C4—1 µF, electrolytic
Semiconductors
IC1—555 timer
D1, D2—1N914 diode
Q1—2N2023 PNP transistor
Q2—IRF511 FET
Other components
BZ1—Piezoelectric buzzer (Radio Shack RS273-066 or equivalent)
Miscellaneous: PC board, turn-signal flasher, 35 mm film canister or other suitable case, wire, solder.

Drill the holes in the film can for the wires. Make all connections to the flasher directly to the prongs, as close to the body of the flasher as possible. A separate ground wire will be necessary. If your car has a three-prong flasher, one prong will provide a ground connection.

It should take only a few minutes to install the STS flasher in your car. It plugs into the original flasher socket as shown in Fig. 7. If the STS fails to work when installed, switch the wires connected to the flasher prongs.

If, when you go to install the smart turn signal in your car, you find that it's too tight under your dashboard to fit the entire unit as one assembly, simply run leads to the flasher terminals and mount the rest of the unit wherever you find room. Just make sure the circuit is well protected and mounted where it won't interfere with anything else. Ω

TRIPLE-OUTPUT DC POWER SUPPLY



Build a triple-output power supply—a power source you'll find quite useful around the home and shop.

JOHN F. KEIDEL

A DC POWER SUPPLY IS REQUIRED for nearly all electronic circuits. Some circuits are passive and don't need a power supply, and others draw power from some other source. However, all stand-alone active circuits need a power supply. It is difficult to find an off-the-shelf benchtop power supply that's both versatile and inexpensive—that's why you want to build it yourself. If you are looking for a multiple-output, bench-type power supply, look no further.

The power supply in this article features metered voltages on all sources, vernier controls (based on 10-turn potentiometers) on its plus and minus 1.3- to 20-volt outputs, and separate adjustments or dual-tracking operation for those same supplies. It also has a precise, fixed 5-volt logic supply that's completely independent of the variable supplies.

This triple-output power supply boasts exceptional line regulation: less than 1 millivolt output change for a 10% change in line voltage. Ripple and noise figures are less than 1 millivolt peak-to-peak at full-load. The maximum current available at each of the variable outputs is 200 milliamperes, and the fixed 5-volt supply can output 300 milliamperes.

Design considerations

Preregulator circuits precede the output regulators on all three supplies. The preregulators dissipate heat and maintain the voltage across the output regulators at a constant 3 volts. Also, a 30- to 40-milliampere thermal-stabilizing current is drawn by all supplies. That improves load regulation, and keeps the voltage-reference element contained within each output regulator at a constant temperature. The normally high heat dissipation of the regulators is greatly reduced by the preregulators.

Circuit operation

Figure 1 is the schematic of the positive and negative variable supplies; look at the positive supply. Tracking preregulator IC1, an LM317T, maintains a constant 3-volt drop across output-regulator IC2. The preregulator works as follows: Resistor R1 in conjunction with IC1's internal reference voltage (1.25 volts) causes a specific current to flow through R2 which, in turn, drops 1.7 volts across it. Those two voltages added together equal approximately 3

volts, which always appears across IC2.

Regulator IC2 establishes a programming current (1.25 volts divided by R3) that flows through front-panel control R18 (a 10-turn potentiometer), which thereby sets a positive output voltage equal to the adjustable drop across R18 plus the 1.25-volt reference. Resistor R4 provides the thermal-stabilizing current that was previously explained.

Capacitor C4 improves output ripple rejection. Capacitors C2, C3, and C5 bypass and stabilize their respective regulators by preventing spurious oscillations.

Regulator IC2 is protected from capacitive discharges caused by short circuits external to the supply. Diode D2 prevents C4 from discharging through IC2 by providing an alternate path.

Dual tracking keeps the positive and negative variable outputs at the same voltage level, but with opposite polarities. The dual-tracking function is made possible by IC5, a TLO71 JFET op-amp configured as an inverting amplifier. In that configuration, IC5 tries to adjust its output so that both input voltages are equal. Since pin 3 of IC5 is tied to ground, it will therefore adjust its output in an attempt to make pin 2 equal to 0 volts.

Note that regulator IC4 is contained within the negative feedback loop of IC5 when S3 is in the DUAL TRACK position. Resistor R20 is the input to the IC5 inverting amplifier and R21 is its feedback resistor. Set up that way, IC4 automatically adjusts its output so that the voltage at the R20-R21 junction (pin 2 of IC5) is at 0 volts, thus matching the voltage at pin 3 of IC5. Because the value of R20 is equal to R21, and because the voltage at pin 2 of IC5 should equal 0 volts, IC4's output must match IC2's output, but with opposite polarity.

In the dual-tracking mode, R18 controls both output voltages. When switch S3 is in the SEPARATE position, R19 controls the negative voltage output while R18 still controls the positive output.

Because the circuit arrangement and operation of both the negative variable supply and the 5-volt logic supply shown in Fig. 2 are virtually the same as those for the positive supply, operating details of those two supplies will not be given. Note, however, that the 5-volt supply has a different ground (and ground symbol on the schematic) than the variable supplies.

Figure 3 shows the meter circuit. Switch S4 selects the output voltage to be displayed on the meter, and also handles the polarity and switches in the appropriate multiplier resistor (R24 to R26). Resistor R23 compensates for variations in different meters. Note that the ground connections for the bipolar supply and the logic supply are independent of each other, so unlike symbols are used in Fig. 3.

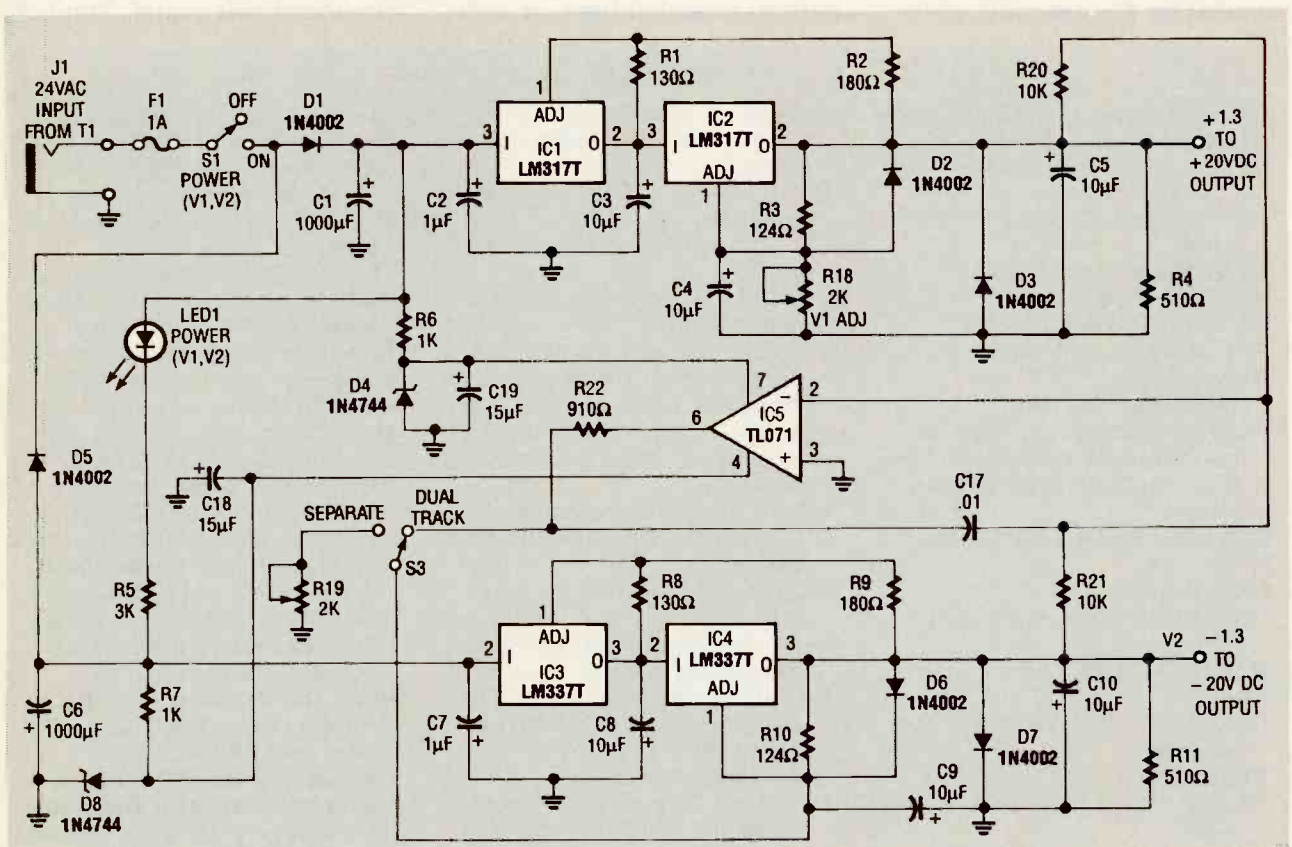


FIG. 1—SCHEMATIC DIAGRAM of variable bipolar 20-volt supplies. Switch S3 controls the dual-tracking option.

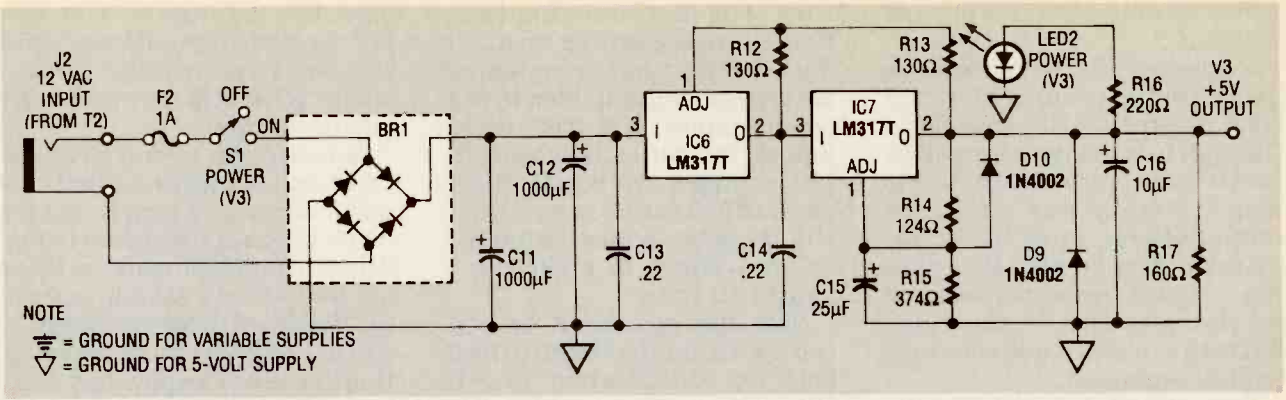


FIG. 2—FIVE-VOLT SUPPLY. The operation of this circuit is similar to the variable supplies, although it has a separate ground.

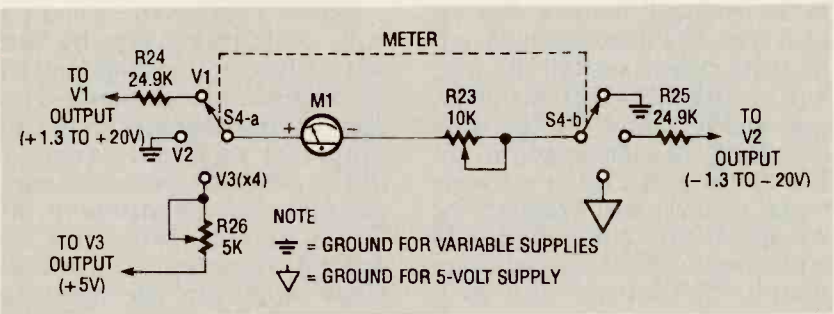


FIG. 3—METER CIRCUIT. This circuit allows the meter to display the output voltage.

Construction

A PC board is strongly recommended for the assembly of the power supply. You can make your own board using the foil pattern provided here, or order one from the source given in the Parts List. Mount all components as shown in parts-placement diagram Fig. 4. Check to see that all diodes, the bridge rectifier, and electrolytic and tantalum capacitors are positioned with the proper polarity before soldering them. A socket is recommended for IC5.

If the PC board is mounted in the recommended case, mounting bosses are provided as an integral part of the case. However, if you use a metal case rather than a plastic one, make sure the heatsinks don't touch the metal side panel. Similarly,

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.

R1, R8, R12, R13—130 ohms
R2, R9—180 ohms
R3, R10, R14—124 ohms, 1%, metal film
R4, R11—510 ohms, 2 watts
R5—3000 ohms, 2 watts
R6, R7—1000 ohms, 2 watts
R15—374 ohms, 1%, metal film
R16—220 ohms
R17—160 ohms, ½ watt
R18, R19—2000 ohms, 10-turn cabinet-mounted potentiometer (Digi-Key 73JB202-ND or equivalent)
R20, R21—10,000 ohms, 1%, metal film
R22—910 ohms
R23—10,000 ohms, PC-mount potentiometer
R24, R25—24,900 ohms, 1%, metal film
R26—5,000 ohms, PC-mount potentiometer

Capacitors

C1, C6—1000 µF, 50 volts, electrolytic
C2, C7—1 µF, 50 volts, tantalum
C3–C5, C8–C10, C16—10 µF, 35 volts, tantalum
C15—25 µF, 25 volts, tantalum
C11, C12, 1000 µF, 25 volts, electrolytic
C13, C14—0.22 µF, 50 volts, ceramic disc
C17—0.01 µF, 50 volts, ceramic disc
C18, C19—15 µF, 35 volts, tantalum

Semiconductors

IC1, IC2, IC6, IC7—LM317T adjustable positive regulator Motorola or equivalent
IC3, IC4—LM337T adjustable negative regulator Motorola or equivalent
IC5—TL071 JFET-input op-amp
D1–D3, D5–D7, D9, D10—1N4002 diode
D4, D8—1N4744 15-volt, 1-watt zener diode
LED1, LED2—red panel-mount light-emitting diode
BR1—Bridge rectifier, 1-amp, 50-volt (Digi-Key DB101-ND, or equivalent)

Other components

M1—15-volt DC panel-mount meter (Radio Shack 270-1754, see text)
J1, J2—Coaxial power-input jack (Radio Shack 274-1563 or equiv.)
S1, S2—Panel-mount SPST switch
S3—Panel-mount SPDT switch
S4—Panel-mount, 2-pole, 3-position rotary switch (Mouser Electronics 10WA155 or equivalent)
F1, F2—1-amp, 120-volt slow-blow fuse
T1—120 to 24 VAC wall transformer with female plug (Jameco Electronics AC2410 or equivalent)
T2—120 to 12 VAC wall transformer with female plug (Jameco Electronics AC1210 or equivalent)
Miscellaneous: project case (Jameco Electronics H2507), five binding posts, three instrument knobs, four 5-watt heat sinks (for IC2, IC4, IC6 and IC7, Digi-Key HS116-ND); two 10-watt heatsinks (for IC1 and IC3, Digi-Key HS114-ND), one 6-pin IC socket, two fuse holders, two LED sockets, wire, solder, hardware.

Note: The following is available from Instrumex, PO Box 490, Blue Bell, PA 19422:

- **Ready-to-use PC board and silkscreened plastic front panel, both to fit case noted above—$23.00 + $2.00 S&H**

PA residents include 6% sales tax. Allow -4 weeks for delivery.

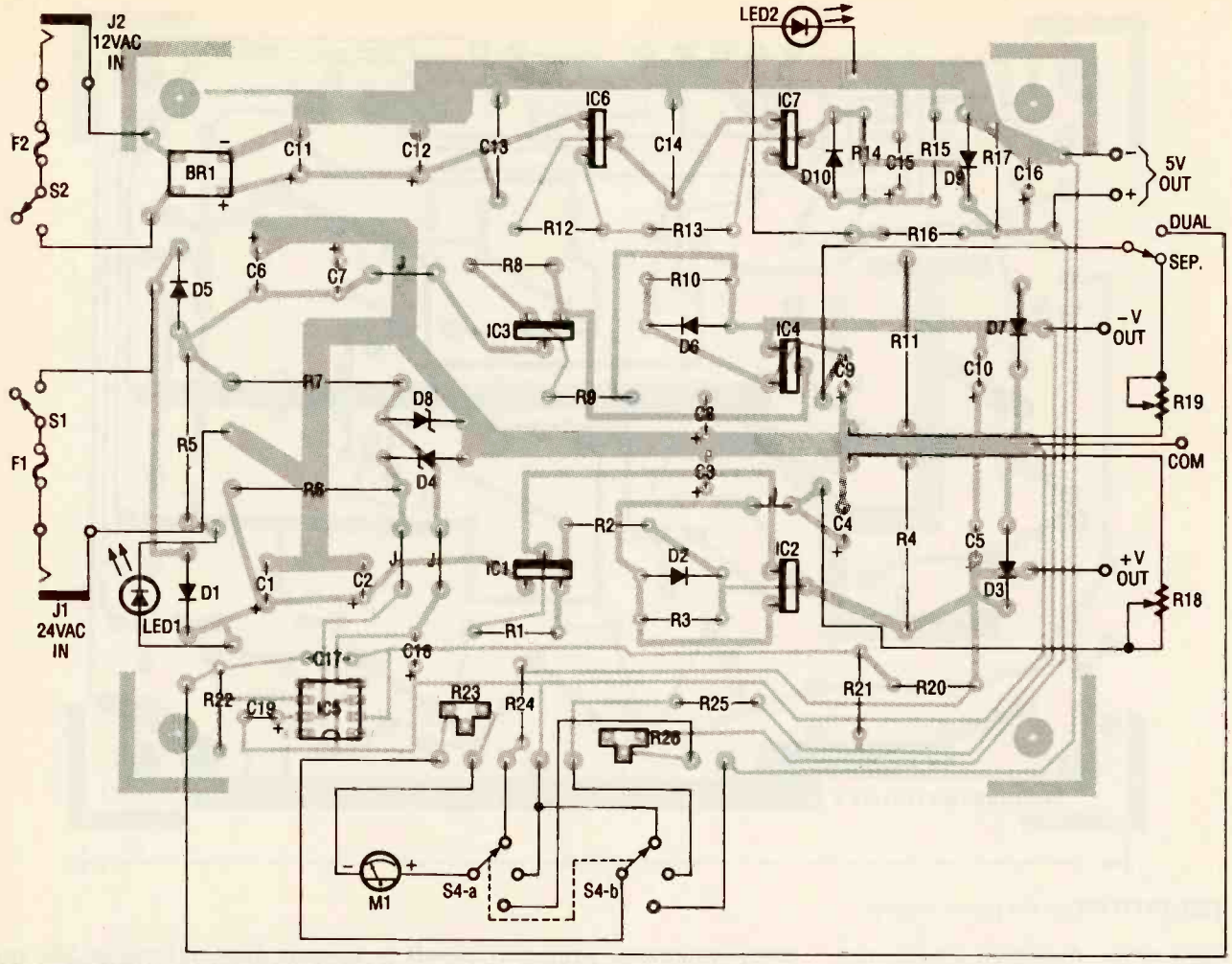


FIG. 4—PARTS PLACEMENT DIAGRAM. Be sure to heatsink the voltage regulators.

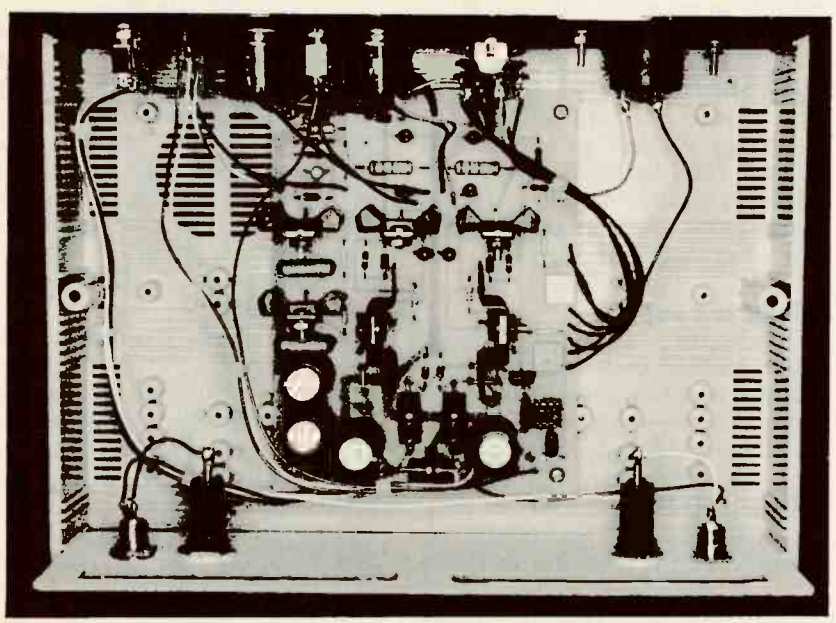


FIG. 5—THE CIRCUITRY IS INSTALLED in a plastic case with slots cut into the rear panel to allow heat to escape. Power input jacks and fuse holders are located below the vent slots.

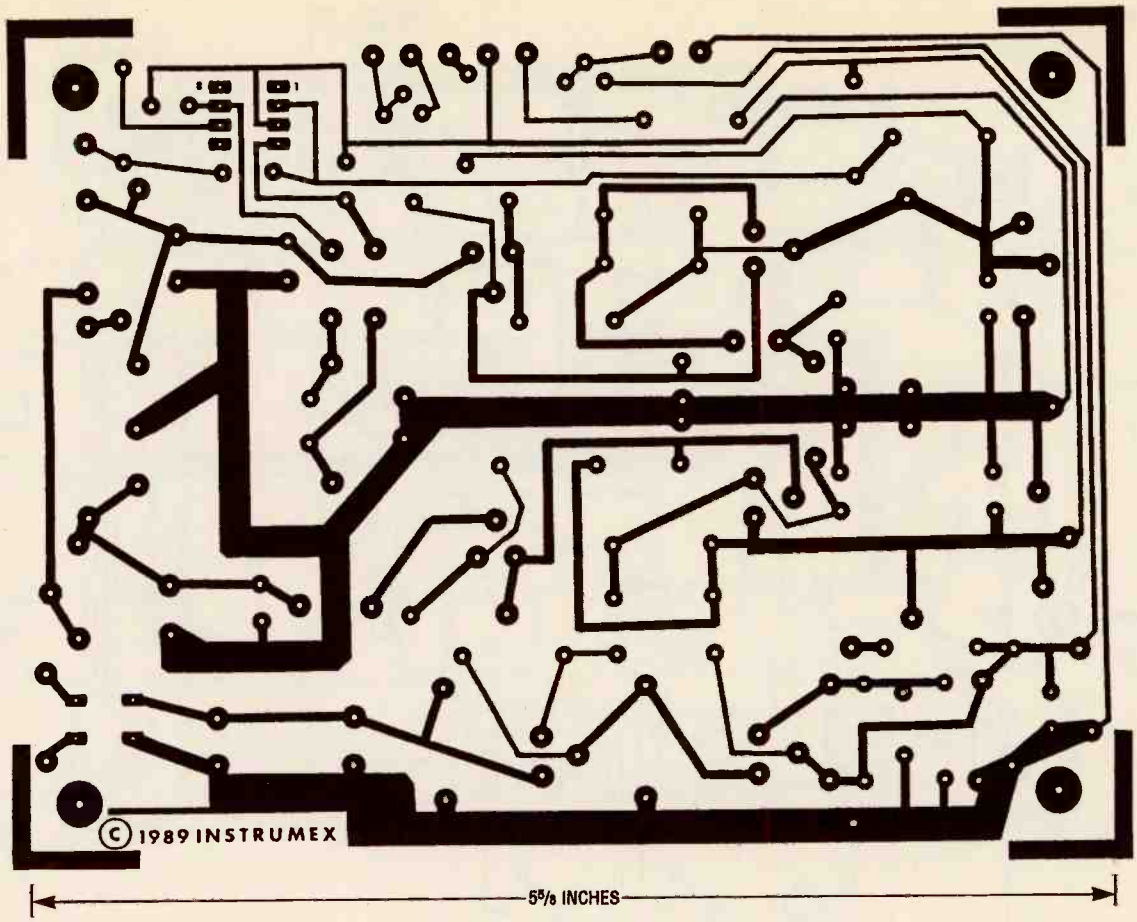
if the supply is constructed on perforated circuit board, make sure that the heatsinks for the different sources cannot touch one another.

Figure 5 shows the inside of the prototype unit. Notice the wiring arrangement for the back- and front-panel controls. Power line wires run along the side of the case from their respective fuse holders to power switches S1 and S2, and then they return to input pads on the rear of the PC board.

Use short lengths of 18-AWG copper wire from output pads on the PC board to the binding posts. Be sure to account for all the wiring connections shown in Fig. 4.

Meter M1 can be re-labeled to read from 0 to 30 volts, but that task requires a lot of care. Remove the meter's bezel and use white paper correction fluid to cover the original numbers. Then carefully remove the adhesive-backed meter face and apply new numbers (0, 10, 20 and 30) using rub-on transfer numbering.

When labeled replace the meter face and shift the pointer as required with the zerp ad-



FOIL PATTERN for the power supply.

justment. Avoid touching the fragile meter pointer!

The plastic case specified in the Parts List is the recommended choice for the project. However, holes in the panels can be difficult to drill because the plastic is brittle and is easy to crack. Alternatively, the panels can be made from sturdy 0.1-inch art board (rigid cardboard) purchased from a stationary or art-supply store. All holes can then be made with a hobby knife. You can also buy a silkscreened front panel from the source given in the Parts List.

Venting the cabinet is very important. Two 4-inch slots, ½-inch wide, were cut in the rear panel to let heat escape. Large rubber feet, although not included with the case, provide that "store-bought" look and prevent the power supply from sliding on the bench.

Calibration

Set the meter switch S4 to the V1 position and S3 to the "separate" position. Adjust the output of the positive variable supply to an exact 20 volts with an accurate external voltmeter. Adjust trimmer potentiometer R23 until the panel meter M1 reads exactly 20 volts. Next, set S4 to the V3 (×4) position, and adjust R26 until M1 reads 20 volts (5 volts ×4). An external voltmeter can be used to verify the exact 5.0-volt output.

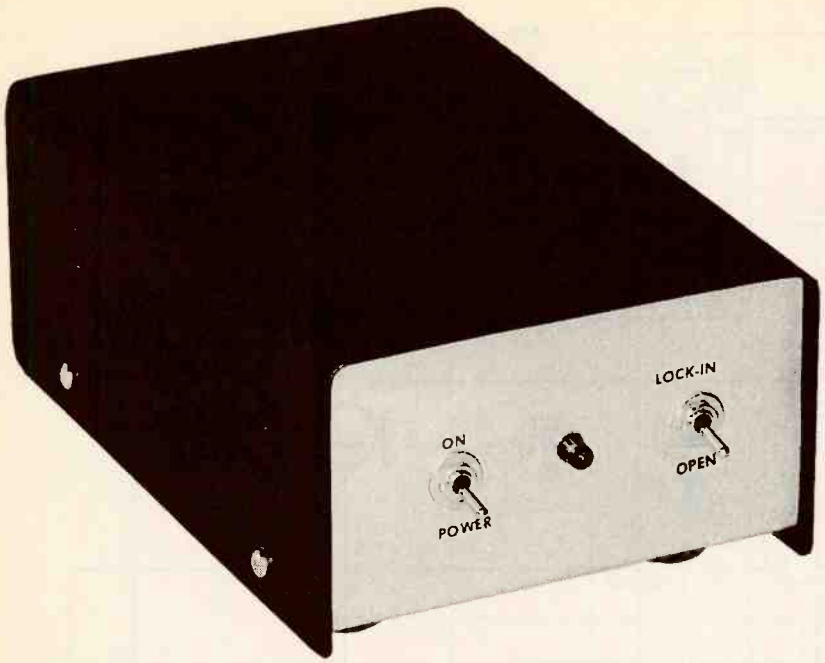
Using the supply

The variable bipolar and fixed logic power sources are completely independent of one another, so they can even be used to power separate projects. Both sources are also "floating," which permits a variety of configurations. For example, by connecting across the outputs of both variable supplies, a 2.6- to 40-volt output of either polarity, at 200 milliamperes can be obtained. By connecting the fixed logic source in series with the arrangement just described (aiding or opposing), a +7.6- to +45-volt or −2.4 to +35-volt output, respectively, at 200 milliamperes is produced.

When powering op-amps that require equal and opposite voltage sources for $+V_{CC}$ and $-V_{EE}$, use the power supply's dual tracking mode. When S3 is set to the "dual" position, potentiometer R18 simultaneously adjusts both variable bipolar sources. Otherwise, leave switch S3 in the "separate" position for independent adjustment.

All outputs are protected against short circuits in the external load by current limiting and thermal overload protective devices, which are built-in features of the voltage-control output regulators.

Any one binding post of a given supply can be connected to the common return of the circuit being powered. Also, that same terminal can be connected to earth ground for optimum safety, if required. Avoid electrically elevating the supplies by connecting them in series with other supplies. Ω



Autopatch Selector for Radio Amateurs

With our autopatch selector you can control almost anything from your UHF transceiver.

PETER A. LOVELOCK

THE SIMPLEX AUTOPATCH, A CIRCUIT that allows amateur radio operators to access the dial-up telephone system from their UHF transceivers, is perhaps the next best thing to a cellular telephone. The problem is, however, that when the autopatch is part of the amateur's own station it is usually limited to one particular transceiver, yet the ham operator might be using two or three transceivers to cover several different amateur bands.

Changing the autopatch's connections to work with more than one transceiver—so that operation is possible on more than one band—normally involves a lot of cable juggling and tends to bring on expletives. Don't forget that there's no way to juggle the connections if there's no one around to do it. Since the autopatch itself is controlled by received DTMF tones, there's no reason why a DTMF signal can't be used to switch the autopatch between various transceivers. That's what this device does.

To prevent unauthorized users from making free telephone calls from your station, an autopatch is normally activated and connected to the telephone line by a special DTMF access code that is broadcast by the remote transceiver. In a similar manner, an autopatch selector that instantly connects the autopatch to one of several transceivers could be controlled by adding a DTMF prefix to the existing autopatch access tones. The autopatch circuitry is shown in Fig. 1.

DTMF

DTMF (dual-tone multifrequency) is the telephone system's standard for "valid tone pairs" that are generated whenever a button on a *Touch Tone*-type keypad is pressed. Each button generates a distinct combination of one low-frequency and one high-frequency tone. Standard telephones use a twelve-button pad labeled 0–9, *, and #. For special applications, the keypads on many amateur radio VHF/UHF handheld and mobile radios have four additional tone combinations that are labeled A–D.

Apart from telephone dialing, the valid tone pairs (referred to as *valid tones*) can be decoded at the receiving end to control almost any function, such as accessing repeaters and simplex autopatches, and even turning on a coffee pot.

Autopatch connection

Figure 2 shows a block diagram of a standard simplex autopatch base-station hookup that provides a connection between a transceiver and the telephone line. The autopatch will not be connected to the telephone line until it receives its access code from the transceiver, which gets the code from the received signal.

Figure 3 is a block diagram showing how a DTMF-controlled autopatch selector connects either of two transceivers to the autopatch. Depending on the received valid-tones prefix, an autopatch selector can connect any of two or more base radios to the single autopatch. Since both the selector unit and the autopatch incorporate DTMF decoders, it is essential that the prefix's valid tones be different from those used for the autopatch access code. For example, if the keypad has 16 DTMF tone-buttons, buttons A, B, and C might be used for the prefixes that connects the autopatch to any of three transceivers, while the # button might be used to reset the selector when the autopatch is in an *option mode* that we'll describe later.

If your remote transceiver's

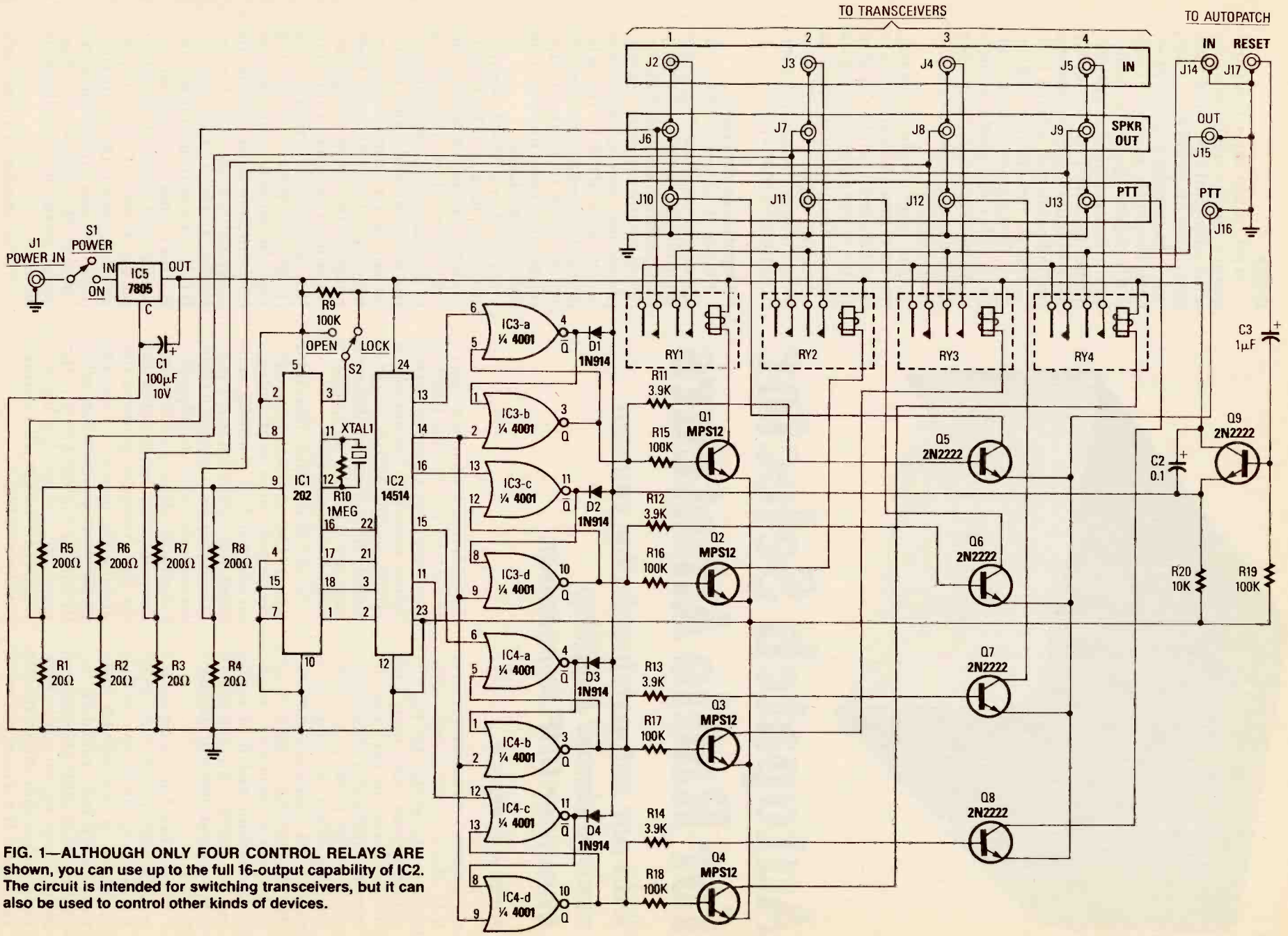


FIG. 1—ALTHOUGH ONLY FOUR CONTROL RELAYS ARE shown, you can use up to the full 16-output capability of IC2. The circuit is intended for switching transceivers, but it can also be used to control other kinds of devices.

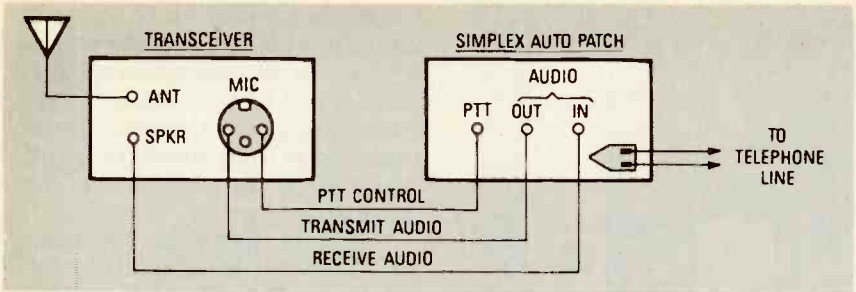


FIG. 2—TYPICAL SIMPLEX AUTOPATCH CONNECTION. It interfaces the telephone line to a transceiver.

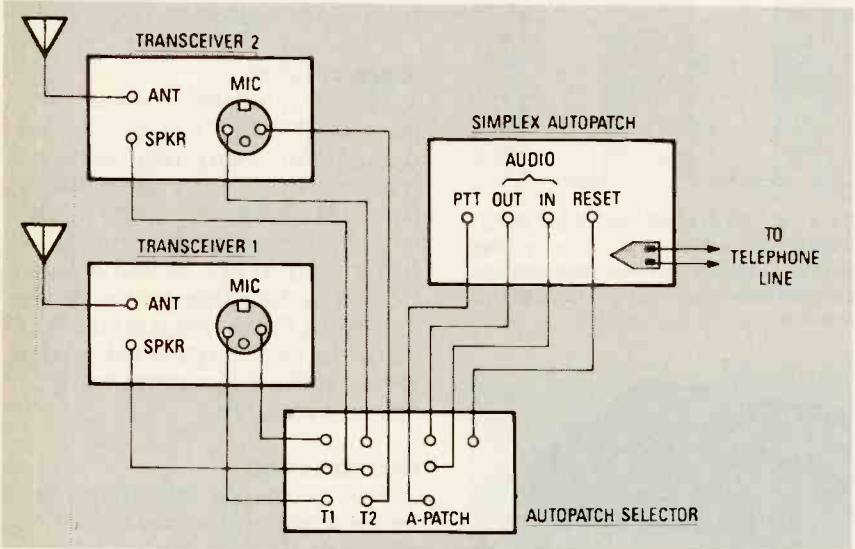


FIG. 3—USING THE AUTOPATCH SELECTOR, a single simplex autopatch can be shared by two or more transceivers. You build as many switching circuits as you need into the selector.

keypad has only 12 buttons, valid tones for buttons 7, 8, 9, and 0 can be used for the selector prefix, limiting numeric buttons 1 through 6 and * for the autopatch's access code.

Functional design

The heart of the autopatch selector is IC1, an 18-pin Silicon Systems type 202 DTMF Tone Decoder integrated circuit. As shown in Fig. 4, IC1 has four outputs: D1, D2, D4, and D8. When valid tones are received at IC1's input terminals, the decoder's outputs provide a binary "2 of 8" code until a valid pause of 40 milliseconds is detected. By itself, the binary code doesn't control anything. This is the function of IC2, a 14514 4-to-16 line decoder. It translates the binary code to raise one of its 16 outputs high for the as long as the tone decoder has a binary output. As shown in Fig. 4, the high period is directly related to the tone pair being received; for example, if valid tones representing a 1 are received by IC2, pin 9 of IC2 goes high.

The 16-button tone pad that's used by many amateur radio VHF/UHF handheld radios will cause any of IC2's 16 output pins to go high, thereby initiating a control function. We say *initiate* because a high output from IC2 drops within 40 milliseconds after the tone input stops.

Referring to the complete schematic shown in Fig. 1, you can see that each of IC2's outputs are connected to a one-shot flip-flop that's made from two sections of IC3 or IC4. The flip-flop toggles when it receives a high from IC2, thereby causing its normally-low $\overline{Q}$ output to go high. The Q output remains high until it receives a high reset pulse at $\overline{Q}$. (That is correct. The reset pulse is applied to the flip-flop's $\overline{Q}$ output terminal, but if you trace the connection you'll find that the $\overline{Q}$ connects to an opposed input; e.g., pin 10 of IC3-c connects to pin 11 of IC3-c.)

The toggling function of the flip-flop permits its high output to turn on an MPS-12 relay driver (Q1–Q4), which in turn actuates a relay (RY1–RY4). The relays have DPST contacts. One pair of contacts switches the audio output (speaker) line from a transceiver to the audio input of the autopatch. The second pair of contacts switches the audio output (phone line) of the autopatch to the microphone input of the same transceiver. The relays are normally deactivated (contacts open), so that there is no connection between the transceiver and the autopatch. When a valid tone pair is detected by IC1, the corresponding IC2 output toggles its associated flip-flop, thereby activating the relay that connects the appropriate transceiver to the autopatch.

In addition to the transceiver's audio input and output, the autopatch's PUSH-TO-TALK line (PTT) must be connected to the selected transceiver. Ideally, the (PTT)-line switching should be done by a third pair of contacts on the active relay. Unfortunately, small and inexpensive 3PST relays are not readily available. As an alternative, (PTT) switching is done by transistor amplifiers Q5–Q7, which are activated by the same flip-flops that control the relays.

The signal path

The input to the autopatch selector from each transceiver speaker output is fed to a resistor network that grounds the speaker output with a 20-ohm resistor, thereby ensuring that the transceiver's output amplifier will have a reasonable load if the speaker is disabled. The speaker's output signal is fed through a 200-ohm resistor to IC1's input, pin 9. The 20/200-ohm resistor network provides approximately 15-dB of isolation between speaker outputs.

The autopatch selector has two operating modes that are controlled by switch S2. When S2 is set to the OPEN position (the switch is actually closed),

IC2 responds to all output signals from all the transceivers, even if one is already connected to the autopatch. Thus more than one radio can be connected to the autopatch in a party-line fashion. In this mode the tones generated by the keypad's # button will disconnect the autopatch selector.

When S2 is set to the LOCK position (the switch is actually open), the first received valid tone pair toggles the associated flip-flop, whose $\overline{Q}$ output drives the reset line low. This low eventually appears on pin 3 of IC3. That disables IC1's crystal oscillator, thereby inhibiting a response to any other tones as long as pin 3 remains low. Thus, the autopatch selector is captured by the first valid prefix tones, and will not permit access by any other prefix until the reset line receives a high pulse that resets the active flip-flop.

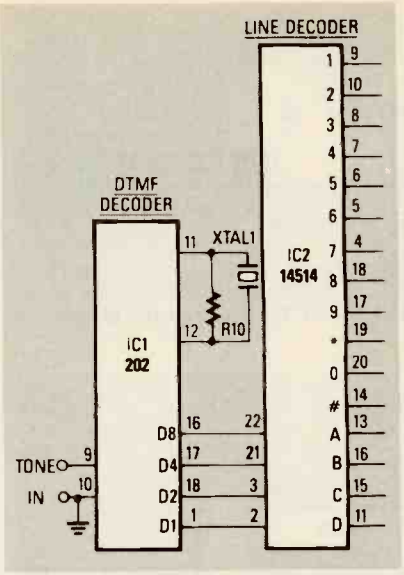


FIG. 4—IC1 DECODES THE DTMF INPUT TONES into a four-line binary-coded decimal output, which IC2 decodes into 16 outputs corresponding to keypad buttons 0–9, *, #, A, B, C, and D.

FIG. 5--THE PROTOTYPE UNIT IS ASSEMBLED on an IC-pattern wiring board. The jacks are mounted on the back of the case.

The diode at the $\overline{Q}$ output of each flip-flop prevents the low on the reset line from toggling the inactive flip-flops.

The OPEN mode would be generally used because it prevents more than one transceiver from accessing the autopatch.

The reset high is generated by the autopatch when it is deactivated, either by receipt of the shutdown tone-code, or by its internal timeout clock. That requires a single connection within the autopatch to a point that is normally high when the autopatch is *off*, and low when the autopatch is *on*. In the case of the commonly-used *Private Patch I*, the most suitable connection is to pin 14 of IC14. A single wire should be carefully soldered to that pin and to the spare phono jack on the rear of the autopatch. With other brands of simplex autopatch unit, it will be necessary to find a logic point for the reset function that is high when the autopatch is *off*, and low when the autopatch is *on*.

The reset high from the autopatch is fed through emitter-follower buffer-amplifier Q9, whose input RC time constant provides a momentary 1-second high to the selector's reset line.

More control

The 16 available control outputs of IC2 are unlikely to be needed for switching sixteen transceivers to the autopatch; two to six radios are more likely. But by using additional flip-flops and relay drivers connected in the same way as those shown in Fig. 1, the unused IC2 outputs can control other devices, such as antenna switchers and rotators.

Construction

The prototype autopatch selector was hand-wired on a 4 × 2¾-inch IC-prototyping board. The board is mounted in a 4½ × 5 × 2-inch aluminum cabinet. The jacks for the transceiver interconnections are installed on the rear apron, along with power supply jack J1.

The required regulated 5 volts at 100 milliamperes can be supplied by one of the associated transceivers. If that is done connect J1 directly across C1, and eliminate the 5-volt regulator (IC5). If you cannot take the power from a transceiver, use the regulator circuit shown in Fig. 1, and drive J1 with the output from a 12-volt DC adapter.

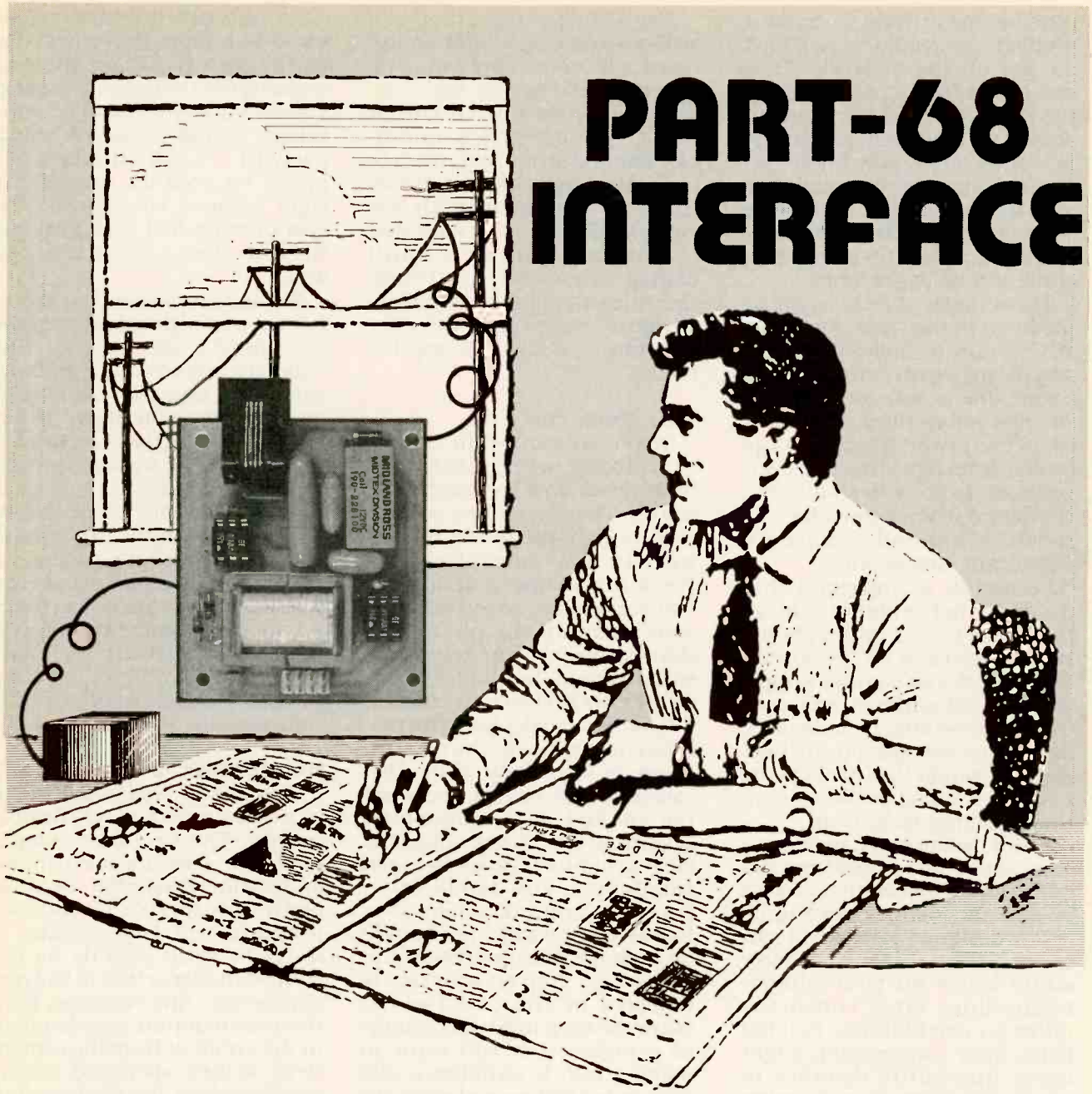
Alternate uses

Although developed primarily for switching an autopatch between transceivers, the switcher can use DTMF tones to control just about anything with a radio. For example, a single DTMF tone can be used to turn base radios on and off, switch antennas, and change frequencies. You could even use the switcher to control the lights in your home from a remote transceiver. Ω

PARTS LIST

All resistors are ¼ watt, 10%, unless otherwise noted
R1–R4—20 ohms, ½ watt
R5–R8—200 ohms
R9, R15–R19—100,000 ohms
R10—1 megohm
R11–R14—3900 ohms
R20—10,000 ohms
All capacitors are rated at least 10-volts DC
C1—100 μF, electrolytic
C2—0.01 μF, ceramic
C3—1 μF, electrolytic
Semiconductors
IC1—Silicon Systems 202P DTMF Decoder
IC2—MC14514 4-to-16 line decoder (Motorola) or equivalent
IC3, IC4—4001 quad 2-input NOR gate
IC5—7805 5-volt regulator
Q1–Q4—MPS12 NPN transistor
Q5–Q9—2N2222 NPN transistor
D1–D4—1N914 diode
Other components
J1—Coaxial power jack to match power supply
J2–J16—phono jacks
RY1–RY4—DPDT relay
S1—SPST switch
S2—SPDT switch
XTAL1—3.58-MHz colorburst crystal holder
Miscellaneous: Prototyping board, IC sockets, cabinet, wire, solder.

PART-68 INTERFACE



With the MPC-2 Part-68 approved phone-line interface, you can make all of your telephone projects FCC type-approved!

MIKE HAGANS and KYLE MAGRILL

MANY POPULAR PROJECTS REQUIRE some kind of connection to your phone line. The list includes telephone remote controls, conversation-recording devices, modems, auto dialers, caller-ID boxes, and even some of the projects in this issue such as the Talking Ringer and the Phone Pager. This article presents a type-approvable protective voice coupler. The interface meets all technical requirements in Part 68 of the FCC rules, and is caller-ID compatible. The coupler's features include ring detection and line-current detection.

Until 1979, it was illegal to hook anything up to your phone line without connecting it through an AT&T-leased coupler. Anyone caught with a second phone or other product connected to his phone system risked having it confiscated. In 1976 the FCC drafted some basic rules that were intended to standardize connections to the phone network and make it

possible for anyone to build a product that could be certified for use on the network. That was the beginning of Part 68 of the FCC's rules. AT&T, trying to protect its monopoly, fought the new rules all the way to the Supreme Court where it eventually lost. Since that day, there have been over 100,000 products licensed, and Part 68 is now several hundred pages long.

Three major objectives are at the heart of the rules. First, the FCC wants to make sure that anything connected to the phone line is safe for the user. Because phone lines are subject to occasional high-voltage strikes from lightning and overvoltages from other sources, connected devices must be able to withstand and dissipate a significant energy surge.

Second, it is important that the device not be able to damage the phone line or injure phone-service people. If an improperly designed device's power supply were to fail while it was connected to the line, it could place dangerous voltages on the line. Not only would that damage the system, it could be fatal to an unsuspecting technician.

Third, whatever happens to your phone line should not degrade your conversation or anyone else's. Malfunctioning or poorly designed equipment can cause distortion, hum, and low audio levels on your phone. Phone lines often run many miles in unshielded, twisted pairs. Your conversation might travel that entire distance in wires only a few microns away from other pairs carrying conversations or data. The system works because the phone company goes to great lengths to be sure that each pair is perfectly balanced and filtered, and that all signals are below specified levels. If your line becomes unbalanced or you exceed the signal limits, you might cause problems for yourself and everyone else who shares a cable with you. It is amazingly easy to mess up a phone line. Just connect one side of the line to ground. You will probably get so much hum and noise on your line that you won't be able to use it.

The FCC also knows that even well-designed, well-built equipment will eventually fail. The equipment must be constructed so that when it fails, it fails completely and is unusable. The reason for that rule is to make sure that the user knows there is a problem with his equipment and to be sure that malfunctioning gear can't damage the system. If you know the rules though, it is easy to design an inexpensive interface that can meet the FCC requirements.

Your phone line

Before we can begin the design process, we need to know a little about how the phone line works. The phone line coming into your home is terminated with an RJ11 (modular) jack. For a single-line installation, two conductors called TIP and RING make up the phone line that connects your telephone equipment to the phone company's Central Office, or CO.

When your telephone instrument is on-hook (hung up), there is about 48 volts DC, called battery voltage, between the TIP and RING conductors. Note that the battery voltage is current-limited, varies between companies, and is *not* referenced to ground. When your handset is picked up, the battery voltage is loaded down, and the voltage drop on your line is detected by the CO. The CO takes the drop in battery voltage as a signal that you want to make a call; it switches a dial tone onto the line and waits for the dial pulses or DTMF (dual-tone multi-frequency) tones that are initiated by your dialing a number.

When you are on the receiving end of a call, the CO switches a ring generator onto your line, which produces a low-frequency AC ring-signal pulse that rides on the DC voltage. Most telephone capacitor-couple the ring signal to an attention getter such as a bell or piezoelectric buzzer. When you pick up the handset, the CO "sees" the DC voltage drop, stops ringing your line, and connects you to the calling party.

An obscure but important thing to note is that when the calling party hangs up, the vast majority of CO's in the U.S. send a short battery-reversal or zero-voltage signal to the receiving party (if it's still off-hook) followed by another one about eight seconds later. Most CO's also dump a dial tone back on the line after a short time, as well.

We acknowledge that we've left out a lot of details about how the phone system works. But this article is about a telephone interface, and we've included enough basic technical information here so that you can begin to design a working protective voice coupler.

If you are really interested in the rather complicated overall operation of a phone system, we heartily recommend Radio Shack's *Understanding Telephone Electronics*; it is an extremely well-written, surprisingly complete, and an inexpensive source of accurate information.

How the MPC-2 works

The MPC-2 was designed to be a very simple and very flexible coupler. The electronic components involved are inexpensive and easily obtainable. Because of the protective (isolation) properties of the coupler, it must be built exactly as described in this article to be type-approvable. Any variation from the construction details given in the article or from the component values specified might greatly reduce the likelihood of your coupler qualifying as FCC type-approved.

Figure 1 is the schematic diagram of the MPC-2 coupler. The telephone TIP and RING lines attach to the coupler board through RJ-11 jack J1. The TIP line is connected to C1, a 0.56 µF capacitor rated at 250 volts DC, which allows the AC component of the incoming ring signal to reach pin 2 of IC2, an H11AA1 AC-input optocoupler. Pin 1 of IC2 is connected to the phone line's RING conductor through current-limiting resistor R1. The output of IC2 is connected to the header J2; the output can

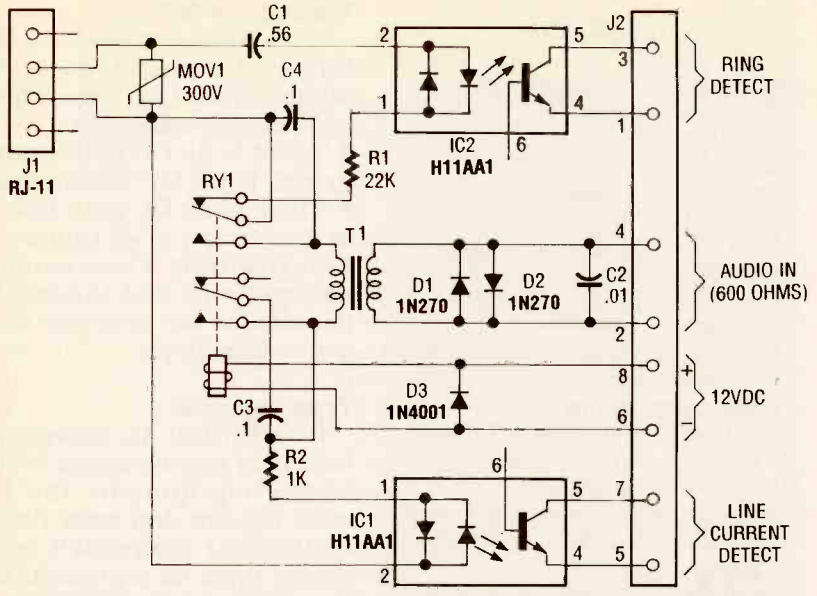


FIG. 1—MPC-2 SCHEMATIC. The interface meets all the technical requirements in the FCC rules, Part 68.

be used to signal your logic whenever a ring is received.

Note that the designations TIP and RING come from the old days when telephone calls were manually switched by an operator on a big switchboard. The connections were then made by cables with standard ¼-inch phone plugs on them; TIP and RING referred to the tip and ring of the connector.

The TIP line is also connected to C3, a 0.1 microfarad, 250-volts DC capacitor which, along with C4, passes caller-ID data to transformer, T1. The transformer is critical to the operation of the circuit. It provides 1,500-volt isolation from the phone line and the correct DC resistance to tell the CO that the line is in use. It also ensures that the phone line will be properly balanced.

Relay RY1 is a standard PC-mount DPDT unit with a 12-volt DC coil. Note that there is a 1N4001 diode across the coil of RY1 to suppress back-EMF when the relay energizes. That makes the relay connection polarity-sensitive. When de-energized, C3 and C4 are connected to T1, allowing the monitoring of the phone line by caller-ID readers or other devices. When RY1 is energized, TIP and RING are connected directly to T1, seizing the line and passing audio to the secondary.

Optocoupler IC1 senses line current. When the unit is on-line (when RY1 is energized), the potential between TIP and RING turns on IC1. When the battery reversal occurs at the end of a call, IC1 shuts off for a moment, signalling your external logic that the call is over. 300-volt MOV1 is used because some phone systems, particularly rural routes, might have elevated operating voltages. It is not uncommon to find a phone line with a nominal 75-volt DC on-hook value and a ring voltage of 100 volts. In that case, a 300-volt MOV provides sufficient overhead to prevent clipping the phone company's voltages.

The final components in our coupler provide signal limiting and waveform shaping to meet FCC specs. The two germanium diodes, D1 and D2, limit signals to the required −9-dBm limit set by the FCC. Because −9 dBm corresponds to about 0.25 volts at the nominal 600-ohm line impedance, only diodes with a very low threshold voltage will work. You cannot use either standard silicon or any type of Zener diode as a limiter because the required junction voltages are too high. Fortunately, some germanium diodes do conduct at about the right voltage. A 0.01 microfarad ceramic disc capacitor (C2) absorbs high-frequency harmonics either generated by the clipping action of the diode limiter or introduced at the audio-input terminals. While frequencies above 3 kHz are filtered in the phone system, the rules require some high-frequency suppression to prevent crosstalk with other pairs in your trunk line.

The MPC-2 passes the limited audio from TIP and RING to pins 2 and 4 of the 8-pin header J2 whether the unit is on- or off-hook. That feature makes the unit compatible with many caller-ID systems. Incoming ring voltage causes an isolated open-collector output at pins 1 and 3 of J2. When the unit is on-line, an open-collector output occurs at pins 7 and 5 of J2. When the calling party hangs up, the optocoupler turns off momentarily, signaling that the call is over. Applying 12-volts DC to J2 pins 6 and 8 will cause the MPC-2 to go off-hook. Simple logic circuits can control the MPC-2 while monitoring its RING DETECT and LINE-CURRENT DETECT lines.

Construction

Building the MPC-2 should be straightforward. You can make the PC board from the foil pattern we've provided (refer to illustration on next page, Fig. 3), or purchase one from the source mentioned in the Parts List. Completed, fully registered (therefore fully legal to use) MPC-2's are also available from the source in the Parts List, as are type-approvable (but *not* type-approved) kits to build them.

Individual parts can be purchased from various vendors. However, be very careful about the quality of the RJ11 jack if you purchase it separately. The RJ11 jack's pins *must* be gold-plated, to a thickness of 50 microns, to be legal for connection to the Public Switched Telephone Network.

Figure 2 is the Parts-Placement diagram. When installing the RJ11 jack (J1), be careful not to bend the pins under the jack,

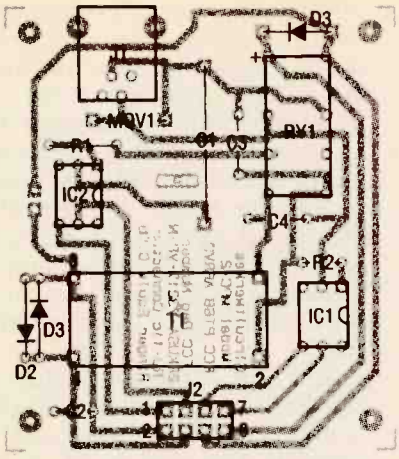


FIG. 2—PARTS-PLACEMENT DIAGRAM. The MPC-2 must be built exactly as described if it is to be type-approved.

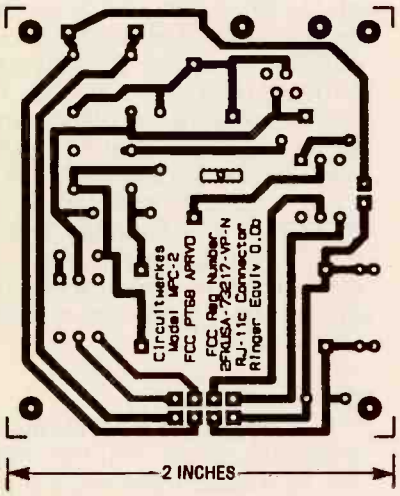


FIG. 3—PRINTED CIRCUIT FOIL pattern is shown full size. Copy it exactly as you see it.

and make sure it's firmly seated before soldering it. We recommend that you use DIP sockets for the two optocouplers. Note that the lettering on transformer T1 should be toward the center of the PC board so that the transformer's primary and secondary windings are oriented properly. The 2×4 eight-pin male header (J2) is optional; you can solder wires directly to the pads on the PC board. If you purchase the type-approved MPC-2 from the source in the Parts List, it includes a matching female IDC-type header connector and a short piece of eight-conductor ribbon cable for connecting the MPC-2 to your projects. Figure 3 shows a completed MPC-2 phone-line interface.

PARTS LIST

All resistors are ¼-watt, 5%.
R1—22,000 ohms
R2—1000 ohms
Capacitors
C1—0.56 µF, 250-volts, Mylar
C2—0.01 µF, 50-volts, ceramic disc
C3, C4—0.1 µF, 250-volts, Mylar
Semiconductors
IC1, IC2—H11AA1 AC-input optoisolator (GE)
D1, D2—1N270 germanium diode
D3—1N4001 diode
Other components
J1—RJ-11C right-angle, PC-mount telephone jack (must be 50 micro-inch gold-plated)
J2—8-pin male header, 2×4, and matching female IDC connector (optional, see text)
T1—Telco line-isolation transformer (Dale TA-40-01 or equivalent)
MOV1—300-volt axial-leaded, metal-oxide varistor
RY1—12-volt DPDT relay (Midland Ross I90-22B100 or equivalent)
Miscellaneous: PC board, two 8-pin DIP sockets, ribbon cable.
Note: the following items are available from CircuitWerkes, 6212 SW 8th Place, Gainesville, FL 32606 (904) 331-5999, Fax (904) 331-6999:
- **MPC-2 PC board only—$9.00**
- **Complete kit for the MPC-2 (not type-approved)—$19.95**
- **Assembled, type-approved MPC-2 (a stand-alone 2×2-inch board)—$29.95**

All parts orders must include $3.50 postage and handling for each coupler. AZ residents add 5.5% tax.

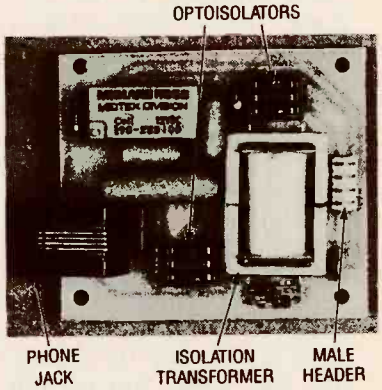


FIG. 3—AN ASSEMBLED MPC-2. You can purchase an identical one from the source in the Parts List.

Testing the MPC-2

You should test the MPC-2 before you connect it to your phone line. The tests should confirm the following:

- There is no DC path from TIP to RING (with RY1 de-energized)
- There is no DC path from TIP or RING to any of J2's pins
- Verify that T1 is oriented properly, and that the two limiter diodes are oriented in opposite directions.

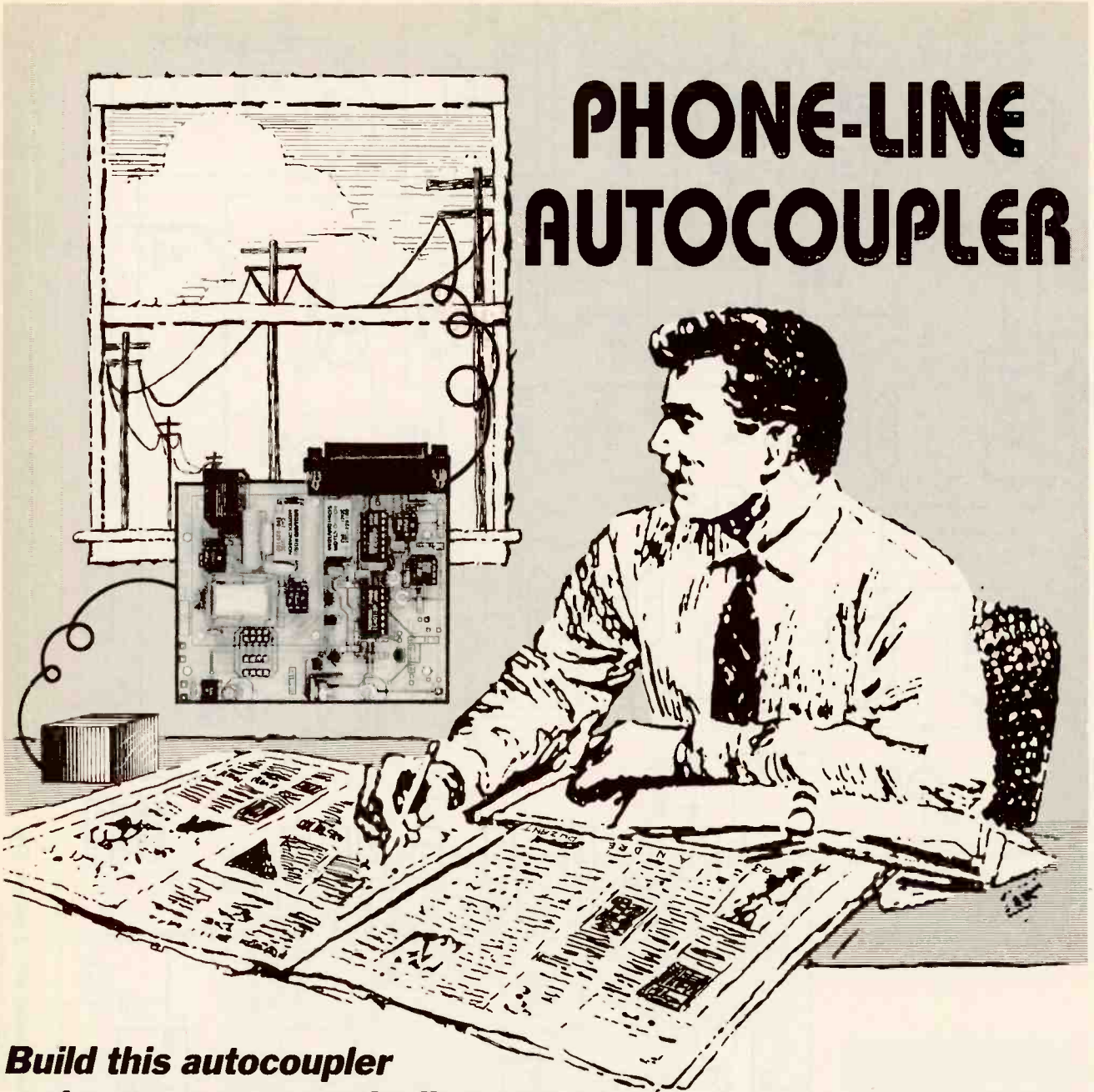
Type approval

In addition to stating the technical requirements for telephone equipment, the FCC rules require that every piece of equipment connected to the phone lines be registered with the FCC, no matter what its function. It is not enough to design a device that meets the specifications: Every product must be tested, certified, and registered. The rules are very clear. Individuals who connect non-registered devices to the phone line risk penalties from equipment confiscation up to fines of $10,000 per day for each device they have. In addition, the use of a non-registered device makes one liable to the phone company for any damages incurred as a result.

So with all that at stake, why doesn't everyone register his gear? Well, you start with the $155.00 fee that the FCC charges each time you register a new device. Usually, that $155 is just the tip of the iceberg. The tests required are complex, and some unusual and expensive equipment is needed. Certification by a testing lab can run from $1,500 to $3,500 for a simple one-line device. The prospect of spending upwards of $1,500 could be daunting if you're a hobbyist and want to make a little phone project for yourself. That's why we are offering our MPC-2 as a pre-assembled, type-approved unit with Part-68 registration that can be transferred to your projects.

Next month we'll detail the construction of an auto-answer/auto-disconnect coupler kit based on the MPC-2 voice-protective coupler. Ω

PHONE-LINE AUTOCOUPLER



Build this autocoupler and you can automatically connect your telephone line to a variety of projects.

MIKE HAGANS and KYLE MAGRILL

IN THE PREVIOUS ARTICLE WE DESCRIBED the MPC-2 telephone interface. The MPC-2 provides ring detection, line-current detection, a caller-ID compatible audio path, and all the isolation, audio limiting, and protective elements to make it—and anything connected to it—comply with the FCC's Part 68 rules. In this article we'll discuss and build an auto-answer/auto-disconnect telephone coupler that incorporates an entire MPC-2 circuit.

The autocoupler's logic monitors the RING DETECT and LINE-CURRENT DETECT lines from the MPC-2 circuit and causes it to "pick up," or go off-hook, after detecting an incoming ring. When the line-current detector signals that the calling party has hung up, the autocoupler forces the MPC-2 to release the line for the next call.

The autocoupler contains an isolated relay that can signal the beginning of a call, or that can stay latched for the duration of the call to control external equipment. Remote pick-up and hang-up switches can be connected to the autocoupler, and LED's can indicate ring and on-line conditions.

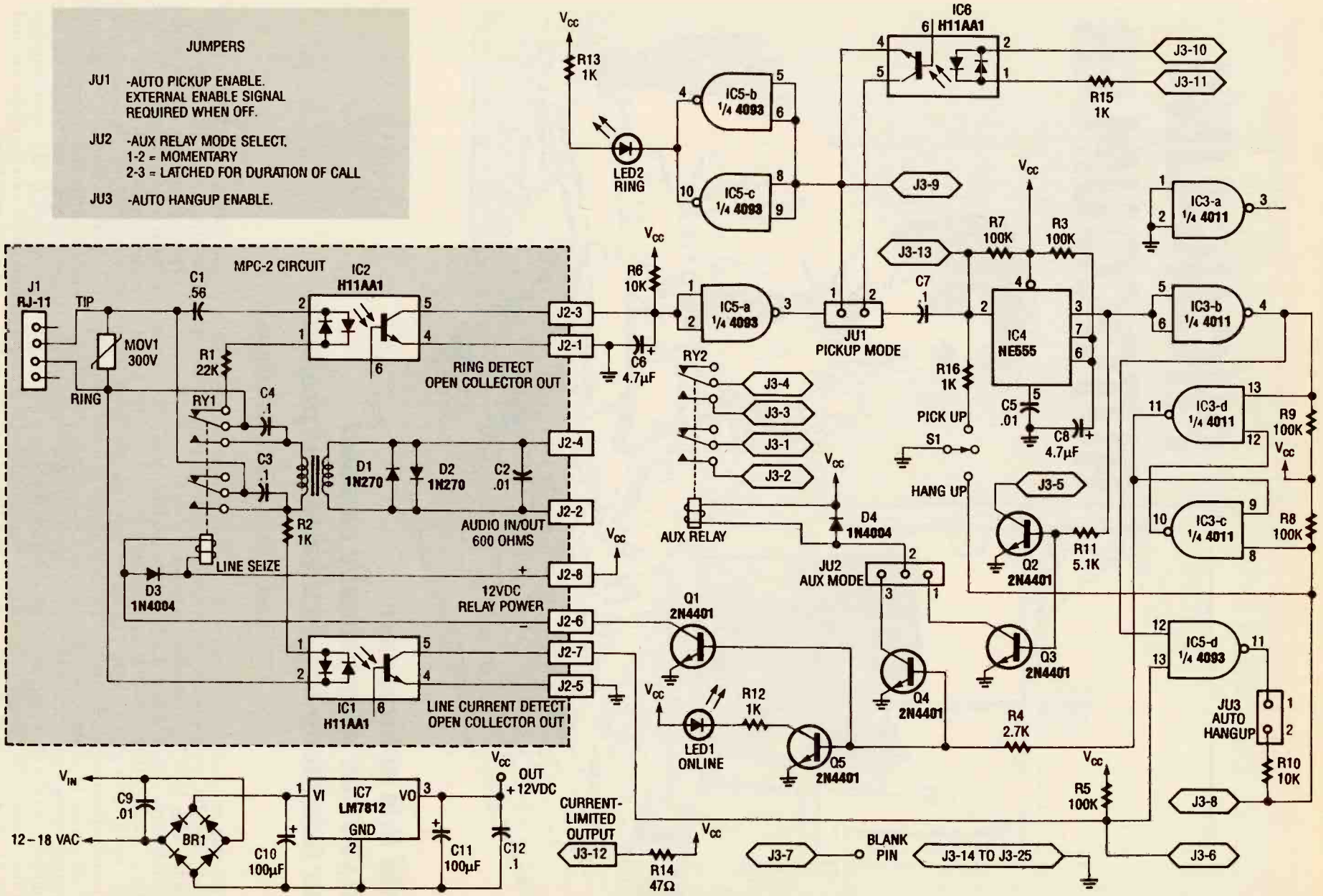


FIG. 1—THE AUTOCOUPLER CIRCUIT shown with the included MPC-2 section. The MPC-2 interface meets all technical requirements in the FCC rules, Part 68.

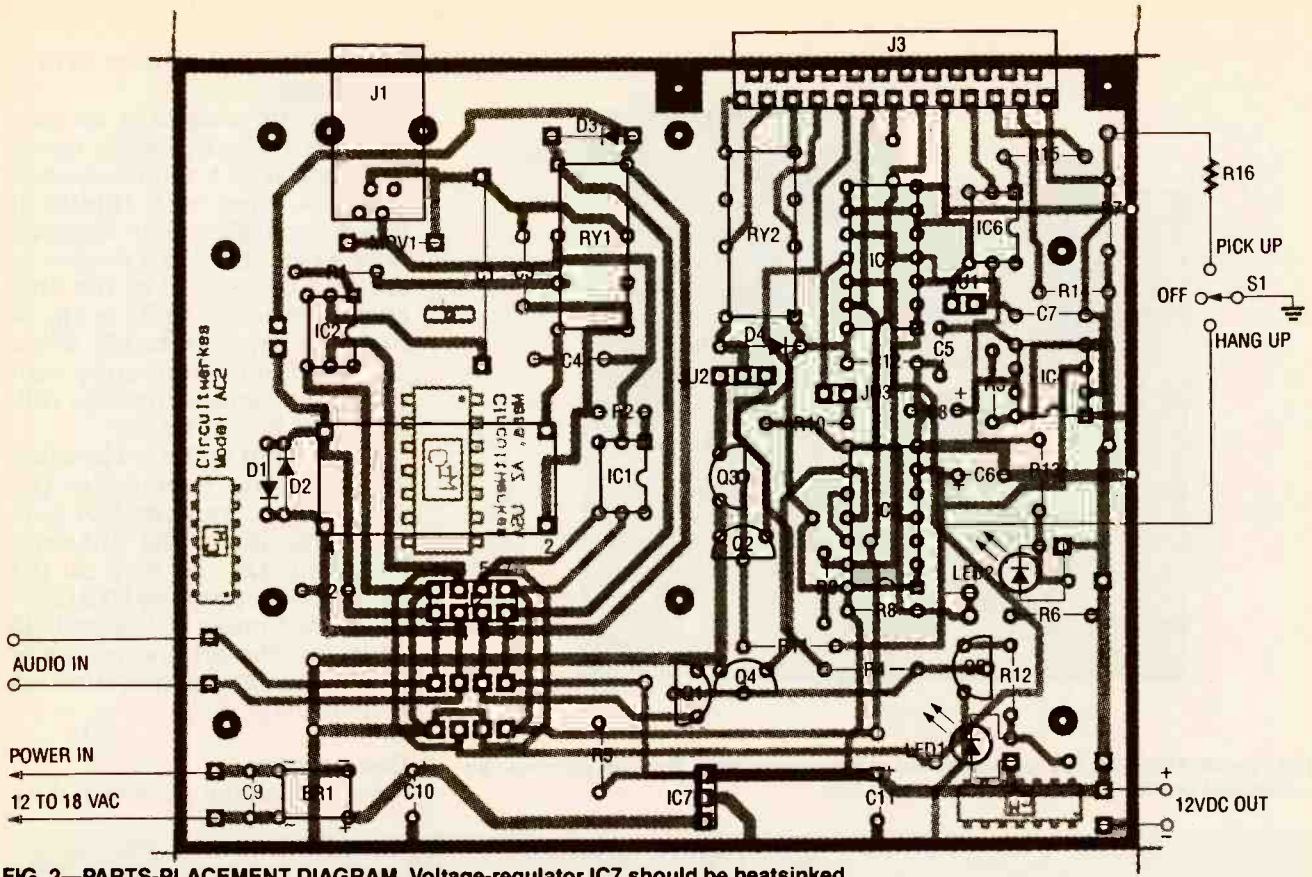


FIG. 2—PARTS-PLACEMENT DIAGRAM. Voltage-regulator IC7 should be heatsinked. Note that the MPC-2 section must be built exactly as described to be type-approvable.

Circuitry

A stand-alone MPC-2 board can be connected to the autocoupler board with an 8-wire ribbon cable or the parts for the MPC-2 section can be installed directly on the autocoupler board. Figure 1 shows the autocoupler along with the MPC-2 circuit.

The RING-DETECT output of the MPC-2 interface is pulled up by resistor R6 and conditioned by capacitor C6 and IC5-a, a 4093 Schmitt-trigger NAND gate configured as an inverter. The hysteresis action of the 4093 significantly cleans up the RING DETECT signal, presenting a square wave (high during the incoming ring signal) to one side of capacitor C7. That capacitor is normally charged through the 100K pull-up resistor (R7) while the output of IC5-a is low. When the output of IC5-a goes high, C7 discharges. When IC5-a's output goes low again at the end of the ring, C7 momentarily loads down R7 (as it charges). The momentary low triggers the input of the 555 timer (IC4), which is set up in monostable (one-shot) mode.

The cleaned-up ring-detect signal from IC5-a also feeds the ring-detect LED circuit consisting of IC5-b and IC5-c in parallel. The inputs of those two gates are pulled high during a ring, causing their outputs to go low. When that happens, ring indicator LED2 turns on. When manual-pickup switch S1 (a momentary SPDT switch with center-off) is activated, pin 2 of the 555 gets pulled low as if a ring had occurred. The 1K resistor (R16) connected to S1 limits C7's instantaneous current flow when the switch is activated, protecting IC5-a.

Jumper JU1 is located between pin 3 of IC5-a and C7. If JU1 is left open, optocoupler IC6 provides the pickup-enable signal. The two inputs to the optocoupler (pins 1 and 2) are connected to pins 10 and 11 of the DB-25 connector J3. An external AC or DC voltage from 5 to 30 volts will turn on IC6, enabling the ring signal to trigger the 555.

The duration of the 555 timer's high output is controlled by C8 and R3, and lasts for about half a second. The 555's output turns on two transistors; Q2 is the open-collector momentary output that appears on J3 pin 3; Q3 is one of two transistors (selectable via jumper JU2) that can operate the auxiliary output relay. The 555 also feeds NAND gate IC3-b, which is set up as an inverter.

A set-reset latch is formed by NAND gates IC3-c and -d. One input of each gate is tied to the output of the other, and the remaining two inputs (one on each gate) are pulled high by resistors R8 and R9. Before a ring occurs, the latch's output (pin 11 of IC3-d) is low, and stays that way because it holds one input of IC3-c (pin 9) low, which causes IC3-c's output to be high. That output keeps pin 12 of IC3-d high, and the circuit is in stasis until triggered by the previous stage (IC3-b) after an incoming ring.

Pulling the SET input of the latch (IC3-d pin 13) low causes IC3-d's output to go high. That causes IC3-c's output, and the other input of IC3-d, to go low.

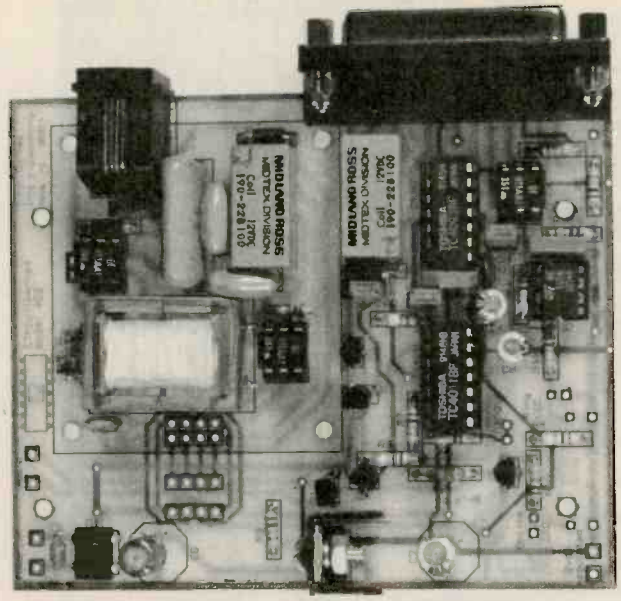


FIG. 3—AN ASSEMBLED, type-approved autocoupler board. You can purchase an assembled one from the source in the Parts List.

PARTS LIST

All resistors are ¼-watt, 5%.
R1—22,000 ohms
R2, R12, R13, R15, R16—1000 ohms
R3, R5, R7, R8, R9—100,000 ohms
R4—2700 ohms
R6, R10—10,000 ohms
R11—5100 ohms
R14—47 ohms

Capacitors
C1—0.56 µF, 250-volts, Mylar
C2, C5, C9—0.01 µF, 50-volts, ceramic disc
C3, C4—0.1 µF, 250-volts, Mylar
C6, C8—4.7 µF, radial electrolytic
C7, C12—0.1 µF, metal-film
C10, C11—100 µF, 35 volts, radial electrolytic

Semiconductors
IC1, IC2, IC6—H11AA1 AC-input optoisolator (GE)
IC3—4011 CMOS quad NAND gate
IC4—555 timer
IC5—4093 CMOS quad Schmitt-trigger NAND gate
IC7—LM7812T 12-volt regulator
D1, D2—1N270 germanium diode
D3, D4—1N4001 diode
Q1–Q5—2N4401 NPN transistor
BR1—DT102 DIP bridge rectifier (1A, 100V)
LED1, LED2—light-emitting diode, any color

Other components
J1—RJ-11c right-angle, PC-mount telephone jack (must be 50 micro-inch gold-plated)
J2—8-pin male header, 2 × 4, matching female IDC connector, and ribbon cable (optional, see text)
J3—short-style right-angle PC-mount DB-25 connector
JU1, JU3—1 × 2 jumper block
JU2—1 × 3 jumper block
T1—Telco line-isolation transformer (Dale TA-40-01)
MOV1—300-volt axial metal-oxide varistor
RY1, RY2—12-volt DPDT relay (Midland Ross I90-22B100)
Miscellaneous: PC board, three 6-pin DIP sockets, one 8-pin DIP socket, two 14-pin DIP sockets, T0-220-type stand-up heatsink (for IC7), three shorting blocks (0.1" jumpers for JU1–JU3)

Note: The following items are available from CircuitWerkes, 6212 SW 8th Pl, Gainesville, Fl 32607 (904) 331-5999:
- **Double-sided, silkscreened autocoupler PC board only—$14.95**
- **Autocoupler PC board with pre-built Part-68 registered MPC-2 section—$39.95**
- **Complete autocoupler kit with pre-built Part-68 registered MPC-2 section (no enclosure)—$69.95**
- **Fully assembled and tested, Part-68 registered autocoupler (no enclosure)—$99.95**
- **Screen-printed black plastic enclosure with machined end panels for the autocoupler—$26.00**

Include $3.50 for shipping and handling. Add $4.50 for COD (cash or certified funds only). Arizona and Florida residents must include appropriate sales tax.

The circuit remains in that condition until the RESET input (IC3-c pin 8) goes low, toggling the latch back to its original state. This takes us back to inverter IC3-b whose output does two things: It triggers the SET input of the latch, and it holds pin 12 of IC5-d low, preventing the latch from resetting for the duration of the 555's pulse. After about a quarter of a second, the line-current detector (IC1) prevents the latch's RESET line from going low by holding pin 13 of IC5-d low while telephone line current is established again.

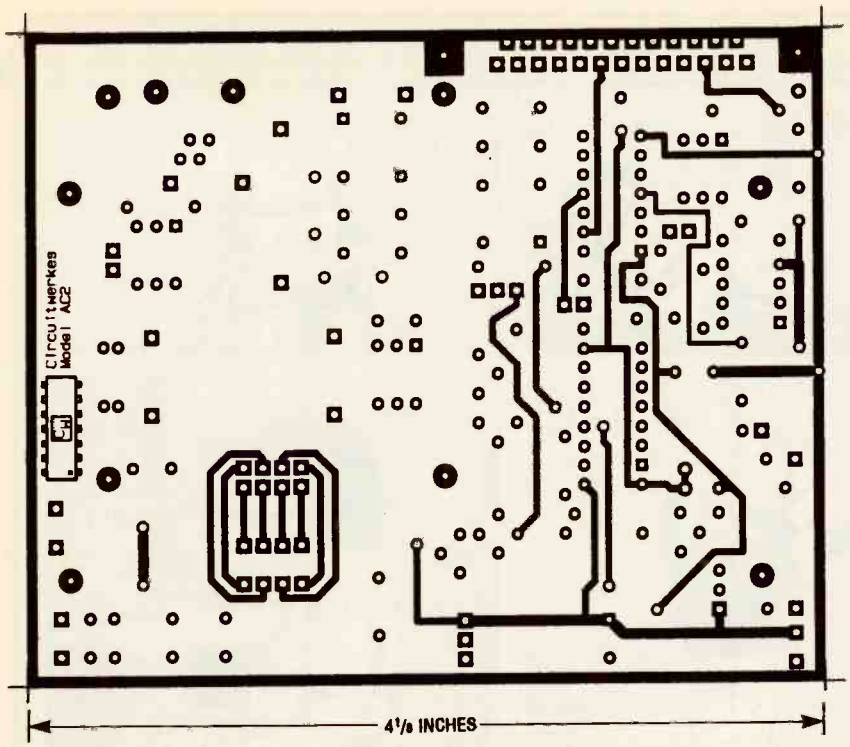
When the coupler is on-line, the only time the latch's RESET line should go low (and cause a reset) is when both inputs of IC5-d are high. That happens only when the 555's output is low and the output of the line-current detector (IC1) is off, or high, as happens briefly when the telephone company's central office signals that the calling party has hung up.

The output of the latch, when set, turns on transistors Q1, Q4, and Q5. Transistor Q1 supplies ground for the line-seize relay RY1. Q4 can turn on the auxiliary-output relay RY2 (if selected by jumper JU2), and Q5 turns on the on-line indicator LED1 through current-limiting resistor R12.

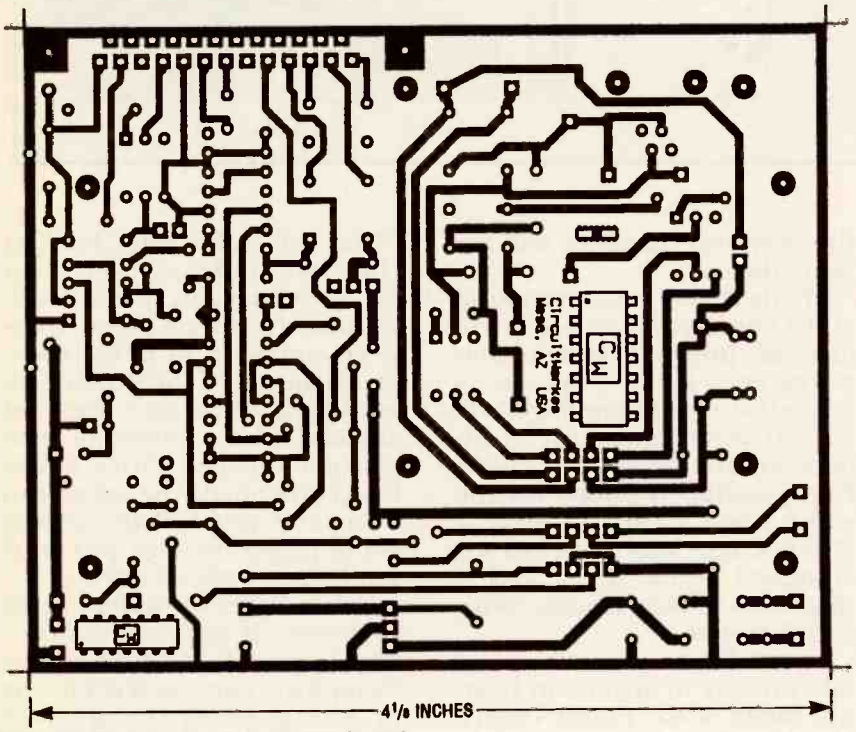
Construction

You can make your own double-sided PC board using the foil patterns we've provided, or purchase one from the source mentioned in the Parts List. Kits are available from the same source.

Note that two 2 × 4-pin headers with mating IDC connectors



COMPONENT SIDE for the autocoupler board.



SOLDER SIDE for the autocoupler board.

and a piece of 8-conductor ribbon cable can be used to attach a stand-alone MPC-2 board (see **Electronics Now**, May 1993) to the autocoupler board, and then you would just leave out the MPC-2 parts on the autocoupler board. An 8-pin header can also be used to mount the MPC-2 board as a daughter board on top of the autocoupler board. Otherwise, you can mount all of the parts on the autocoupler board.

Solder the components on the board following the Parts-Placement diagram in Fig. 2.

Voltage-regulator IC7 should have a heat sink attached to it. Be sure to apply heat-sink compound on the back of the regulator before attaching the heat sink. The indicator LED's can either be board-mounted or panel-mounted and connected with wire jumpers. When the board is finished, insert the IC's into their respective sockets. Figure 3 shows a completed unit.

Initial testing

Verify that all IC's are properly installed and that polarity-sensitive devices are oriented properly before connecting power, audio, or a phone line to the autocoupler. Then, you can connect 12 to 18 volts (AC or DC) to the board's power-input pads. When power is applied, the two relays will energize for about a half second, and then drop out. That indicates the initial operation of the one-shot and latch circuits. If the unit is connected to a phone line when powered up, it will seize the line and hold it until a line current zero-crossing occurs, at which point the unit will drop the line.

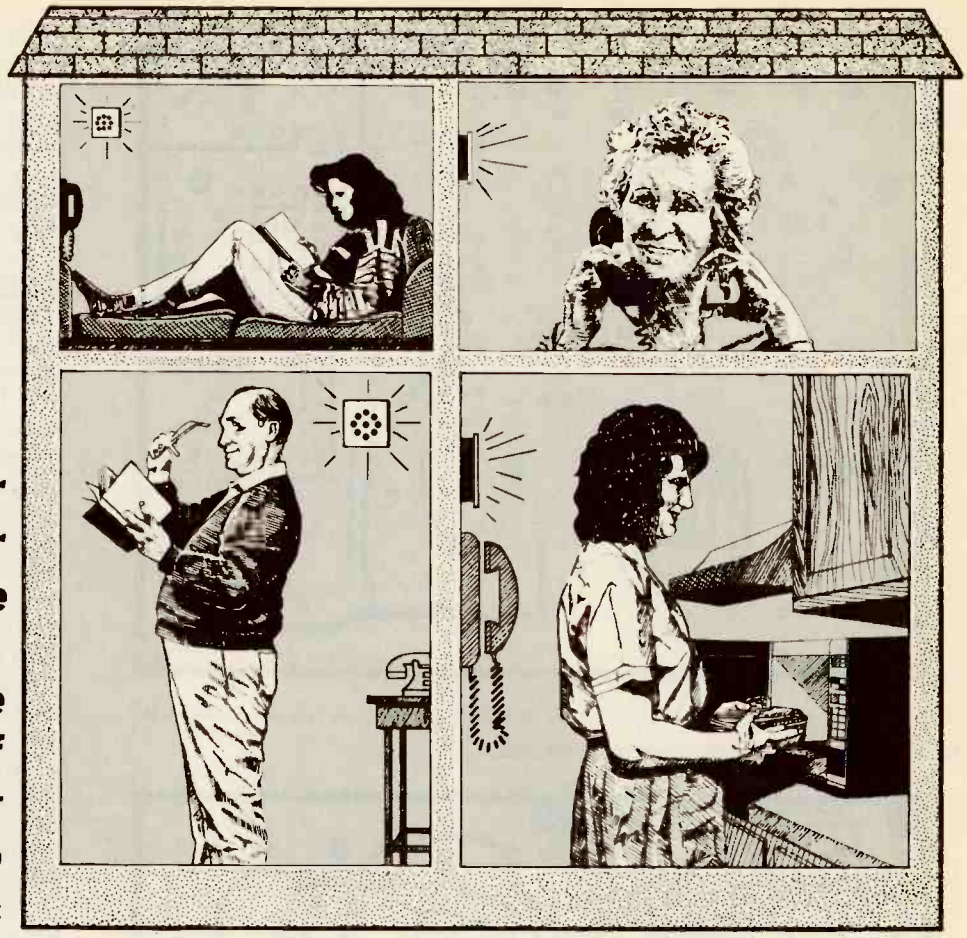
Almost every modern central office in this country generates a zero-crossing in the telephone-line battery voltage less than a minute after dial tone is applied to the line—if no activity is detected in that period of time. That also occurs after the calling party hangs up. If your local central office is one of the rare systems that does not support that signaling, you might have to include a preset timer or, preferably, a dial-tone detector that will hang up your autocoupler automatically.

If the initial power-up occurs as has been described, you are ready to test the device on the phone line. Remember that the phone line carries voltages that are high enough to give you a nasty shock if you happen to be touching the tip and ring conductors on the bottom of the MPC-2 coupler section during a ring.

Connect the RJ-11 jack to your phone line with a standard modular cord, and have someone call your line. As soon as the phone starts ringing, you should see LED2 light up. The coupler should answer at the end of the first ring; when it

(Continued on page 109)

THE PHONE PAGER



Build this pager for your telephone system, and save yourself a lot of yelling and running up and down stairs

JOHN E. CARTER, K8YVT

THE PHONE PAGER IS A TELEPHONE system accessory that will simplify telephone communications within your home or workplace. It contains an electronic circuit that, when connected to your telephone, becomes an audio pager. It will save you or other members of your family a lot of yelling or running up and down stairs to notify someone else that he or she has a call waiting. (It could be a call for you!)

Phone Pager is a stand-alone unit housed in a small box that is plugged into a phone with a length of telephone line cord, and takes its power from a wall-mounted AC/DC adapter. Its internal speaker permits you (or any other person called) to hear a short message anywhere in the room where a Phone Pager-equipped telephone is located—bedroom, den, basement, or wherever. You (or the other person being called) then picks up the telephone handset and accepts the call.

Phone Pagers connected to all of the phones in your house will form an intercom system that works even if the telephone is not in use. One Phone Pager will permit voice communication between any phone and Phone Pager-equipped phone on the same line. A caution here—Phone Pager was designed for standard phone lines, and it might not work in an office with a PBX system.

Phone Pager permits you to talk directly to anyone in hearing range of the Phone Pager's speaker. Simply press the the assigned activation key on the keypad of your standard Touch-Tone telephone and talk. (You don't have to have a Phone Pager attached to the phone from which you make the paging call, but the person you are paging must be near a Phone Pager-equipped phone.

You'll have four to six seconds to make an a short statement—"This call is for you, Joe," or "I've got it, Martha—it's for me"—before you are cut off. Wait for the person paged to answer, and when he or she does, just hang up. If the person you are trying to contact does not answer, take a message with pencil and paper. With a Phone Pager installed, the caller can hear both you and the person being paged because you're all on the same phone line.

Phone Pager works well as an intercom. If someone in your house wants to announce "Soup's on, come and get it," he or she goes to the nearest phone, presses the activation key, and makes the statement. The dial tone is silenced by pushing the activation key, so the announcer won't be interrupted by it. Most telephone systems include a delay of 10 to 15 seconds before the jarring "off-hook" tone sounds. That will give you enough time to say something meaningful before being interrupted.

After a selectable time period has passed, the Phone Pager automatically returns to its normal silent state, waiting for the next key actuation to turn it on again. It can be activated at all times, whether the phone line is in use or not, because it is always connected to the line.

The asterisk or "*" key was selected for the prototype because of it's convenient location at the lower left corner of a telephone keypad, but any of the other 11 keys on the pad can be organized as the Phone Pager activation key.

When used as an intercom, Phone Pager can call children playing in some remote part of the house. It can also keep you in touch with a disabled person elsewhere in your home who might need assistance. And, of course, it can be used on the job in a office or factory if the phone system will permit its use.

The Phone Pager can screen calls if you have an answering machine. It's easy for you to screen calls if you are near the answering machine when it sounds off, but obviously this can't be done if you are out of earshot of the machine.

If you have friends or relatives whose calls you are always willing to accept, give them instructions in how to activate any Phone Pagers in you home. For example, if an "approved" person calls you from outside your home and gets your answering machine, he or she will know which key to press to activate your Phone Pagers. (For this feature, the value of a "tip" resistor in the circuit must be changed, but this will be explained later in this article.)

The Phone Pager will also come in handy if you are an amateur radio operator and you use your telephone as an auto patch for a repeater at home. The auto patch looks like another phone across the line. Phone Pager will permit you to make calls from a mobile unit to a Phone Pager installed in your radio room.

Depress the assigned activation key once to get a dial tone (or go off-hook), and depress it a second time to activate the Phone Pager. Anyone in hearing range of the Phone Pager can then use it to make a short reply to your call, or he or she can switch on your radio transmitter for a longer conversation with you.

During normal TouchTone dialing, the key is usually depressed for less than a quarter of a second. However, to activate the Phone Pager, you must hold down the key for a little more than a half second. As a result, the detect circuitry ignores the shorter bursts initiated by normal dialing.

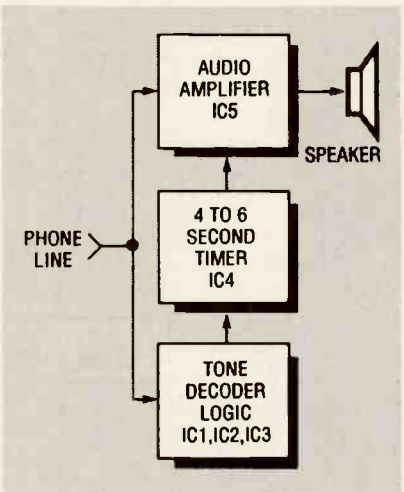


FIG. 1—PHONE PAGER block diagram. Circuitry is partitioned by function.

How Phone Pager works

Figure 1 is the block diagram for Phone Pager, and Fig. 2 is its schematic diagram. The Tone Decoder Logic block of Fig. 1 consists of two LM567 tone decoder IC's and the quad two-input NAND gate IC3. Timer IC4 performs the 4- to 6-second timing function, and audio amplifier IC5 boosts the audio. When the designated activation key is depressed (in the prototype it is "*,"), one LM567 is tuned to 941 Hz, and other is tuned to 1209 Hz.

Refer now to the schematic Fig. 2. Both of the output pins numbered 8 of tone decoders IC1 and IC2 go low when the correct tone is present on their inputs. They are connected to three sections of IC3, the CD4011 two-input NAND gate which is configured as an OR gate. (The fourth section is a spare.) Pin 11 of IC3-*a* goes low when there is a simultaneous low at both sets of input pins (1 and 2) of IC3-*a* and (5 and 6) of IC3-*b*. This condition is met when both tones are present.

Resistor R7 and capacitor C9 (between the output of IC3-*d* and pin 2 of IC4) inhibit the triggering of the 555 timer IC4 until their RC time constant has timed out. If either C9 or R7 are increased, holdoff time increases; if they are decreased, holdoff time deceases. This RC time delay performs three important functions:

- Eliminates false triggering of the 555 when normal ringing is present.
- Prevents false triggering by normal conversation.
- Retains the use of the selected key for normal TouchTone phone keying.

The negative-going pulse at pin 2 of IC4 causes its output pin 3 to go high for the period determined by another RC time constant set by the product of R8 (between pins 7 and 8) and C10 (between pins 1 and 6). Four to six seconds is generally enough time to give a simple message. The time constant determined by 33-kilohm resistor R8 and 100-microfarad capacitor C10 yields about that much time.

The same relationship applies to R7 and C9, but you can substitute other values for R8 and C10 if you are not satisfied with that time constant. Diode D1 allows the voltage at the input of IC4 to return instantly to +5 volts when the output of IC3-*d* returns to normal.

Timer IC4 powers the amplifier, which is bridged across the phone line allowing your voice to be heard. After the RC time constant of C10 and R8 times out, the Phone Pager returns to its normal quiescent state.

Building Phone Pager

All of the components listed in the Part List are standard components readily available from most mail-order electronics parts distributors or retail stores. You will get the best looking circuitry by mounting all the components on a printed circuit board. However, if cir-

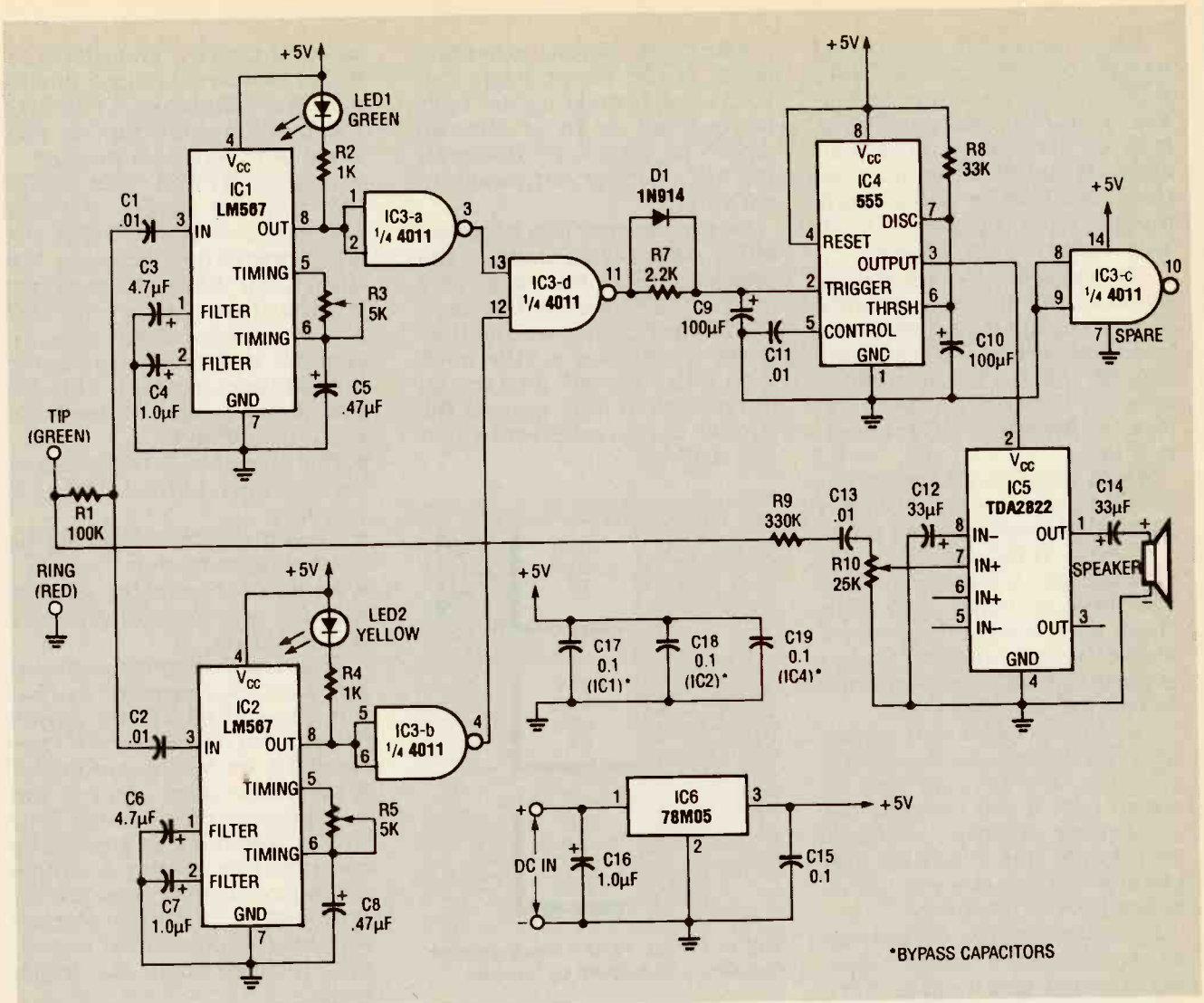


FIG. 2—PHONE PAGER SCHEMATIC showing connections to the telephone line and 5-volt power source.

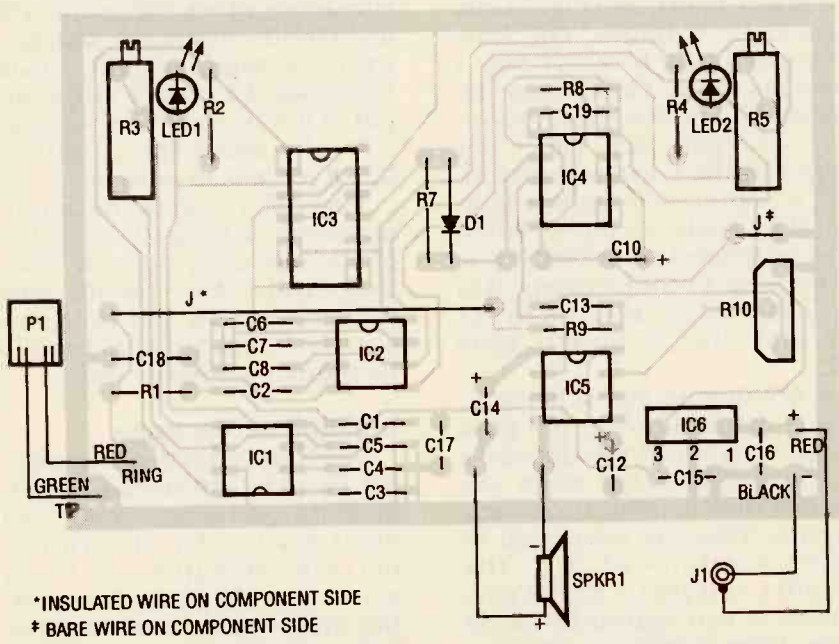


FIG. 3—PARTS PLACEMENT DIAGRAM for the Phone Pager. Note the positions of the two wire jumpers.

cuit appearance is not that important to you, you can use standard perforated board and point-to-point wiring and still obtain satisfactory results.

To provide for all options, the foil pattern for the circuit board is included in this article if want to make your own board. However, you can purchase a completed circuit board from the source given in the Parts list.

Figure 3 is the Parts Placement diagram. There is nothing critical about parts placement in this project. Notice, however, that resistor R9 must be connected across a large gap between the phone input (green TIP) and capacitor C13. To eliminate any coupling problems that might arise if a copper circuit board trace spans this gap, it is closed by a length of insulated hookup wire positioned where shown.

PARTS LIST

Resistors (all are ¼-watt, 10%, unless otherwise specified)

R1—100,000 ohms
R2,R4—1000 ohms
R3, R5—5000 ohms, multiturn trimmer, Bourns 3006-1-502 or equivalent
R7—4700 ohms
R8—33,000 ohms
R9—330,000 ohms
R10—25,000 ohms, single-turn trimmer, Bourns 3355 or equivalent
R11—200 ohms (test circuit)

Capacitors

C1,C2,C11,C13—0.01 µF, 35 volts
C3,C6—4.7 µF, 35 volts, tantalum
C4,C7,C16—1.0 µF, 35 volts, tantalum
C5,C8—0.47µF, 35 volts, tantalum
C9,C10—100µF, 25 volts, aluminum electrolytic
C12,C14—33µF, 25-volt, aluminum electrolytic
C15,C17,C18,C19—0.1µF, 50-volt, ceramic multilayer

Semiconductors

IC1, IC2—LM567CN tone decoder, National Semiconductor or equivalent
IC3—MC14011 quad two-input NAND gate, Motorola or eqivalent
IC4—NE555 timer, Signetics or equivalent
IC5—TDA2822M, 1-watt audio amplifier, SGS-Thomson
IC6—78M05, 5-volt, 500-mA voltage regulator, TO-220, Texas Instruments or equivalent
LED1—light-emitting diode, yellow, T-1, Hewlett-Packard HLMP-1400 or equivalent
LED2—light-emitting diode, green, T-1, Hewlett-Packard HLMP-1503 or equivalent

Other components

J1—Power jack, coaxial, PCB-mount (for AC/DC adapter)
SPKR1—8-ohm speaker, 0.3-watt, 2-inch diameter
P1—plug, four-conductor telephone, RJ11¼

Miscellaneous: plastic electrical outlet box (3-½ × 2 × 2-½ inches); plastic wall outlet cover (4-½ × 2-¾), AC-to-DC wall adapter, 12-volt, 500 milliampere with coaxial plug; telephone line cord1/14 modular plug, seven feet; modular "Y" telephone adapter RJ11/14(1 plug, 2 jack) duplex; 9-volt alkaline transistor battery; grommet.

Note: The following parts are available from JEC TECH, 13962 Olde Post Road, Pickerington, OH 43147

- **Complete kit including wall-outlet AC/DC adapter, all components (except battery), circuit board, duplex telephone adapter, plastic outlet box, drilled faceplate and speaker. $48.95**
- **Printed circuit board with the 2822M (IC5) audio amplifier soldered in place, $12.95 Add $4 for shipping and handling. Ohio residents add appropriate state sales tax.**

COD orders accepted 24 hours a day—614-927-3495.

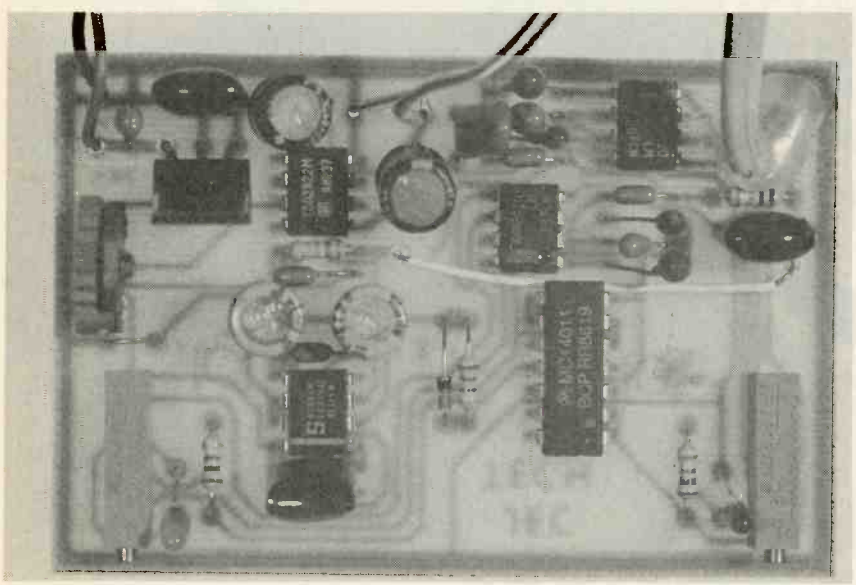


Fig. 4—COMPLETED CIRCUIT BOARD showing wiring to power jack, speaker and telephone plug.

Strip about ⅛-inch of insulation from each end of a wire about ¼-inch longer than that necessary to span the gap, and bend and insert its ends in the associated holes from the component side of the circuit board. Cut another shorter length of bare, tinned copper wire and insert it from the same side of the board as the longer jumper between one side of C10 and ground, as shown in Fig. 3. (It is located between trimmers R5 and R10.)

Observe the polarities of the aluminum and tantalum electrolytic capacitors because this circuit will not work if any of them are reversed. Insert the IC's carefully to avoid damaging their pins. Also, use extra care when soldering the IC pins to the circuit board to prevent excessive heat from delaminating adjacent copper conductors. After all soldering is complete, carefully check your work. If you can spot no errors, trim any excess lead lengths close to the board.

Figure 4 is a photograph of the completed circuit board showing the wiring to the speaker, telephone line and AC/DC adapter.

Note: The values shown on the schematic Fig. 2 provide a hold off time of approximately 0.5 second, adequate for most Phone Pager applications. However, if, after completing all assembly and test routines, you are not satisfied with that holding time, you can go back later and substitute different values of resistors and capacitors in small increments to get the time constant you want.

Packaging Phone Pager

The prototype Phone Pager was housed in a standard plastic electric outlet box with a 3-½-inch inside length to accommodate the circuit board. These boxes are available in most building or electrical supply stores.

The faceplate for the Phone Pager is a blank plastic electric outlet cover with two molded holes and screws with threads that fit the threaded holes in the outlet box. Drill a pattern of

holes about 0.30-inch in diameter within a two-inch circle through the cover to act as a speaker grill. Drill enough holes to permit the speaker tone to be heard clearly, but not so many that the faceplate is weakened and subject to damage.

The 2-inch speaker SPKR1 on the prototype was selected so that it would fit in the outlet box after it was bonded to the back surface of the outlet cover/grill. Apply a thin bead of RTV silicone or other suitable adhesive around the rim of the speaker, and clamp it in position until the adhesive sets up. Avoid spilling any adhesive on the speaker cone.

Drill a ¼-inch hole in one side wall of the outlet box to admit the coaxial plug from the AC/DC adapter as shown in Fig. 5, and mount the power jack J1. Drill any adjacent holes needed to secure the jack bracket to the box wall with rivets or small screws and nuts. Drill a hole in the opposite wall of the box large enough to admit the telephone line cord and a clamping grommet, also as shown in Fig. 5. Install the grommet.

Strip the insulation from both ends of about a six-inch length of a black and red twisted pair of hookup wires, and insert and solder the wires to the circuit board, as shown in Fig. 3 and to the lugs on the power jack J1, also as shown in Figs. 3 and 5, observing the color coding shown. Cut about a six-inch

TABLE 1
VOLTAGE MEASUREMENTS
PIN-TO-GROUND (RING)

Pin Number	IC3	IC4	IC5	IC1/IC2
1	3.6	0	0.28	3.9
2	3.5	5.0	0	3.8
3	0	0	0	2.1
4	0	5.0	0	5.0
5	3.5	3.3	0.03	2.4
6	3.5	0	0.85	0
7	0	0	0	0
8	0	3.5	0.28	3.5
9	0			
10	5.0			
11	5.0			
12	0			
13	0			
14	5.0			

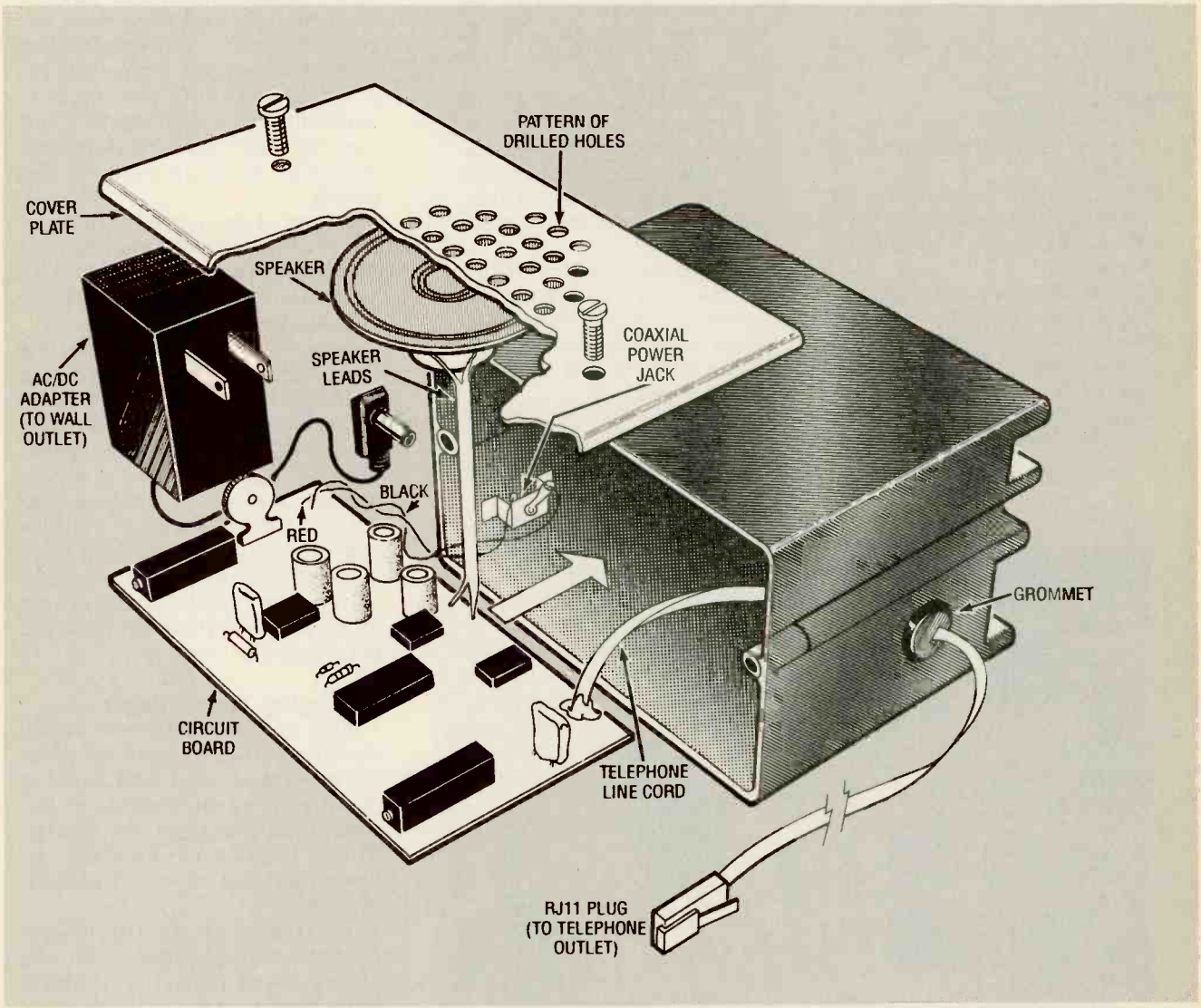
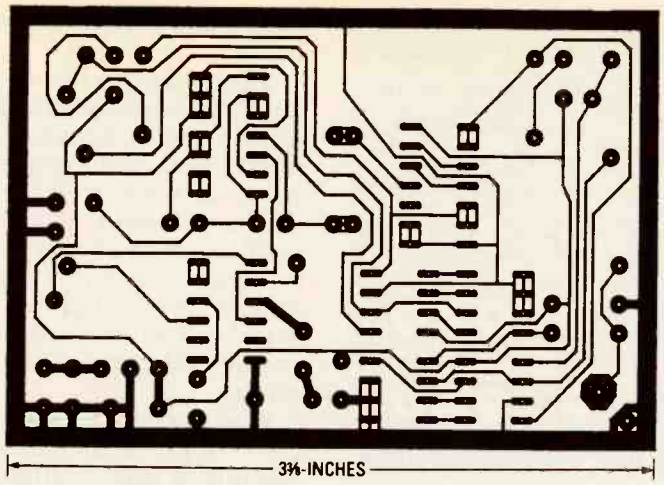


FIG. 5—EXPLODED VIEW OF THE PHONE PAGER ASSEMBLY. The speaker can be bonded to the inside of the cover, and the circuit board can be bonded to the inner wall of the case with RTV silicon or other suitable adhesive.



FOIL PATTERN for Phone Pager single-sided circuit board.

length of miniature twinlead, strip the insulation from the wire ends, insert them and solder the connections between the circuit board and the terminals on the speaker SPKR1, as shown in Figs. 3 and 5.

Cut about a seven-foot length of standard telephone line cord, strip back the insulation at both ends and install a modular RJ11/14 telephone jack on one end. Pull about four inches of the other end of the cable through the grommet and clamp it in position. Solder the red wire to the RING terminal and the green wire to the TIP terminal on the circuit board as shown in Fig. 3.

Phone Pager is now complete enough to permit test and alignment. Do not perform the final assembly procedures on the Phone Pager until you have completed the testing.

Test and alignment

Plug the wall-outlet-mounted AC/DC adapter in the AC outlet, and insert the plug at the end of its line cord in the power jack in the outlet box. Obtain a suitable voltmeter to make voltage measurements, and begin by measuring the adapter output to ground (the RING terminal shown in Fig. 3.). Its output should be between 13 and 15 volts. Next, measure the output of the 5-volt regulator IC7 to verify that it is 5 volts.

Referring to Table 1, make individual voltage measurements between each of the pins on integrated circuits IC1 to IC6 and ground while comparing them with the values listed in Table 1. If any measurements differ by more than a few volts from those listed in Table 1, check to see if you can find a reason. Any major discrepancy indicates a fault that needs to be found and corrected.

If all of the voltage measurements are satisfactory, start aligning the decoders. A Touch-Tone telephone, a duplex "Y" adapter, and the test circuit shown in Fig. 6 are used in the testing. Connect a fresh 9-volt transistor battery, a 220-ohm resistor R11, and hookup wire to form the test circuit. Either a surface-mount RJ11/14 jack or a wall plate with an RJ-11/14 jack will be needed.

Plug the duplex adapter into the RJ11/14 jack to which you have wired the battery and resistor. This provides the telephone voice voltage that generates the tones. Plug the Touch-Tone phone into one of the jacks on the adapter and plug the Phone Pager into the other one. Power up the Phone Pager, pick up the telephone handset, depress one of the keys, and listen for the tone. If you can't hear a tone, recheck the connections on the test circuit.

Monitor the green and yellow LED's on the Phone Pager. They should light up when a tone is detected. The tuning ranges of trimmers R3 and R5 were selected so that either is capable of being tuned from 697 Hz to 1477. In the prototype, tuning was done only to 941 Hz and 1209 Hz.

First tune one of the decoders to 941 Hz and the other to 1209 Hz so that the "*" can be detected. It is important that you be able to confirm that you are tuned to both frequencies, and that both decoder IC1 and IC2 are not tuned to the same frequency. A simple method to determine this will be discussed later.

Start by tuning in at least one frequency. Hold the "*" key down temporarily. (A large rubber band can be stretched over the telephone's keypad to hold down an eraser set on the key.) Tune either trimmer resistor R3 or R5 until its corresponding LED lights up. Then find the middle of the trimmer's response range. This can be done

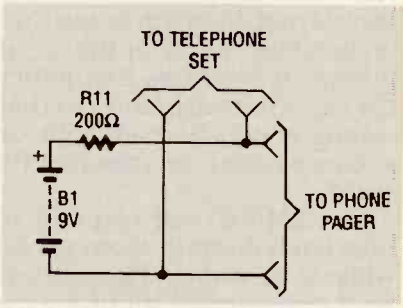


FIG. 6—PHONE PAGER TEST CIRCUIT consisting of a 9-volt transistor battery, a resistor, and wiring

by turning the trimmer shaft in one direction until the LED goes out. Note that position, and then turn the shaft in the other direction, counting those turns, until the LED goes out again.

The desired shaft setting is the position midway between the two end settings. If the LED does not light, the value of resistor R1 is probably too high. Temporarily bridge a 10,000-ohm resistor across R1 to see if it causes the LED to light. If either of the LED's remains illuminated continually, check the polarities of all electrolytic capacitors against schematic Fig. 2, and remove and reposition any one of them if you have made a mistake.

A determination of the optimum value for resistor R1 can be performed later. The value

given in Fig. 2 should be considered as a starting point for any substitutions.

When a trimmer is set at its midpoint for a desired frequency, determine if it it is locked to the low (941 Hz) or the high (1209 Hz) frequency. Figure 7 shows the frequency matrix of a TouchTone keypad. It consists of three high-group frequencies along the horizontal axis and four low-group frequencies along the vertical axis. You can easily determine if you're tuned to a low or high frequency by depressing an adjacent key to see if the related LED still lights up.

In tuning the "*" key, press the "0" (zero) key, and if the LED still lights up, you are tuned to the low 941-Hz tone. Similarly, press the "7" key, and if the LED still lights, you're tuned to the 1209-Hz tone. Note: The LED should not light up when you press either the "0" or the "7". If it does, it indicates that either the capacitors are faulty so that tuning is not sharp enough, or a component is incorrectly wired.

The LM567 will respond to tone levels down to about -15 dB when it is tuned. Those levels were measured on the prototype at pin 3 with a Hewlett-Packard HP-3551 transmission test set in the bridged-reading mode. The bandwidth of the response curve was approximately ± 25 hertz, depending on the level of the tone. Note that the bandwidth varies according to the change in frequency at the time the reading is taken.

However, you will probably not need to use a transmission test set if you have carefully followed the alignment directions given here. The setting should be close to optimum without having to make any additional measurements.

If all tests have been passed at this time, tune in the other frequency. Depress the "*" key again and tune the other trimmer (either R3 or R4) for midrange on the other frequency, following the same procedures that were given earlier. You should hear tones from the speaker during the timing cycle

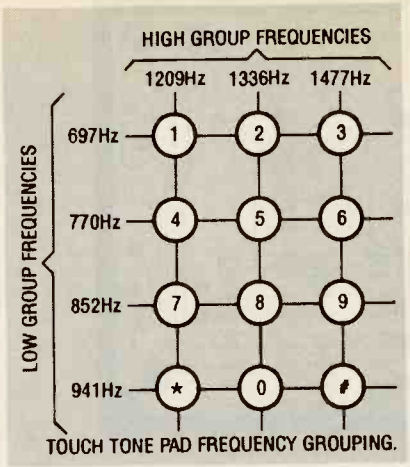


FIG. 7—MATRIX OF FREQUENCIES activated by the keys of a touch-tone telephone.

when you decode the second frequency. Retune each trimmer until you are satisfied that they are both at midrange. Caution: Be sure that the decoder/timer is not activated by any other keys on the TouchTone pad while performing this procedure.

Observe the LED's while depressing different keys. The only time both LED's should light simultaneously is when the key you want to detect is pressed. Even if the circuit operates, you might not be satisfied with the output audio from the speaker. That volume depends on a number of factors: input level related to the make of your telephone, and the voltage provided by your local phone company. You can substitute another value for Tip resistor R1, which controls the level of the audio input to the tone decoders. Make trial-and-error substitutions in increments of about 20,000 ohms.

If the level is too high, you might experience false tripping with normal speech level on the line. If the level is too low, the decoders might not be able to decode the tones properly. If you experience false "tripping," substitute a higher value for resistor R1, again in increments of about 20,000 ohms, until you find one that works well. The optimum value is one that still allows the tones to be decoded, but doesn't trip during normal conversations. Substitute a lower value for R1 when the decoders are unable to decode the tones.

If you want to use the Phone Pager in conjunction with an answering machine, as was mentioned earlier, reduce the value of resistor R1 in increments of about 20,000 ohms until you find a value that gives a satisfactory audio output. It should be comparable to that generated when Phone Pager is connected directly to a telephone.

When the Phone Pager is complete, apply small spots of RTV silicone or other suitable adhesive to the corners of the circuit board on the foil side. Then position the board in the outlet box as shown in Fig. 5, and press it into position. After the adhesive has set, carefully arrange the wiring within the case to avoid any twists or interference with any component, and close the cover with speaker mounted on the inside. Secure the cover to the case with the two screws provided. The Phone Pager is now finished and ready for use.

Phone Pager can be organized so that any of the other 11 keys on the TouchTone keypad phone can be used for activation. If you want to use a key other than the "*" key, refer to the frequency matrix in Fig. 7 and tune the trimmers accordingly.

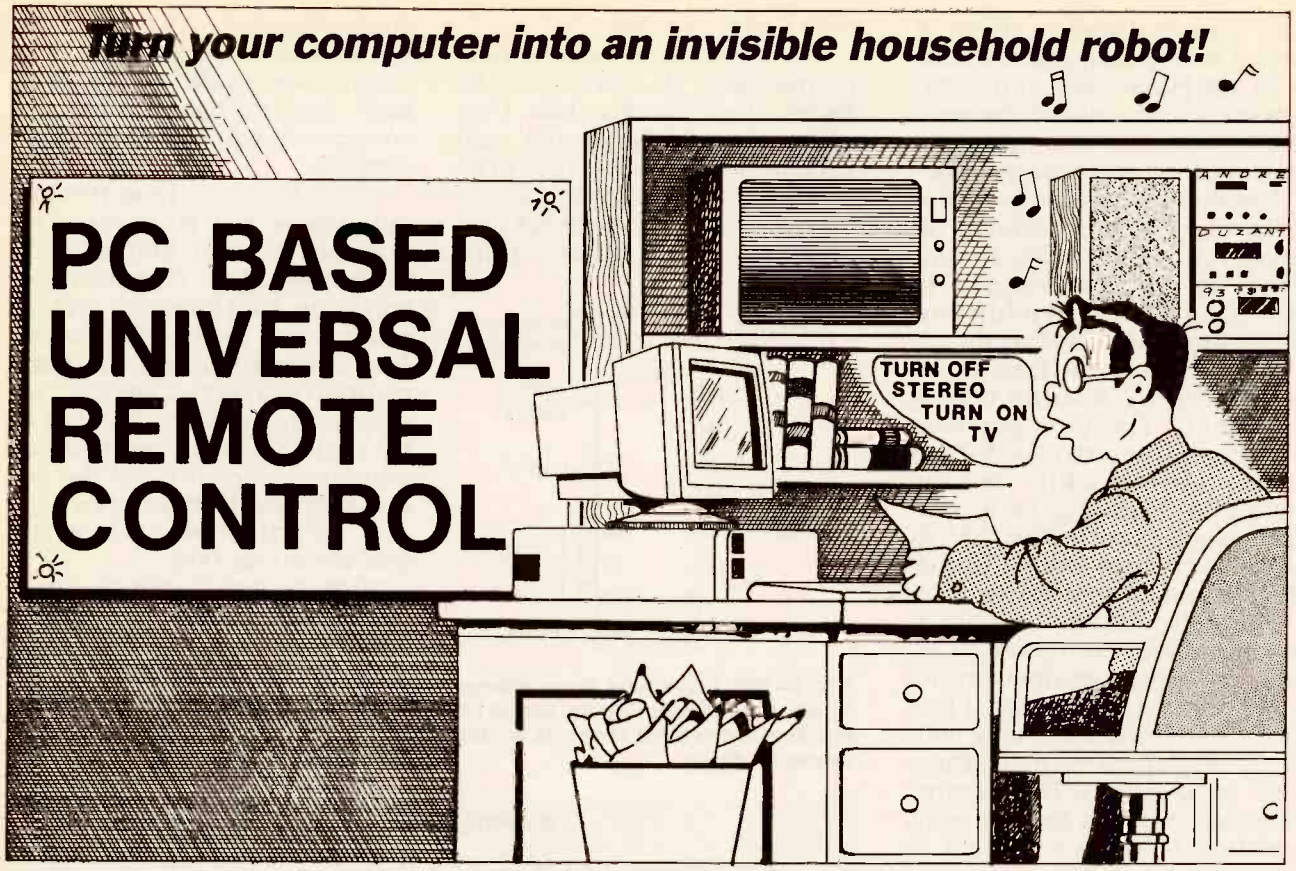
Installation

Decide where you want to place your Phone Pager. For a final Phone Pager installation, disconnect your phone from its standard RJ11/14 jack and plug a duplex adapter in its place. Then re-connect the phone plug in one jack and Phone Pager in the other. Plug the AC/DC adapter in the wall outlet, and put the adapter plug in the jack in the case. Phone Pager is ready to work for you.

At a minimum you'll probably want one at any extension phone, assuming that you consider the kitchen or hall phone to be your "base" primary phone. After you have tested your Phone Pager and found out how well it works, you'll probably want one on every phone in your home. Ω

Turn your computer into an invisible household robot!

PC BASED UNIVERSAL REMOTE CONTROL



JON BEK

INVISIBOT IS THE NAME OF THE AUthor's home-control system. It stands for Invisible Robot. Invisibot started off by combining X-10 control with a voice-recognition and synthesis system. That gave the author the capability to say things like *Please dim the lights*, and have Invisibot respond accordingly. (Note that our sidebar contains detailed information on the X-10 and voice-control parts of the system.)

The one thing he wanted Invisibot to do that wasn't available "off-the-shelf" was to control TV's, VCR's, and other IR-controlled consumer-electronics gear. Even though we all have several remotes to control these toys, they always seem to hide under seat cushions, in magazines, and other unlikely places. When we do manage to locate a remote, it's usually the wrong one, or the batteries are dead. We're sure you've experienced the same problem.

Of course, there are the "smart" units that can control several devices, even ones from different manufacturers, but the thought of buying yet one more remote holds limited appeal. Invisibot was created to eliminate the need to push any remote-control buttons again.

Universal remotes

There are two types of universal remote controls: learning and preprogrammed. Typically both can remember the codes for several devices. In addition to its infrared transmitter, the "learning" control also has an IR receiver that it uses to learn how to control your devices. You put the universal remote into a "learn" mode, point your other remote at it, and press a button. The universal remote then memorizes the pattern it receives. That pattern can be assigned to a button on the learning remote so that each time you press that button in the future, the remote will send the corresponding pattern.

The other type of "smart" remote is preprogrammed with the signal patterns for many popular devices. To set up a preprogrammed remote, you enter a code corresponding to the model of TV or VCR you want to control; henceforth, the remote will use those codes. The advantage of the preprogrammed remote is that it's faster and simpler to set up; in addition, you can use one to replace a lost or damaged original. This project uses a Memorex AV-4 preprogrammed "smart" remote, that can be purchased from a corner drugstore for about $40.

Rows and columns

The AV-4 consists of one IC, a few resistors, several diodes, the infrared transmitter LED's, a capacitor, and a simple row-by-column, or matrix keyboard. Picture a tic-tac-toe board with columns labeled 1, 2, 3, . . . and rows labeled A, B, C, ... Each button on the keyboard corresponds to one letter/number

pair. The goal was to devise a circuit that would connect to an existing PC simply and inexpensively, and activate the rows and columns of the keyboard matrix under software control.

A standard parallel port provides a suitable interface. All signals run at five volts, so connecting to the remote is straightforward. In addition, the printer port is directly addressable, even in BASIC, so programming wouldn't be a challenge. The only problem was how to control a 5-by-8 switch matrix using only the eight bits that comprise a standard parallel port. Five CMOS 4051 8-channel analog multiplexers make the job easy.

The 4051's, shown in Fig. 1, have three address inputs (A0, A1, and A2), eight channel inputs (0–7), and an input/output (I/O) pin. Each 4051 internally connects one of its eight channel lines to its I/O pin. The channel selected depends on the combination of signals applied to the input-select lines.

The address inputs are weighted in a binary fashion (A0 = 1, A1 = 2, A2 = 4). You select the desired channel by applying "highs" to the appropriate address inputs. For example, to select input channel 5, you would apply +5 volts to the A0 and A2 address inputs. The three address inputs provide a total of 2^3, or eight combinations, ranging from 0 to 7.

The 4051 has one other input, chip enable, or $\overline{EN}$ for short. When $\overline{EN}$ is brought high, the IC prevents any connection between I/O and the input channels, regardless of the states of the address inputs.

Circuit details

The complete circuit, shown in Fig. 2, consists of five 4051's, some pull-up resistors, and a connector. Note that the eight columns from the remote's keyboard form a "bus" to which the eight channel lines of all five 4051's are connected in parallel. Also note that each of the remote's five rows connects to the I/O line of a different 4051. Thus, all the channel lines will be selected simultaneously, but with only a single I/O line.

The computer's parallel port connects to J1. Of the eight lines, three form a bus that drives the address inputs, and each of the other five lines drives a separate $\overline{EN}$ input on the 4051's. That arrangement presents the same binary input

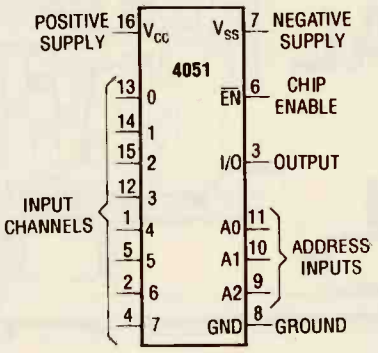


FIG. 1—THE 4051's have three address inputs, eight channel inputs, and an I/O pin. One of the eight channels is connected to I/O pin.

combination to all five 4051's, but as long as the software drives only one of the five $\overline{EN}$ lines high, only a single row-column connection can be made at any one time.

To understand how the circuit works, let's go through an example. Assume first that the PC has set all the $\overline{EN}$ lines high, so all the 4051's are off, and no row-column connections exist. Now assume that we want the computer to "press" the key corresponding to intersection A1 in the matrix. That corresponds to a binary value of 001 at the address inputs. By driving A0 high and the other two (A1 and A2) low, we obtain 001.

With the 4051's still disabled, the PC drives the $\overline{EN}$ line of IC1 low, which turns the device on. That makes the connection between row A and column 1, just as if we'd physically pressed that key.

MY FRIEND, INVISIBOT

I've always been fascinated by robots. Since the first time I saw "Forbidden Planet" as a child, I was certain that someday one of those electronic servants would cater to my every whim. I still don't have anything that looks like Robby the Robot, but I do control many of the lights and appliances in my house with spoken commands—and my invisible robot responds verbally as well!

The primary elements of "Invisibot" came as two off-the-shelf accessories for my PC: the X-10 CP290 computer interface, and the Covox Voice Master Key system.

The X-10 product has been around for years; it consists of a master control unit and one module for each appliance you want to control. The modules can be installed in place of normal light switches in the wall, or plugged in between the AC power outlet and the device being controlled.

The X-10 system communicates commands to the control modules by taking advantage of the fact that higher frequencies can piggyback on top of lower frequencies. The power service in your home is low-frequency 60-Hz alternating current. The X-10 system injects high-frequency signals via the power outlet on the 60 Hz. The information encoded in those high-frequency signals then travels over your existing house wiring to the control modules, which decode and act on it.

Each module must normally be set to a unique address; the control module sends one command at a time to a unique address.

Modules vary in price and functionality, but their average cost is about $12. You can purchase compatible modules from Radio Shack, Sears, and Stanley hardware dealers.

The CP290 controller attaches directly to the serial port of your PC, and is sold with software that allows you to start controlling your home immediately. The CP290 typically sells for about $40; you can purchase one from Egghead Software or Radio Shack. I was fortunate enough to be able to purchase mine some time ago for $19 on a close-out sale.

The other major component of the Invisibot consists of a Covox Voice Master Key, which provides both speech recognition and synthesis. The Master Key plugs into a standard PC bus; it can record and play back speech or other sounds, and includes an excellent speech-recognition package.

A memory-resident software module allows you to store a set of commands, each of which can be sent to DOS when the board recognizes a given phrase. For example, when I speak the command, "Oh butler, brighten the den," the system sends the proper commands to DOS to: 1) Play back a prerecorded voice file containing the words, "Yes sir! Right away sir!" and 2) Run the X-10 control program with the proper parameters to increase brightness in the den to 100%.

Not being content to control things through X-10 modules, I then designed the universal remote control project described here. Ω

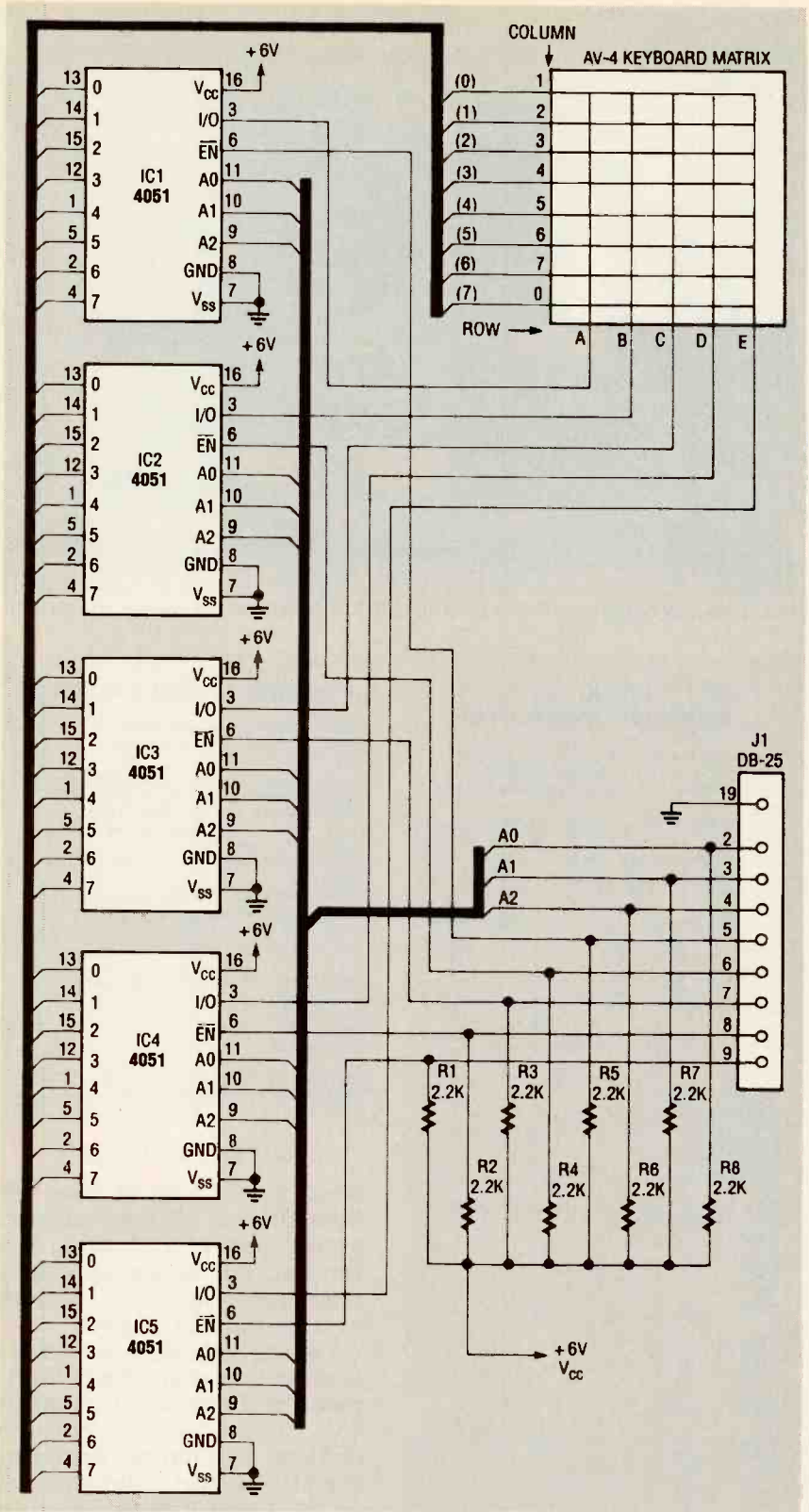


FIG. 2—INVISIBOT DRIVES A UNIVERSAL REMOTE CONTROLLER with five 4051 1-of-8 multiplexors.

Remember that until $\overline{EN}$ goes high again, the remote control will act as if the key remains pressed. Hence the software must reassert $\overline{EN}$.

Construction

Because of the simplicity of the circuit, the prototype was built using wire-wrap and point-to-point techniques. No PC board patterns are provided. The following are instructions for disassembling the remote control, mounting its PC board on a piece of perforated board, wiring the 4051's, making the remainder of the connections, and installing the device in a suitable enclosure.

First, remove the PC board from the AV-4 and clip off the metal battery contacts, leaving long power leads. Next, identify the row and column locations of the keyboard matrix. Then, using a hobby knife, carefully scrape a small patch of insulating paint from each trace of the matrix, leaving its shiny copper surface exposed.

Carefully solder connecting wires to the exposed traces of the AV-4 board. Cleaning them with a new rubber eraser or alcohol swab will help make a better solder connection. Tinning the wire and the traces before soldering will also help.

Mount the components on the perforated construction board, leaving enough space for the AV-4, as shown in Fig. 3. Mount five 16-pin DIP sockets for the 4051's, and a sixth to be used as a socket for the eight pull-up resistors. Then make all connections, using Fig. 2 as a wiring guide. Remember to connect pin 16 of each IC to V_{CC}, and pins 7 and 8 to ground.

Connect the power leads of the circuit and the AV-4 to the wall-mount transformer, *carefully observing polarity.* Bend the resistor leads to fit cleanly into the DIP socket, remove excess lead length, and insert the resistors. Now insert the 4051's,

PARTS LIST

R1–R8—2200 ohms, ¼-watt
IC1–IC5—4051 CMOS 1-of-8 decoder
J1—25-pin female DB-25 connector
6-volt DC, 300 mA, wall-mount transformer
Six 16-pin DIP sockets
Perforated construction board
Universal remote control (Memorex AV-4 or equivalent)
6-foot male-to-male DB-25 ribbon cable
Metal project case large enough to accommodate construction board and remote control
PC-board standoffs and mounting hardware

observing normal rules for handling electrostatic discharge-sensitive devices. Now we're ready to test the controller.

Important: Always apply power to the interface before attaching it to the PC, and disconnect it from the PC before turning off the controller. Because the interface draws very little power, you might want to leave it on all the time.

Use a nibbling tool (or a drill and a file) to make openings in the project enclosure for the DB-25 connector (J1), the power cable, and the AV-4's infrared LED's. Mount the board in the enclosure using four stand-offs, and the interface is complete.

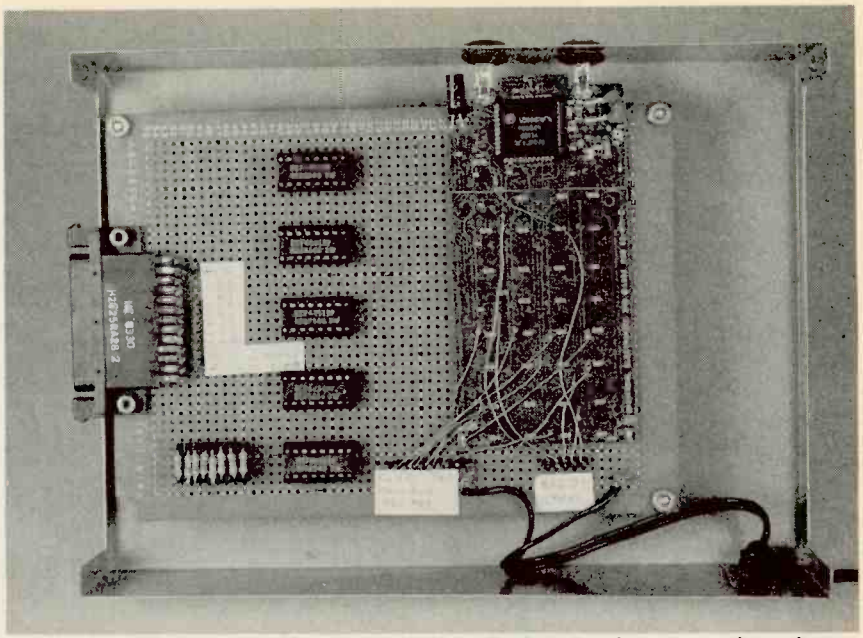


FIG. 3—MOUNT THE CONTROLLER AND CIRCUIT BOARD in the case as shown here.

Programming considerations

We don't have enough space to present a complete listing of the entire program. Moreover, if you don't use an AV-4 and a Sony TV, the commands won't work for you anyway. However, we present enough information so that you can test the unit and modify the command structure to suit your needs. In addition, the code will be posted on the *Electronics Now BBS* (516-293-2283, 1200/2400, 8N1) as a file called NVISIBOT.BAS. All code was developed in Microsoft QuickBASIC.

The interface uses only the data lines of the port, and ignores the control lines, so the software does not use the familiar LPRINT command. Instead, it uses the OUT instruction, which sends a byte of data directly to the specified port.

Listing 1 shows a set of constants that makes it easy to specify different rows and columns in the software. The first group (Chip1–Chip5) provides the values to enable each 4051; the second group shows the values to enable each row of the matrix; and the third group shows the values to enable each column. Enabling a particular position in the matrix is simply a matter of executing an OUT statement. (*Editor's Note: Determining the address of your LPT port can be tricky; more on that below. For now, assume use of LPT1 at an address of 0378 hex, or 888 decimal.*) To enable position A1 in the matrix, execute the command:

LISTING 1—INVISIBOT CONSTANTS

```
REM ***********************************
REM * INVISIBOT INTERFACE CONTROL *
REM ***********************************
REM
REM lpt 1 port = 378h = 888 decimal
REM data lines: A = 1, B = 2, C = 4
REM chip inhibit lines: chip 1 = 8,
REM chip 2 = 16, chip 3 = 32,
REM chip 4 = 64, chip 5 = 128

REM ****** chip ENABLES table *****
chip1 = 255 - 8 - 7
chip2 = 255 - 16 - 7
chip3 = 255 - 32 - 7
chip4 = 255 - 64 - 7
chip5 = 255 - 128 - 7

REM ****** data channel table *****
data0 = 1
data1 = 2
data2 = 3
data3 = 4
data4 = 5
data5 = 6
data6 = 7
data7 = 0

REM ****** chip correspondence ****
REM | chip# | URC Row |
REM      1         A
REM      2         B
REM      3         C
REM      4         D
REM      5         E

rowa = chip1
rowb = chip2
rowc = chip3
rowd = chip4
rowe = chip5

REM ****** data correspondence ****
REM |  ABC  | URC Column |
REM     000         1
REM     001         2
REM     010         3
REM     011         4
REM     100         5
REM     101         6
REM     110         7
REM     111         0
```

LISTING 2—STALL ROUTINE

```
REM ********************************
REM *        STALL ROUTINE         *
REM *                              *
REM * make a URC keypress long     *
REM * enough to ensure command     *
REM * gets sent, then clear the    *
REM * keypress and allow circuit   *
REM * to settle                    *
REM ********************************
stall:
REM hold the button down
REM for a time ...
FOR i = 1 TO 1500
NEXT i

REM let all buttons up and wait
REM for a time ...
OUT 888, 255
REM FOR i = 1 TO 5
REM NEXT i

RETURN
REM ********************************
```

OUT 888, ROWA + COL1

Next execute a short delay, and then disable all rows and columns. Listing 2 shows a subroutine that delays processing after "pressing" a key, followed by a "release" of all keys.

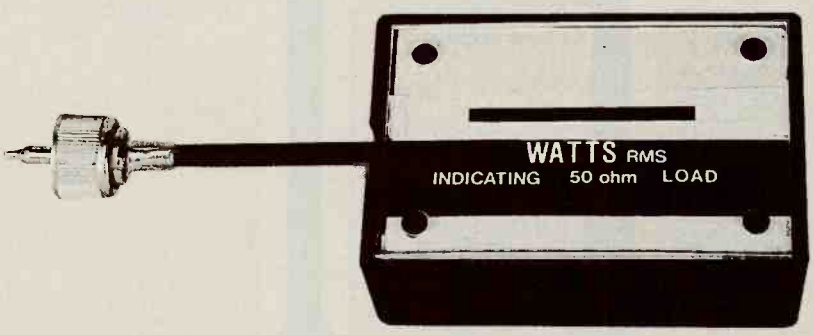
Listing 3 shows a demonstration routine that selects the TV mode of the AV-4, turns on the TV, ramps up the volume, changes the channel, and turns the TV off again. Unless you use an AV-4 and a Sony TV, these commands probably won't work for you.

Listing 4 shows a diagnostic routine that enables each row and column of the matrix, requesting that you press Enter after each position. The routine

(Continued on page 106)

BRIAN MCKEAN.

BUILD A NOVEL LCD AMMETER AND RF POWER METER



Make useful and inexpensive ammeters, power meters, or temperature indicators from Duracell's Copper Top Testers

DURACELL INC. REVOLUTIONIZED the marketing of consumer electronics batteries with its *Copper Top Tester*, a disposable instrument for measuring power cell charge that is built into the blister packages for its products. The tester consists of a thin-film resistor combined with a liquid-crystal bargraph display. This article shows how the tester can be recycled to make low-cost ammeters, wattmeters or transition temperature sensors.

The tester provides a reliable indication of the charge on a power cell or battery in seconds. All you do is position positive and negative terminals of the cell to match the corresponding contact pads of the tester, insert the cell between the contact pads, and squeeze the pads with thumb and forefinger down on the cell terminals.

After a few seconds you'll see a colored band gradually rise on the face of the tester. When it stops rising, observe the height of the column: If the colored band does not rise above the red "replace" zone, (or is only slightly above it), dispose of the cell. However, if the stripe stops near the top of the column, you can be assured that you have have a fresh, reliable cell.

The tester is an attractive feature on the product package, especially for those people who buy lots of disposable cells and do not own a separate battery tester—which means most of the population. Before discussing the practical instruments that you can make from a recycled *Copper Top Tester*, lets find out how it works.

How it works

The tester is an assembly on a thin plastic substrate of a tapered thin-film resistor back-to-back with a colored stripe coated with a photochromic liquid-crystal emulsion. Both sides of the tester are shown in Fig. 1.

The apparent rising color band or column is really the result of a progressive state change of the heat-sensitive liquid-crystal film. The optical density of the liquid-crystal film changes at a transition temperature of 43°C (109.4°F). The liquid crystal is opaque below this threshold and transparent above it. As the heat migrates across the plastic substrate, a gradual transition from opaque to transparent occurs, slowly revealing the underlying colored stripe.

When a cell is clamped between the tester's conductive pads, current flows in the tapered thin-film resistor, raising its temperature in accordance with the power law.

Different versions

The patented tester (Duracell Inc. No. 4723656) is produced in different versions to test most standard alkaline cells—AA, C, and D, for example. The deposition of resistive film is approximately 0.001-inch thick. As shown in Fig. 1, it is about 1-$^{1}\!/_{16}$-inch long, tapered from $^{3}\!/_{16}$-inch at one end to $^{1}\!/_{16}$-inch at the other end.

The resistance values of the element are about 6 ohms for the AA and C cell tester and 4 ohms for D cells. The resistive wedge is terminated at both ends by conductive-film pads that act as terminals. Although more conductive than the resistive elements, the pads add nearly 1 ohm to the value of the resistive element if the measurement is made from the extreme ends of the pads.

For example, the resistance of a D-cell tester element taken across both ends is about 3.7 ohms. But if the measurement

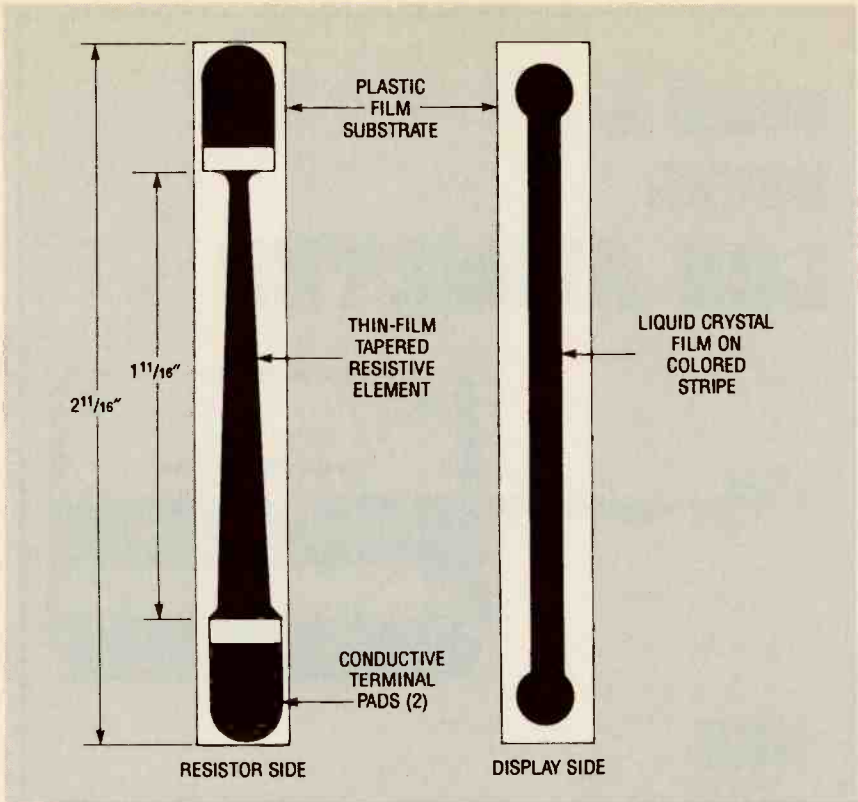


FIG. 1—DURACELL'S COPPER TOP TESTER: Resistive element side (left) and liquid-crystal thermochromic display side (right).

is taken from the ends of the pads, the overall resistance is about 4.6 ohms.

The heating produced by the element is proportional to its resistance and the square of the applied voltage. The tapered element linearizes the liquid-crystal display. As in any thin-film resistor, the resistance at the wide part of the taper is less than it is in the narrow part. As a result, the narrow region dissipates more power than the wide region. This means that a weak cell, which delivers less current, can't heat up the wide region enough for the the liquid-crystal film to reach its transition temperature.

The display element is a coating of thermochromic liquid-crystal emulsion 0.001-inch thick by 3/32-inch wide.

The tester is bonded to the inside of the clear plastic blister package with a welt over the liquid crystal bargraph to protect it during manufacture and use. This cover reduces the sensitivity of the element to environmental temperature changes and prevents it from contacting hot objects directly.

Recycling the tester

The tester can be removed from the bubble pack by carefully peeling it off. Removal will probably damage the printed legends on the package, but they are not important in the recycled applications. You will want to calibrate any devices you make from the testers and then mark the display face of the tester with graduations that are appropriate for its application. You might also want to add appropriate numbers to match those graduations.

To obtain the most accuracy from any instruments you make from these testers, the instrument should be calibrated only after the tester is installed in its final package so that it will be stabilized in its normal thermal environment.

A suggested method for remounting the tester on a rigid substrate for experiments or making instruments is shown in Fig. 4. The conductive contact pads on each tester are coated plastic, so they cannot be soldered. However, adequate electrical contact can be made with brass or bronze leaf or coil springs. Copper or brass screws, washers and nuts can also be used to make satisfactory electrical connections.

Figure 4 shows how small coil springs can be used as contacts. Pierce the centers of the pads with a pin and twist the springs into the holes. The springs act as connectors for the tester, and permit it to be mounted to a rigid substrate. The free ends of the spring can be straightened to form leads which can be soldered to a suitable rigid conductor, such as blank circuit-board material.

If you use this method, straighten the spring ends to shapes that permit them to be soldered to a conductive surface before twisting the springs into the tester's terminal pads. When soldering the ends of the spring to the conductive surface, hold them with metal tweezers or a folded copper strip to conduct away heat that would flow up the spring and melt the plastic pads.

In this mounting method, the copper cladding was removed from the region on the strip between the two terminals to provide electrical isolation. A thin strip of foamed plastic about 1/16-inch thick provides suitable thermal insulation.

Alternatively, you could use small copper or brass screws and nuts with a stack of small brass washers under the terminals at each end to provide the necessary 1/16-inch tester standoff distance.

Building an ammeter

The tester can be recycled as the sensor and display for a compact AC or DC ammeter with a useful operating range of 100 to 400 milliamperes.

Figures 2 and 3 are normalized voltage vs. current curves obtained from salvaged testers. They will permit you to calibrate any ammeters you build. Figure 2 was plotted from 5-ohm resistive elements taken from AA and C cell testers, and Fig. 3 was plotted from 6.7-ohm elements taken from D-cell testers. These graphs also correlate the apparent height of the color bar with applied voltage.

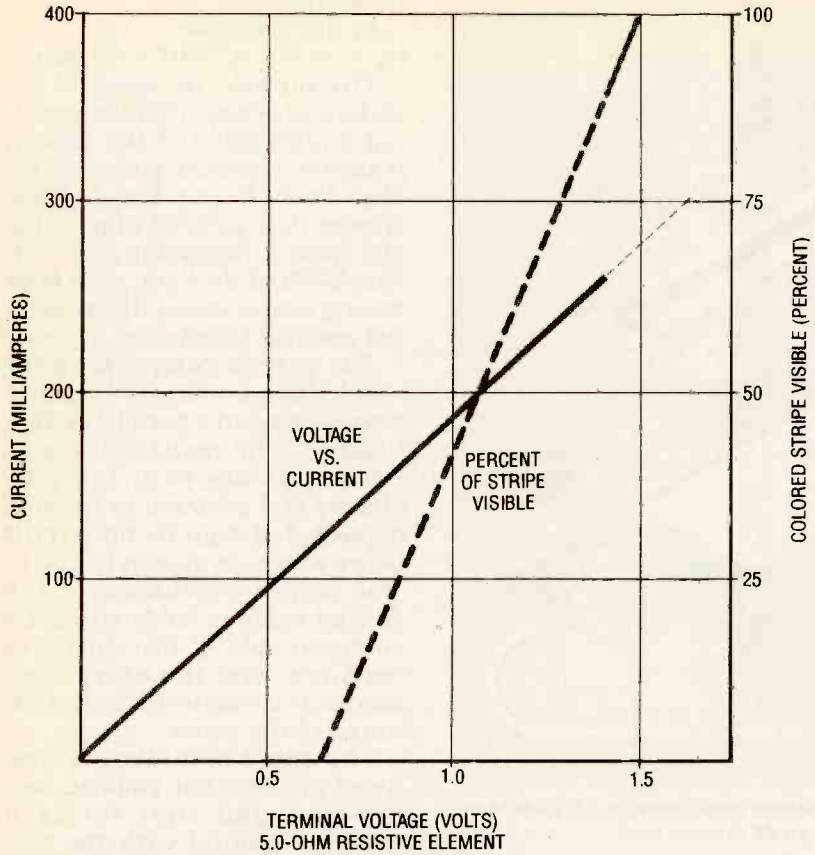


FIG. 2—CURRENT VS. VOLTAGE and voltage vs. visible stripe graph for an AA cell tester (5-ohm resistive element).

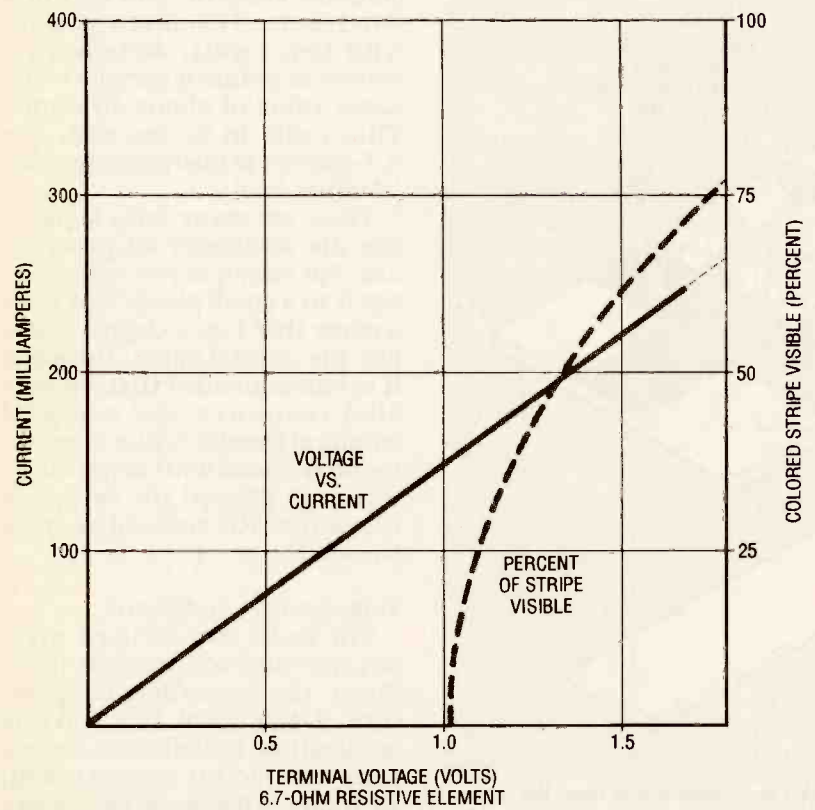


FIG. 3—CURRENT VS. VOLTAGE and voltage vs. visible stripe graph for a D cell tester (6.7-ohm resistive element).

An unmodified tester will not respond to current less than 100 milliamperes. However, the upper range of the ammeter can be extended by connecting a suitable shunt resistor across the tester.

An ammeter made from a tester will not be a precision instrument, but with careful calibration, a reading resolution of ±25% full scale can be obtained. Calibration points can be made with pen and ink and clear numbers can be transferred with decals or with artist's transfer sheets.

Flexible insulated leads terminated with miniature alligator clips can be soldered or clipped to the conducting pads on the tester substrate (Fig. 4). Small plastic boxes with hinged covers can becomes cases for the miniature ammeters.

RF dummy load

The tester-substrate assembly shown in Fig. 2 can be adapted to form an indicating radio-frequency dummy load as shown in Fig. 5. The tester actually measures the power dissipated by a resistive element, so it can measure alternating current power as well as direct current power. Because the resistive element is a film, it has low equivalent inductance and capacitance; this characteristic makes it acceptable for measuring radio frequencies.

Figure 5 shows a concept for building a low-power (less than 8-watt) 50-ohm load. The circuit can be calibrated with either a DC or low-frequency AC source. The connector installed should match the socket on the intended radio-frequency source or sources.

The resistive load is placed in series with the tester's resistive element so that their sum equals approximately 50 ohms. A practical approach is to parallel ten standard 1-watt, 470-ohm, carbon composition resistors. They are capable of withstanding up to 8 watts of input power, and they provide an approximate resistance of 47 ohms in accordance with the rule for calculating the resistance value of multiple resistors

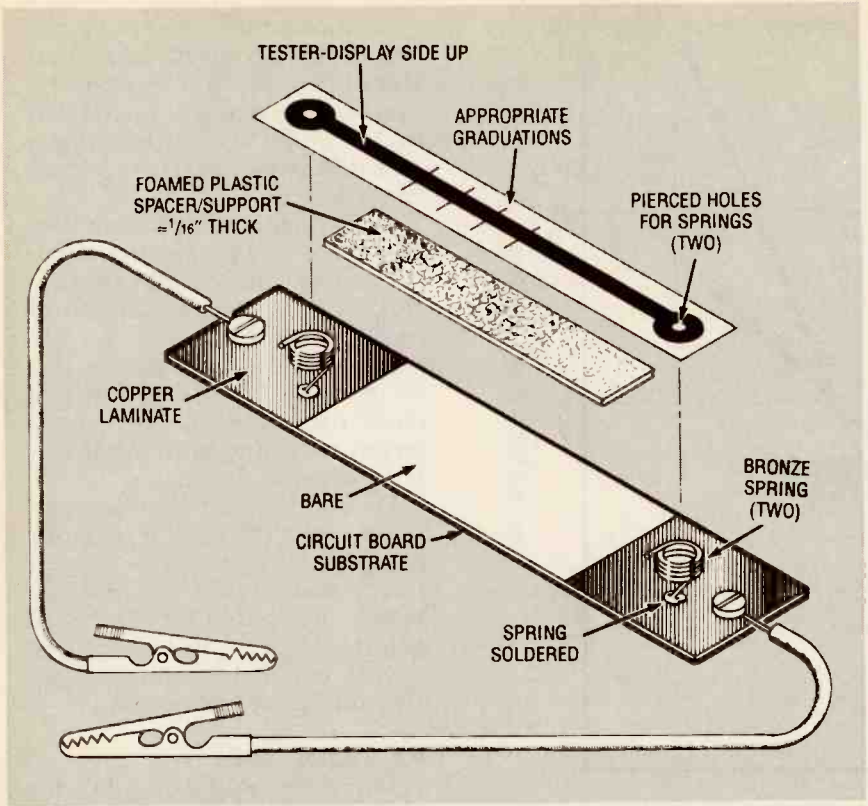


FIG. 4—ONE WAY TO MOUNT THE TESTER for practical applications such making an ammeter (shown) or as the indicating element in an RF dummy load.

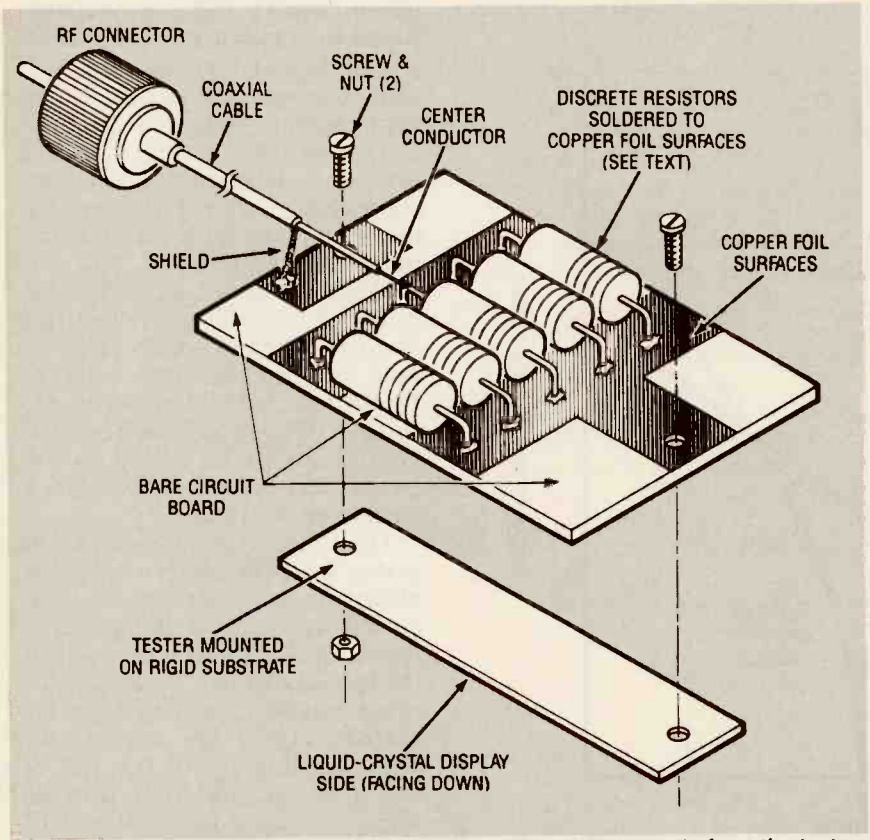


FIG. 5—AN INDICATING 50-OHM RF DUMMY-LOAD wattmeter made from the tester. One-watt resistors are connected in parallel to provide approximately 50-ohms resistance and be able to dissipate up to 8 watts.

in parallel.

In this example:

$R_T = 1/10R = 470/10 = 47$ ohms.

The cluster of parallel resistors in series with the nominal 5-ohm value of the tester's resistive element yields a 52-ohm load. Experiments have shown that this 52-ohm value will have a negligible effect on the VSWR of the load, even after taking into account the individual resistor tolerances.

The carbon composition (or thick-film carbon) resistors were ganged in a parallel configuration. The resistor leads at both ends are bent into "L" shapes and soldered to isolated copper-clad regions on circuit board stock, as shown in Fig. 5. The center conductor of the coaxial cable is soldered to the common side of the cluster of resistors, and the other common side is connected to the terminal of the tester.

The cable shielding is soldered to a separate isolated copper-clad pad that forms a common ground with the second terminal of the tester.

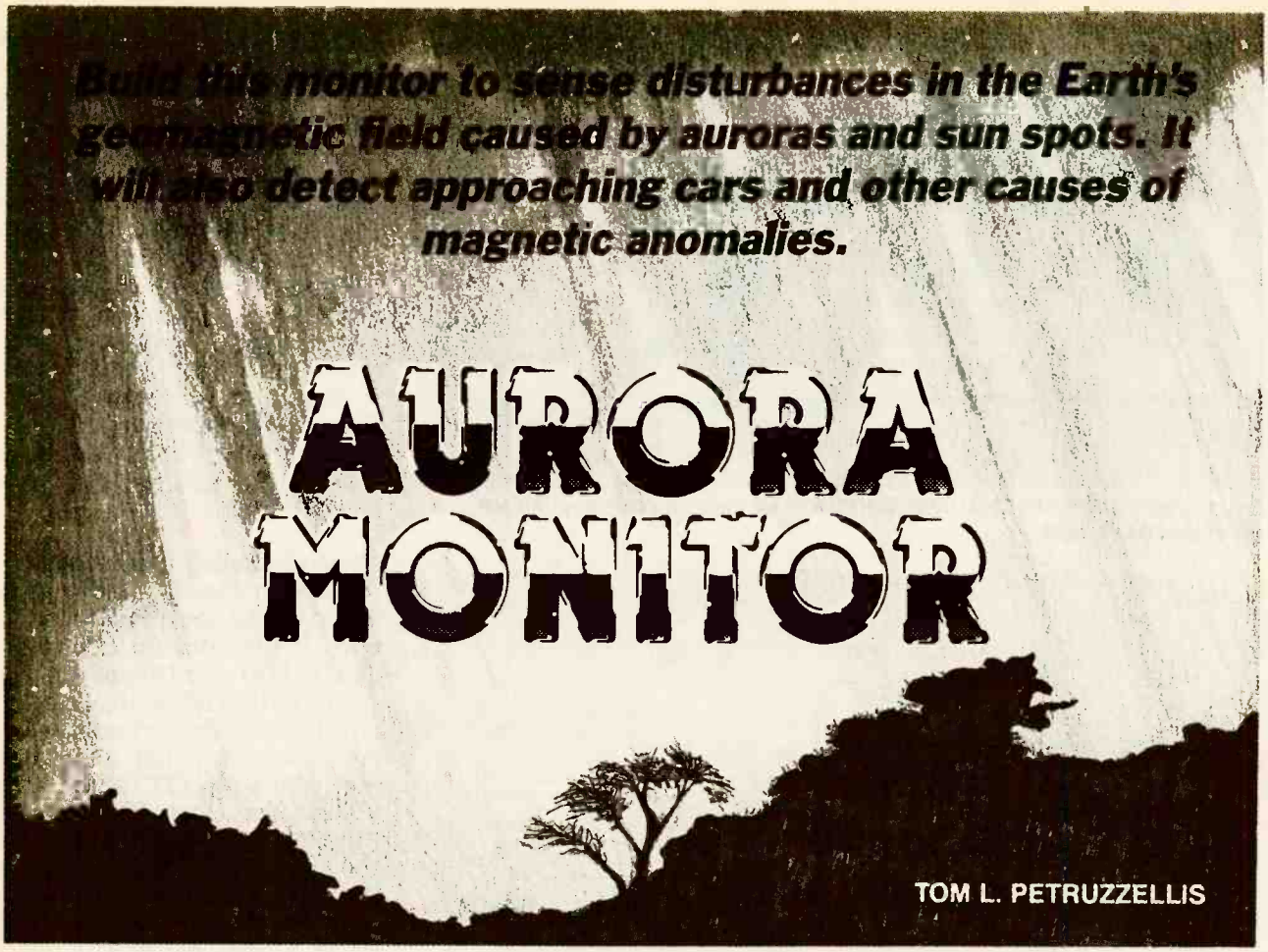
If you want to use the tester with the nominal 6.7-ohm resistance element, you can mix five 1-watt, 470-ohm resistors with five 1-watt, 430-ohm resistors to obtain a parallel resistance value of about 45 ohms. This value in series with the 6.7-ohms will also provide a satisfactory load.

There are many ways to package the wattmeter for practical use. For example you can package it in a small plastic box with a cover that has a cutout to admit the coaxial cable. However, it is recommended that the parallel resistors and exposed length of coaxial center conductor be shielded with metal foil or screen to prevent the escape of unwanted RF emissions from the load.

Temperature indicator

The tester can be used without electrical connections to indicate the transition temperature of 43°C (109.4°F). For this application, cut off the terminal pads and mount the part flush with the surface of the object

(Continued on page 110)



THE AURORA BOREALIS IS ONE OF nature's most spectacular nighttime displays. Shimmering curtains of green, white, and even red light dance in the northern skies. Visible effects of charged particles from the sun raining down on the Earth's ionosphere, northern lights or auroras, are visible in the northern night sky during high sunspot activity. The Aurora Australis, the southern hemisphere's counterpart of the Aurora Borealis, can be seen at night by looking toward the south pole.

These displays of undulating light are formed when flares from the sun's surface (sunspots) launch showers of high-energy ionized particles and X-rays into space. Mostly electrons, the showers stream out from the sun and are attracted by the Earth's magnetosphere, an invisible magnetic field around the Earth.

Shaped like an pumpkin, the magnetosphere terminates at both magnetic poles but is many miles thick above the equator. Dimples at both poles form "sinks" that funnel the particles toward the poles where they ionize the gas in the ionosphere. Those collisions induce the gases to emit their characteristic light wavelengths—as in neon signs and fluorescent lamps.

The charged particle bombardment of the magnetosphere initially compresses it, temporarily increasing the strength of the Earth's geomagnetic field. The aurora monitor described here is sensitive enough to detect changes in the field caused by those "magnetic storms." Thus it can indirectly sense sunspots and predict the presence of auroras in the night sky.

The monitor also senses changes or anomalies in the magnetic field caused by large metal objects such as cars or trucks moving near the monitor. This permits it to act as an intrusion detection monitor able to detect the approach of vehicles at night in restricted areas. The monitor can also detect the presence of permanent magnets (such as those in speakers), and stray fields from AC-power lines.

Early warning of auroras will both permit you to observe them in the night sky or use them for boosting the range of your amateur radio transmissions. Auroras and their accompanying magnetic storms generally block or scramble the lower radio frequencies, but the higher frequencies can overcome this interference. Radio amateurs aim their antennas north during those storms, thus taking advantage of the phenomena to reach other hams on the opposite side of the Earth that could not be contacted during periods of low sunspot activity.

In addition to scrambling low-frequency radio communications, the magnetic storms

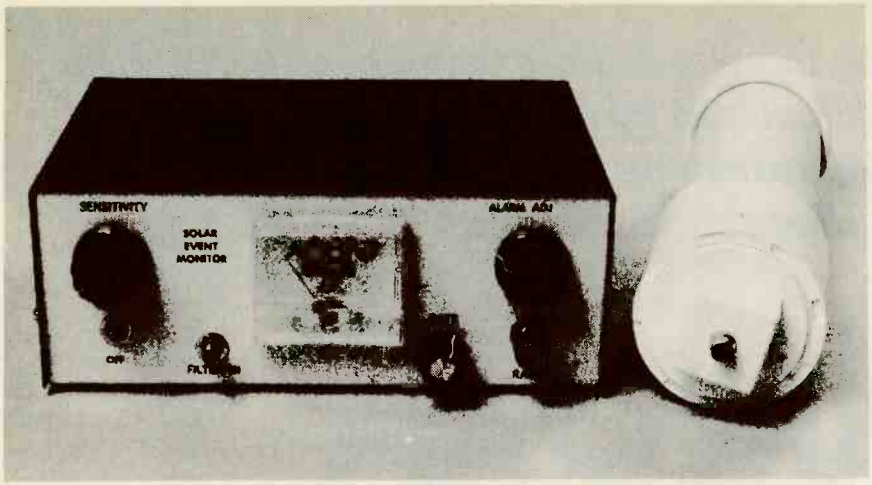


FIG. 1—THE TWO PARTS OF AURORA MONITOR are the control/display unit, left, and the sensor head, right.

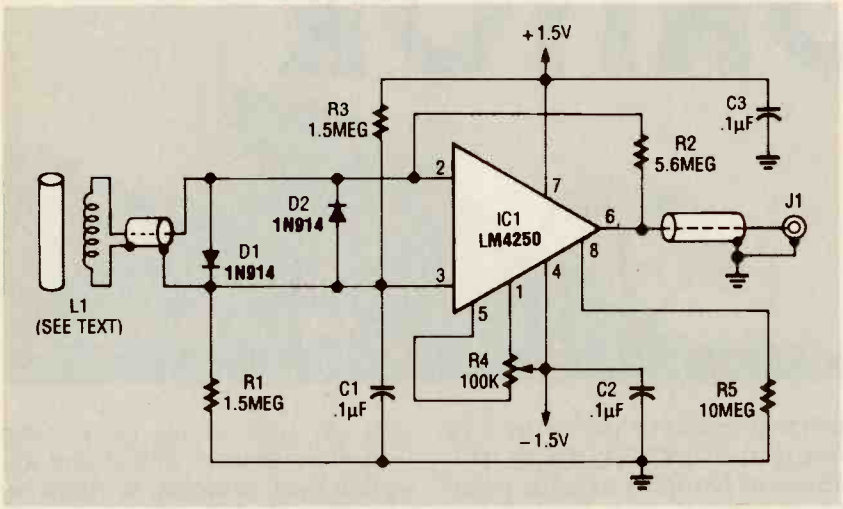


FIG. 2—SCHEMATIC FOR THE SENSOR HEAD circuit.

caused by auroras can induce large currents in power transmission lines. Those currents can cause overload, plunging large regions of the country into darkness. Auroras and related magnetic storms are quite common during the decreasing parts of the 11-year sunspot cycle such as the period we are now in.

Detecting magnetic activity.

Figure 1 shows the author's prototype Aurora Monitor. It is sensitive to a pulse of one ampere at distance of one meter, which corresponds to one milligauss. (The Earth's magnetic field is about 0.5 gauss.)

The Aurora Monitor has two components—the sensing head and the control/display unit which are connected by a coaxial cable. The sensing head contains a sensing coil, a DC nano amplifier capable of current amplification of 500, and a separate power pack, all enclosed the tubular case shown on the right side of Fig. 1.

The control/display unit contains an active filter, additional amplification circuitry, a moving-coil ammeter, and an audio oscillator with speaker. Figure 1 shows the front-panel controls and indicators of the monitor: moving-coil ammeter, SENSITIVITY, RATE, and ALARM ADJUST potentiometers as well as power (OFF), filter-in and RANGE switches.

How the sensor head works

Refer to the sensor circuit schematic, Fig. 2. Gain is provided by IC1, a National Semiconductor LM4250 programmable operational amplifier. It is protected from overvoltage and transients by diode D1 and D2, and its overall gain is set by resistors R1 and R2. The output of IC1 is driven to zero or balanced by network R3 and R4. Its output should remain at zero as long as no changes occur in the ambient magnetic field.

Bypass capacitors C2 and C3 are placed across the positive and negative power supply. Power for the sensing amplifier is obtained from two C cells. The circuit draws very little current, so it can be left on at all times—the reason why it has no power switch.

Control/display operation

Refer to Fig. 3 for the schematic of the control/display circuit. It provides an additional gain of 200 over that of the sensor circuit. The control/display circuit includes an adjustable low-pass notch filter, IC2, a Linear Technology LTC1062. By adjusting the clock frequency of the filter with resistor R11 and the capacitors C4, C5, and C6, the filter cancels interference frequencies and noise in the 2-Hz to 10-kHz band. The notch filter can also screen out 60-Hz noise. Switch S2 inserts or removes the filter.

IC3, an LM201A general purpose op-amp, filters out the clock noise generated within the filter chip. The output of IC3 is fed into the non-inverting input of IC4-a, half of a dual 747 general purpose op-amp. The overall gain of IC4-a is adjusted by resistor R16. Trimmer potentiometer R15 adjusts the offset or balance. PULSE SHAPE potentiometer R17 and capacitor C5 form an optional pulse-shaping network for coupling the Aurora Monitor to a chart recorder or an analog-to-digital conversion board of a personal computer.

The output of IC4-a is coupled to a voltage follower at IC4-b. The output of IC4-b is divided into two channels. One channel is fed through 5000-ohm SENSITIVITY potentiometer R18, which adjusts the output level of the signal fed to the 100-microampere panel meter M1. Movement of the meter's needle

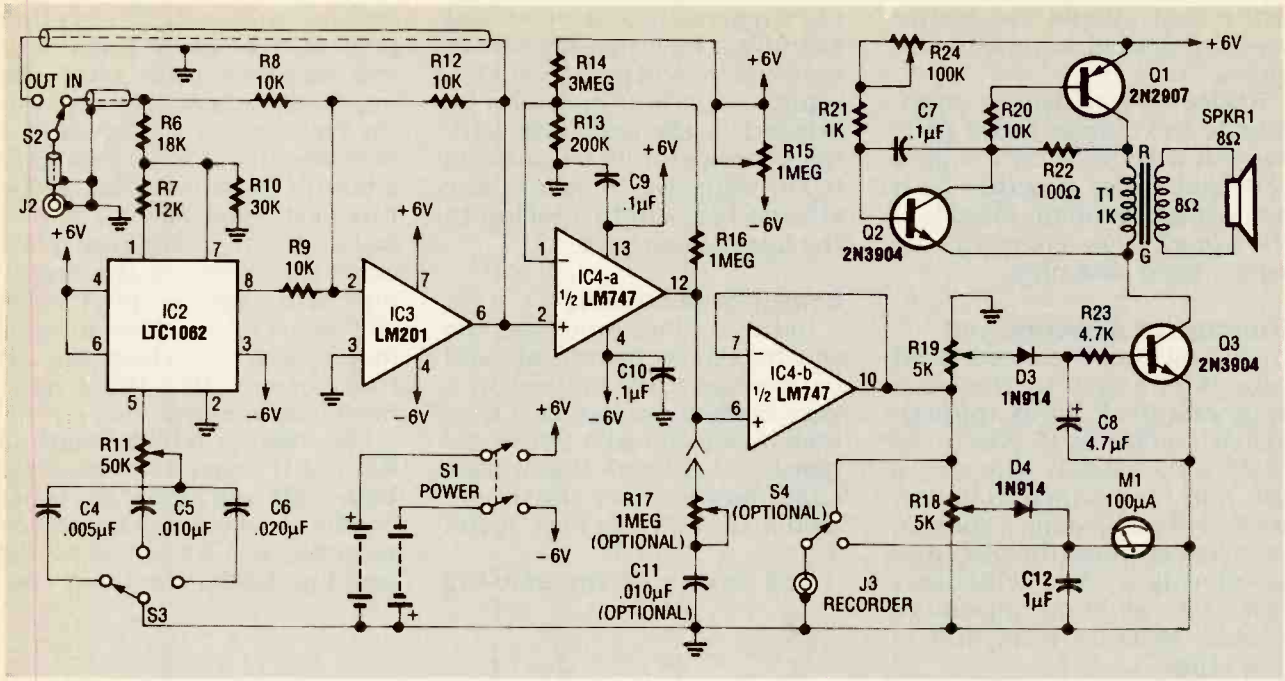


FIG. 3—SCHEMATIC FOR THE DISPLAY-ALARM circuit.

shows changes in the local magnetic field. Potentiometer R18 also adjusts the output signal that can be fed to a chart recorder for data logging.

The other channel is fed through ALARM ADJUST 5000-ohm potentiometer, R19, which sets the threshold or setpoint for the reflex oscillator circuit that follows it. The oscillator consists of transistors Q1, Q2, and Q3 and associated components. Speaker SPKR1 gives an audible indication of changes in the local magnetic field. The network of diode D3 and aluminum electrolytic capacitor C8 performs additional filtering for the input signal to the reflex oscillator section.

Transistor Q1 controls the audible alarm by clamping the negative voltage returning through the ground path. When a magnetic event occurs, the speaker emits an audible alarm, and the meter gives a visual indication of a changing magnetic field. The adjustment of ALARM ADJUST potentiometer R24 can remove distortion from the sound of the speaker.

The author's prototype control/display unit is powered by eight AA cells: four cells provide positive voltage and four cells provide negative voltage. As an alternative, the monitor can be powered by rechargeable nickel-cadmium cells.

Construction

Finished sensor and control/display PC boards can be purchased from the source given in the Parts List. However, the circuit boards can be fabricated and drilled with the foil patterns included here. The outline dimensions of the author's prototype sensor board are 2 1/16 × by 2 9/16 so the smaller dimension can fit inside the pipe section used as the sensor head housing.

The outside dimensions of the control/display board in the prototype are 2 7/8 × 5 inches to fit inside the instrument case selected. Unless the completed board is purchased, holes must be drilled in the board for mounting transformer T1 and mounting the board in the instrument case.

The circuitry can also be built on standard punch board for point-to-point wiring. The outside dimensions of the circuit boards can be modified for packaging in the instrument and sensor head cases of your choice.

Sensor circuitry

Refer to sensor parts-placement diagram Fig. 4. It is recommended that all integrated circuits for this project be mounted in sockets. Position the socket for IC1 and all resistors, capacitors and diodes on the sensor board, paying attention to the polarity of the diodes. Solder all board-mounted components in position and trim excess leads. Set the sensor board aside and assemble and solder all board-mounted components to the control/display board.

Control/display circuitry

Refer to control/display placement diagram Fig. 5. Position the three sockets for IC's 2, 3 and 4, the three transistors Q1, Q2 and Q3 and all resistors, capacitors, diodes and board-mounted potentiometers as shown, making sure that the polarities of the diodes and the electrolytic capacitor are observed. Solder all leads and trim them close to the PC board.

Verify the locations of the 1000-ohm and 8-ohm windings of transformer T1 and orient it as shown in Fig. 5. Insert the tabs of the transformer through the drilled holes and bend them to clamp the transformer to the board. Before soldering any transformer winding leads, check the windings with an ohmmeter. The reading across the 1000-ohm winding should measure in hundreds of ohms

while that across the 8-ohm winding should be only a few ohms.

Solder all transformer windings to the correct board pads and cut a length of bare copper wire and solder it across both mounting tabs on the foil side of the board. Now complete the sensor-head assembly.

Winding the detection coil

The coil L1 in the sensor head detects changes in the local magnetic field. Wind approximately 10,000 to 15,000 turns of 28 AWG magnet wire over a soft iron core ½-inch in diameter and 12 inches long. (The iron core concentrates the flux lines by offering a lower reluctance path than air.) Coil impedance should measure from 200 to 300 ohms.

Wind the fine insulated magnet wire carefully on the iron core to avoid kinks and breakage. Tape the ends of the winding temporarily to the core and carefully solder hook-up wire at each end to form permanent terminals. The terminals can be secured to the core with with room-termperature vulcanizing (RTV) adhesive to relieve any strains that might develop in the fine magnet wire.

Sensor-head housing

In the author's prototype, the sensing circuit board, coil, and battery pack are housed in a case made from standard 2⅛-inch inside diameter PVC water pipe cut to a length that will accommodate all of those elements as shown in Figs. 6 and 7.

The covers of the sensing head housing are PCV caps that press fit over the 2⅛-inch outside diameter of the pipe. The upper cap is a simple cup, but the lower cap is a sleeve with a threaded insert at its end. Drill a hole in the square base of the threaded insert for jack J1 and fasten it with a ring nut. Then close the cover on the empty pipe and drill two pilot holes 180° apart in the sleeve for self-tapping screws to clamp the cap in position after the sensor head is assembled.

Cut about a 6-inch length of RG-174/U coaxial cable, strip both ends and solder the inner conductor of one end to the jack terminal and its shield to the jack lug. Solder the inner con-

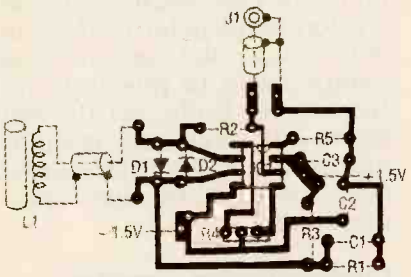


FIG. 4—PARTS ASSEMBLY DIAGRAM for the sensor head. Note that the coil L1 is a separate assembly wired to the circuit board. Refer to Fig. 7 for the mechanical assembly.

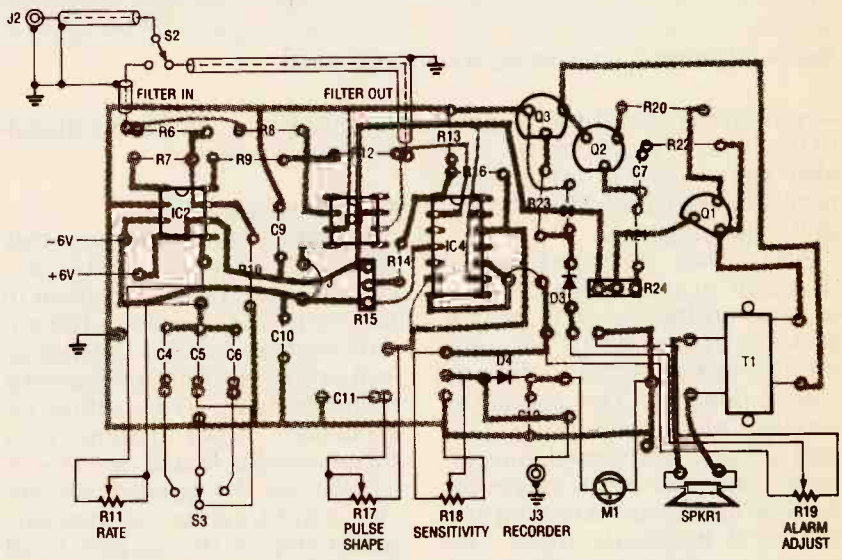
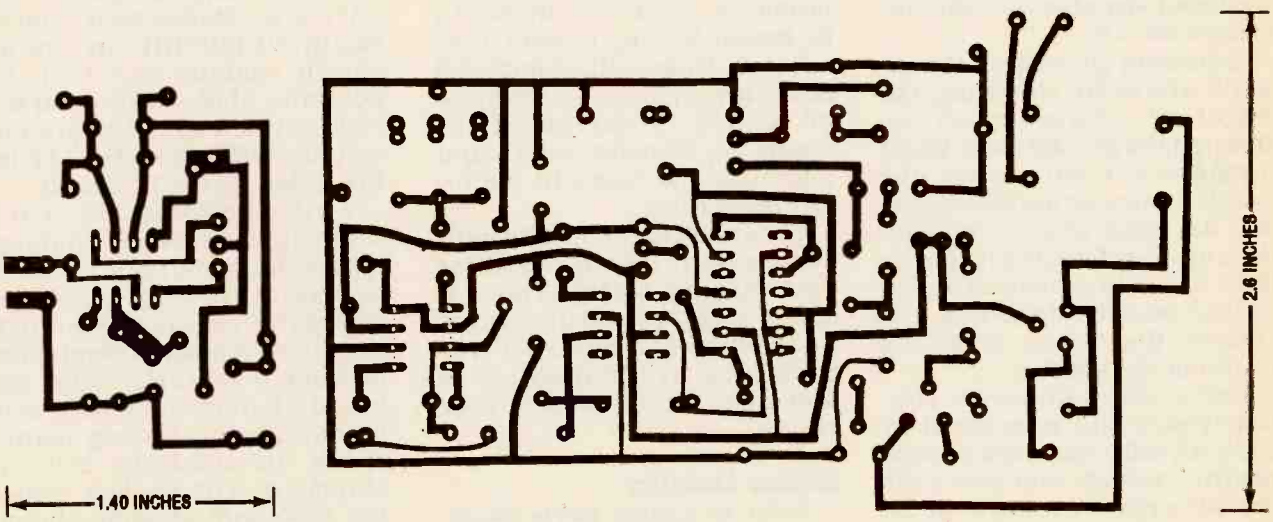


FIG. 5—PARTS ASSEMBLY DIAGRAM for the display-alarm unit. Note the panel-mounted potentiometers, switches, meter and speaker.



FOIL SIDE OF SENSOR CIRCUIT board

FOIL SIDE OF CONTROL-DISPLAY board

PARTS LIST

All resistors are 1/4-watt, 5%, unless otherwise specified
R1, R3—1,500,000 ohms
R2—5,600,000 ohms
R4, R24—100,000 ohms, PCB trimmer potentiometer, carbon, Digi-Key CEG-15 or eqivalent
R5—10,000,000 ohms
R6—18,000 ohms
R7—12,000 ohms
R8, R9—10,000 ohms
R10—30,000 ohms
R11—50,000 ohms, panel-mount potentiometer, Radio Shack No. 271-1716 or equivalent
R12, R20—10,000 ohms
R13—200,000 ohms
R14—3,000,000 ohms
R15—1,000,000 ohms, PCB trimmer potentiometer, Digi-Key CDG-16 or equivalent
R16—1,000,000 ohms
R17—1,000,000 ohms, panel-mount potentiometer, carbon, Radio Shack No. 271-1714 or equivalent
R18, R19—panel-mount potentiometer 5,000 ohms, Radio Shack 271-1714 or equivalent
R21—1,000 ohms
R22—100 ohms, 1/2W, 5%
R23—4,700 ohms
Capacitors
C1, C2, C3, C7, C9, C10—0.1μF, 35-volt
C4—0.005μF, 25-volt
C5, C11—0.010μF, 25-volt
C6—0.020μF ,25-volt
C5—0.010μF, 25-volt
. C8—4.7μF, aluminum electrolytic, 25-volt
C12—1μF, 35-volt
Semiconductors
Q1—2N2907, PNP transistor
Q2, Q3—2N3904, NPN transistor
IC1—LM4250 (National Semiconductor), programmable op-amp
IC2—LTC1062 (Linear Technology) active filter
IC3—LM201A (National Semiconductor) op-amp
IC4—LM747 (National Semiconductor) dual op-amp
D1 to D4—1N914 diodes
Other Components
S1—DPDT toggle power switch, panel-mounted. Digi-Key No. or equivalent ON-OFF
S2, S4—SPST toggle switches, panel mounted, Radio Shack No. 275-326 or equivalent
S3—three-position rotary switch, break before make, panel-mounted
M1—100-microampere moving-coil meter, GC (Rockford, IL) No. 20-1111 or equivalent
SPKR1—8-ohm speaker, 2-inch diameter, Radio Shack No. 40-245 or equivalent
T1—1000-ohm to 8-ohm transformer, Radio Shack No. 273-1380 or equivalent
L1—sensing coil (See text)
PL1 and PL2—plug, RCA-type, Radio Shack No. 274-339 or equivalent
J1, J2, and J3—jack, RCA-type, Radio Shack No. 274-346 or equivalent
Miscellaneous: PC boards for sensor and control-display, sockets for IC's (three 8-pin and one 14-pin DIP), Instrument case with removable cover (Radio Shack No. 270-274 or equivlent), PVC pipe with 2 1/16-inch I.D.(see text), two PVC end caps for 2½-inch O.D. pipe (one plain, the other with a threaded end plug), two quad AA-cell holders, one dual C-cell holder, two C and eight AA alkaline cells, knobs for potentiometers and switches, RG-174/U coaxial cable (see text), spool of No. 28 AWG magnet wire, iron rod ½-inch O.D. × 12 inches long, non-magnetic stainless steel self-tapping screws, hook-up wire, bare copper wire, solder, nuts, bolts, lockwashers, PVC adhesive, RTV adhesive, miscellaneous hardware.
Note: The following monitor parts are available from Tom L. Petruzzellis, 340 Torrance Ave., Vestal NY 13850:
- PC board only—$12.95
- Kit of parts less cell holders, alkaline cells, cases, speaker—$59.95

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ductor and shield of the other end to the sensor circuit board as shown in the parts placement diagram Fig. 4.

Attach the coil to the sensor circuit board with about a 6-inch length of RG-174/U coaxial cable as shown. Connect the inner conductor to one terminal and the shield to the other as shown in Fig. 4, and solder both in position. The prototype includes a twin C-cell holder that, with cells in position, has a maximum width dimension of less than 2 inches permitting it to slide easily into the sensor head pipe section.

Cut three lengths of hook-up wire to extend the lengths of the positive, negative and ground leads of the battery pack. Solder one end of those wires to the holder leads and the other ends to the sensor circuit board as shown in Fig. 4.

Bond the upper cap to the PVC pipe section with PVC cement. Then position IC1 in its socket, making certain that pin 1 is located correctly as shown in Fig. 4. Finally, insert the C cells in the holder.

Wrap a layer of polyurethane foam around coil L1 to center it within the pipe section and insert both in the pipe section with the cover at the end. Then assemble the completed circuit board and battery pack to make sure that all of these parts will fit in the pipe section. Set the assembly aside until you are ready to perform the checkout steps.

Control/display unit

The control/display assembly is housed in a standard 7 × 5 × 3-inch aluminum electronics instrument case with a removable cover. Drill the holes in the front panel of the case for power ON switch S1, FILTER IN switch S2, RANGE switch S3 and (if used) optional recorder switch S4. Also drill the holes for SENSITIVITY, ALARM ADJ., and RATE potentiometers (R18, R19, and R11 respectively). Cut out the hole for mounting meter M1. Note: If you want to use the monitor strictly as a security monitoring system the meter can be omitted.

Drill the holes in the back panel for jacks J2 and J3, and PULSE SHAPE potentiometer R17.

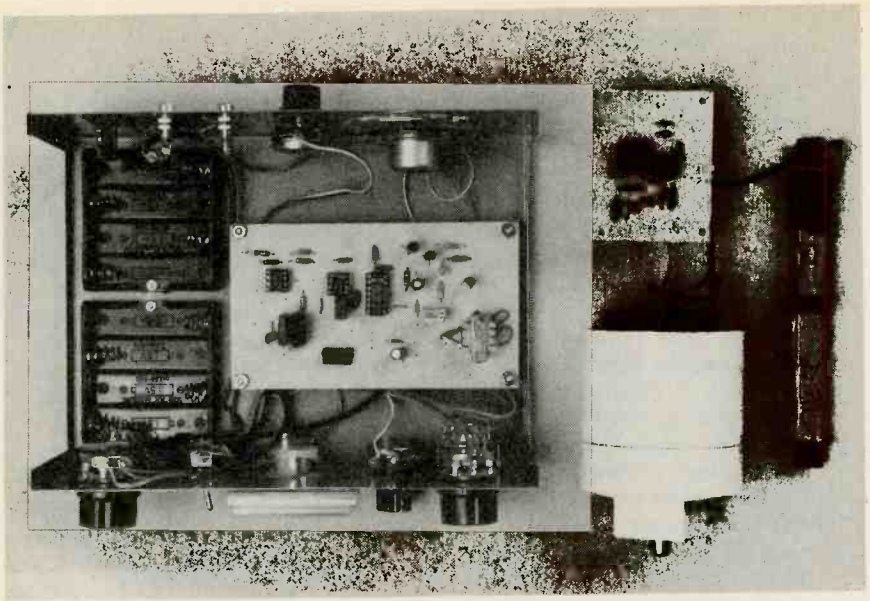

FIG. 6—AURORA MONITOR WITH HOUSING COVERS REMOVED showing internal arrangement of circuit boards and panel mounted components. Control-display unit is at left and sensor head is at right. Sensing coil L2 is at extreme right.

Drill a series of holes in a circular pattern for the speaker SPKR1. Drill holes in the bottom of the case for mounting the control/display circuit board and two quad AA cell holders.

Assemble the panel-mounted switches, jacks, potentiometers, meter and speaker to the front and back panels of the case as shown in Fig. 6. (You might prefer to bond the face of the speaker to the inside of the back panel with RTV adhesive rather than bolts and nuts.)

Determine the length of speaker wires needed to permit assembly of the circuit board in the instrument case, cut the wires to length and solder them to the board. Cut and solder all leads from panel-mounted components to the circuit board as shown in Fig. 5, allowing sufficient lengths to permit unimpeded circuit board assembly, yet not allowing too much slack.

Cut about a 6-inch length of RG-174/U coaxial cable to connect INPUT jack J2 and the FILTER IN switch S2 and two other lengths about 6 inches long to connect S2 to the FILTER-IN and FILTER-OUT pads on the control/display board as shown in Fig. 5. Strip all cable ends and solder and trim all connections.

Assemble the control/display board to the base of the case with screws and ½-inch insulating standoffs, lockwashers and nuts. Bolt the two quad AA cell holders to the base of the case as shown in Fig. 6. Position the IC's in their sockets on the control-display board, making sure that all pin 1's are in their correct positions. Insert the eight AA cells in the spring-loaded holders, observing the correct polarity.

Cut a length of RG-174/U coaxial cable cable to the length that will suit your installation (up to 20 feet). Strip the wire ends and attach phono plugs PL1 and PL2 to cable ends and solder or crimp them in position.

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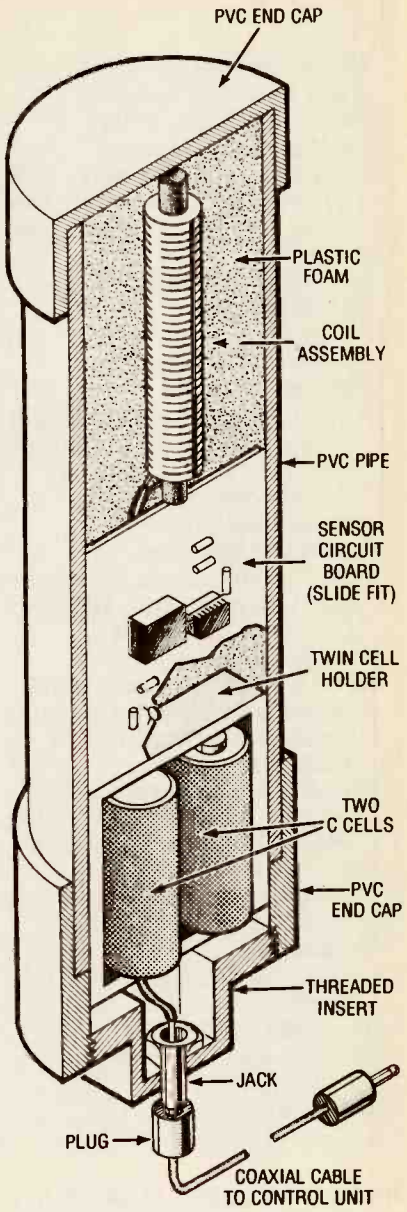

FIG. 7—MECHANICAL ASSEMBLY of sensor head. The coil is wrapped in polyurethane foam and inserted into the case followed by the circuit board and the C-cell holder. The lower cap is fastened to the pipe with non-magnetic self-tapping screws.

Test and checkout

Test the sensing circuit first. Connect a general purpose oscilloscope or multimeter to the output of IC1. Position a permanent magnet near coil L1 and the oscillscope display should show a pronounced pulse. If a multimeter is used, its readout should jump.

Next, move L1 away from the magnet and the reading on the multimeter should fall to zero. If the reading does not go to zero, adjust trimmer potentiometer R4 in the sensor circuit. When

(Continued on page 109)

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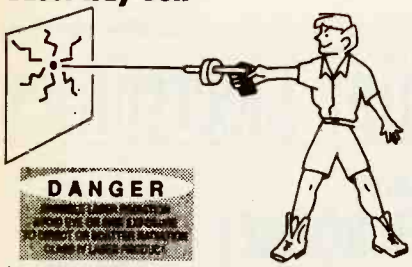

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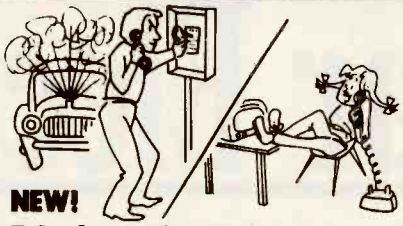

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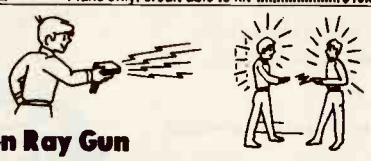

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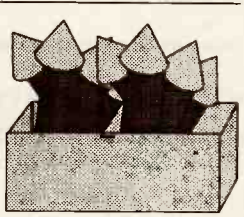

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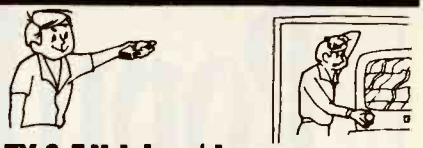

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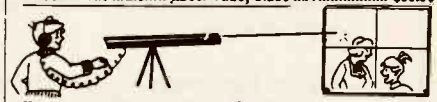

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DTMF DECODER

Continued from page 38

Sockets are recommended for IC1 and IC2. Those ICs, and the LCD module, are ESD-sensitive devices, so handling precautions must be taken. The crystal holder should be mounted on its side and secured to the board with double-sided tape to provide mechanical stability and prevent the crystal from shorting any traces on the PC board (see Fig. 4).

The display module, which comes preassembled on its own board, is mounted to the DTMF board, back-to-back, with ¼-inch spacers and screws. The electrical connections between the two boards can be made with header pins soldered between the two boards at the mating pads (see Fig. 5). Alternately, you can mount the two boards separately and run flexible hookup wire between them. Before mounting the display, check the DTMF board carefully for any soldering errors.

Checkout and operation

Potentiometer R9 adjusts the display's contrast. After applying power, advance R9 until the blocks comprising the display are visible, and then reduce R9 for the desired contrast. Remove power for several seconds and then reapply power. The display should show "*ELECTROMAGIX*" for several seconds and then clear, displaying just a cursor.

Attach a wire from the high side of your scanner's speaker to the audio input on the DTMF board, and one from the ground side of the speaker to audio ground on the DTMF board. Tune to a frequency with DTMF traffic, and you should see the digits displayed as you hear them. A Touch-Tone pad on a 2-meter band transmitter would be invaluable for checkout.

Note that performance decreases rapidly as the signal-to-noise ratio decreases. For monitoring weak signals, an outboard passband filter is needed. Many inexpensive scanners have such poor audio quality that they won't pass Touch-Tone pairs without distortion, and the distorted tones

(Continued on page 110)

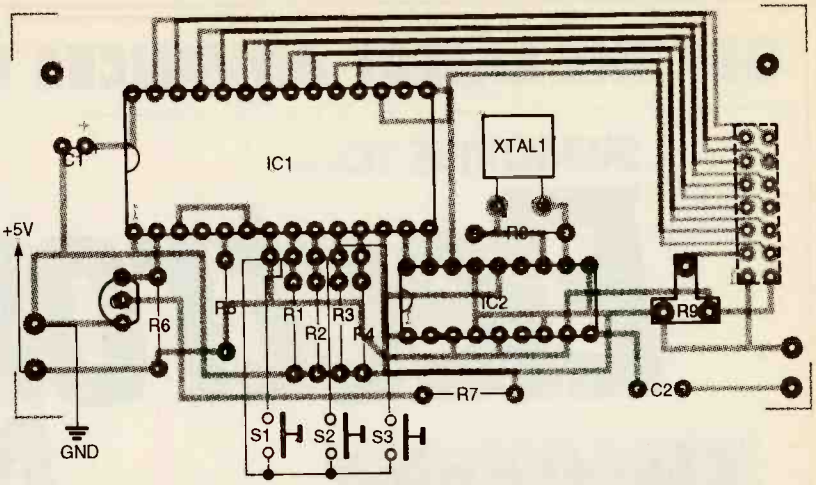
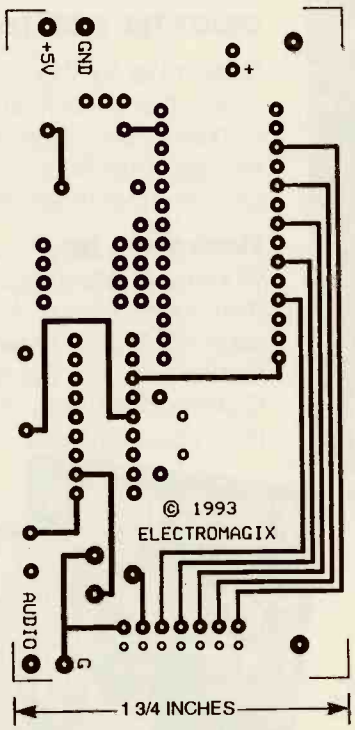
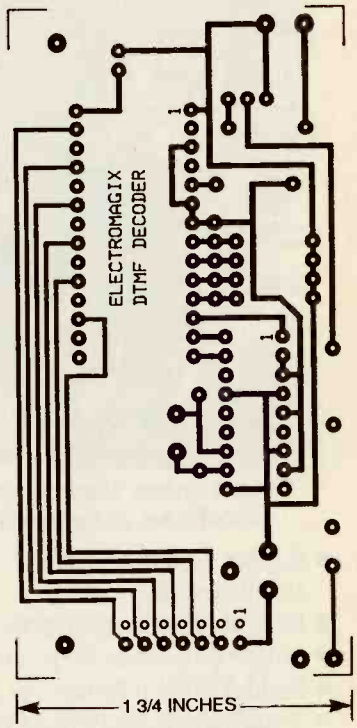


FIG. 3—PARTS-PLACEMENT DIAGRAM. Sockets for IC1 and IC2 are recommended.



DTMF BOARD component side.



DTMF BOARD solder side.

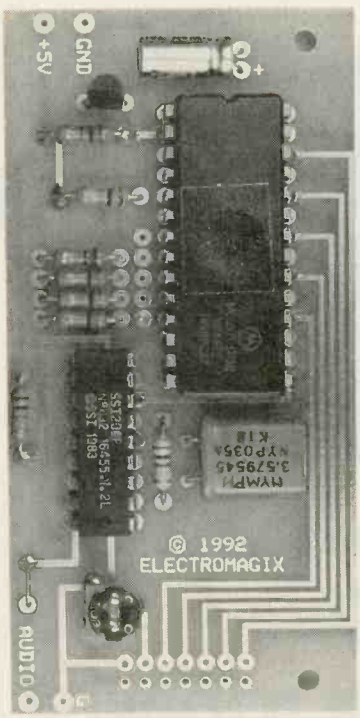


FIG. 4—NEARLY COMPLETE BOARD. Notice how the crystal holder is bent on its side and secured to the board with double-sided tape.

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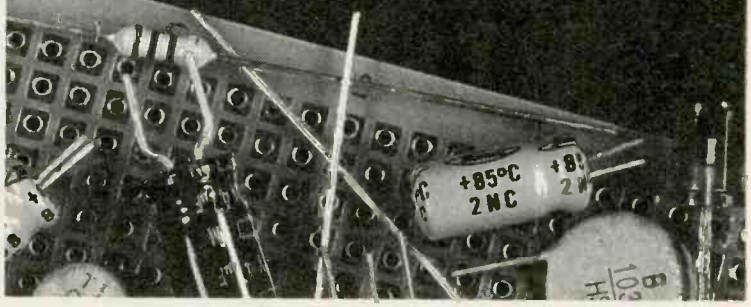

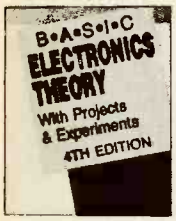

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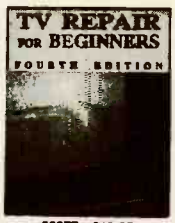

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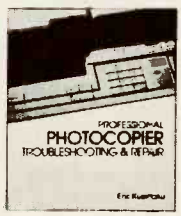

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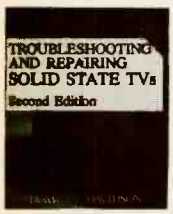

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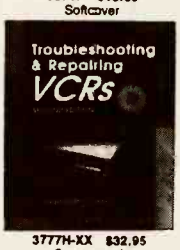

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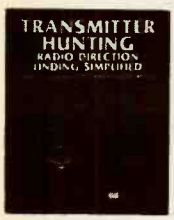

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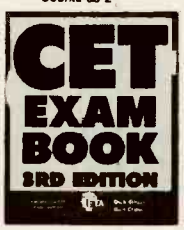

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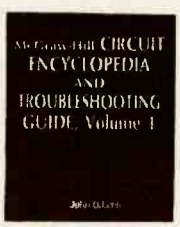

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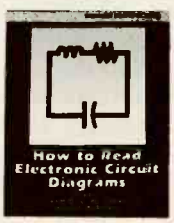

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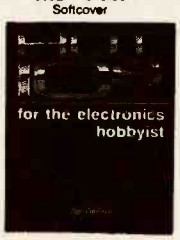

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UNIVERSAL R/C

Continued from page 90

LISTING 3— EXERCISE FUNCTIONS

```
REM ************************
REM the following code exercises
REM some basic command functions

REM select the tv
REM as the device to control
PRINT "sending tv: a5"
OUT 888, rowa + col5
GOSUB stall
INPUT x

REM turn on the tv
PRINT "sending POWER: e6"
OUT 888, rowe + col6
GOSUB stall
INPUT x

REM crank up the volume
FOR k = 1 TO 20
PRINT "sending VOLUME UP: b6"
OUT 888, rowb + col6
GOSUB stall
INPUT x
NEXT k

REM change the tv channel
PRINT "sending CHANNEL DOWN: c6"
OUT 888, rowe + col6
GOSUB stall
INPUT x

REM turn off the tv
PRINT "sending POWER: e6"
OUT 888, rowe + col6
GOSUB stall

END
```

will be useful for verifying that the circuit is wired properly. You should see a change in the state of each line as it is tested.

To determine which LPT port to use, run the program shown in Listing 5. It will display the decimal and hexadecimal addresses of those parallel ports that are installed on your machine.

Adapting for other devices

When writing your own control program, keep the following in mind: Because the interface does not include a backup battery, the control program should send the proper setup commands for your particular device when you first start the program. Because the PC can "press" the remote control's buttons much faster than a human being, you could even program it to send keystrokes on-the-fly, each time you send a command. Doing so would allow you to overcome the four-device limit typical of inexpensive remotes, allowing you unlimited control over TV's, VCR's, CD players, video-disc players, and other IR-controlled devices.

The circuit described here is not specific to the Memorex AV-4; it could be attached to almost any device with a 5 × 8 or smaller keyboard matrix.

With only slight modifications, it could control much larger layouts. One way to increase the capacity of the interface while still using only eight data lines would be to add more 4051's. With additional decoding, the five control lines could control $2^5 = 32$ different 4051's. That's a 32 × 8 matrix, or a whopping 256 keys! Ω

LISTING 4— SONY TEST COMMANDS

```
REM the next piece of code
REM initializes the URC for
REM a SONY TV (000)
REM the "INPUT x" statements
REM aren't necessary, they're
REM just here so you can
REM observe each command.
REM The AV-4 has a surface-
REM mounted LED that blinks
REM once as each command is
REM received, and multiple
REM times when a valid device
REM code has been
REM successfully programmed.
REM ***************************
PRINT "sending A: e5"
OUT 888, rowe + col5
GOSUB stall

INPUT x

PRINT "sending V: e3"
OUT 888, rowe + col3
GOSUB stall

INPUT x

PRINT "sending 4: e1"
OUT 888, rowe + col1
GOSUB stall

INPUT x

PRINT "sending #0: b2"
OUT 888, rowb + col2
GOSUB stall

INPUT x

PRINT "sending #0: b2"
OUT 888, rowb + col2
GOSUB stall

INPUT x

PRINT "sending #0: b2"
OUT 888, rowb + col2
GOSUB stall

INPUT x
REM ************ end URC init
```

LISTING 5—LPT ADDRESSING

```
REM display addresses of lpt ports
REM jkh 2/21/93
DEF SEG = &H40
lpt1 = &H8: lpt2 = &HA: lpt3 = &HC
a = PEEK(lpt1) + 256 * PEEK(lpt1 + 1)
b = PEEK(lpt2) + 256 * PEEK(lpt2 + 1)
c = PEEK(lpt3) + 256 * PEEK(lpt3 + 1)
PRINT "Decimal", "Hex"
PRINT "LPT1:"; a, HEX$(a)
IF b > 0 THEN PRINT "LPT2:"; b, HEX$(b)
IF c > 0 THEN PRINT "LPT3:"; c, HEX$(c)
```

Continued from page 46

capacitors C7, C9, and C11 is very critical. Some difficulty might be experienced at first, "getting in the ballpark," since the bandpass filter is quite sharp (10 MHz), and it will have high attenuation when misaligned. Once you get a picture of any kind, the rest is easy. If the unit appears to work but the TV set tuning is critical, the picture "grainy," or the color poor, make sure that C13 is set on the proper side. (As mentioned before, there will be two settings, and the lower frequency is correct.) When aligned, the picture on the selected UHF channel should be of excellent cable quality.

After alignment is complete, verify the fine-tuning adjustment R12. Normally R12 is left in the halfway position, and adjusted only to touch up the frequency setting.

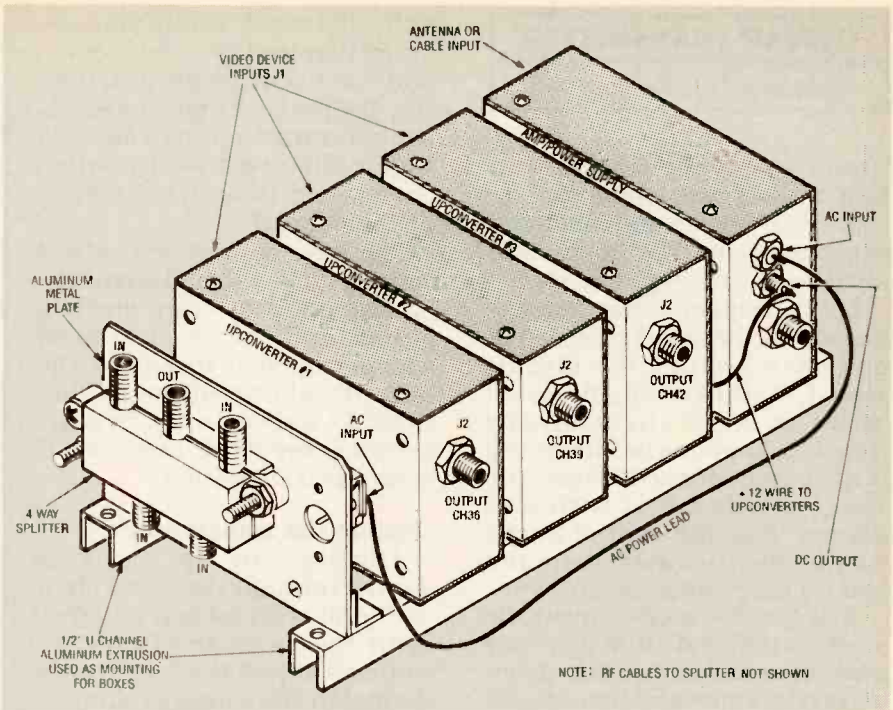

FIG. 11—ALL OF THE MODULES for the prototype Video Master are mounted together on a pair of aluminum rails, with everything feeding into a 4-way splitter.

The upconverter can now be installed in your TV system, and should operate reliably with no attention from you. For overall system stability, we recommend leaving the upconverter system on all the time, hence no switch is installed in the system. Ω

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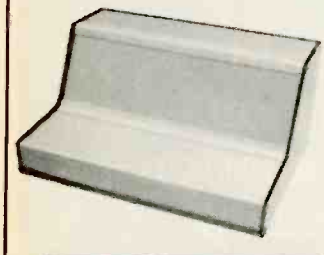

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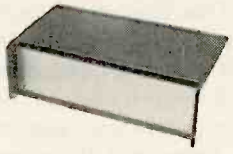

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CIRCLE 10 ON FREE INFORMATION CARD

GUITAR TRANSMITTER

Continued from page 58

heads with your fingers and that it goes out when you remove your fingers and touch the sensors again. The operations should be "touch-on/touch-off."

If this happens, position the battery in the space provided in the case behind the circuit board, and carefully dress all wires to avoid stressing any wire terminations or interfering with cover closure. Close the cover, and fasten it with four screws. Position control knobs on the potentiometer shafts and secure them with setscrews.

Place an FM receiver near the transmitter and tune it to any station or blank location determined by your selection of C15. Then tune L2 with a plastic IF core alignment tool until the transmitted carrier cancels the FM station.

Plug the Guitar Transmitter into an electric guitar, pluck the strings, and listen for "clean" and "distorted" audio signals. Verify that the DISTORTION, TONE, and LEVEL controls are functioning properly. The DISTORTION should transition from clean to highly distorted sound when the EFFECT is on (i.e., EFFECT LED is lighted).

The TONE control will permit you to adjust the high-frequency response of your electric guitar, and the LEVEL control will permit you to adjust the output volume of your "distorted" sound only. When EFFECT is bypassed, only "clean" sound is transmitted.

Tuning the transmitter

During tune up, play your guitar through the clean channel, and then switch channels with the touch sensor so that you can adjust the level control to match the output volume of the distorted channel with that of the clean channel.

The volume of the clean channel has been set to a pre-determined level so that the guitar signal will remain undistorted when played vigorously. Ω

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OFF THE PRESS

Continued from page 10

Weekender" transceiver, a five-band quad antenna that works all bands from 20 to 10 meters, and an active attenuator that will find hidden transmitters.

The ARRL Handbook is updated every year to include technical advancements in amateur radio. This 71st edition includes topics not discussed in earlier editions: digital signal processing (DSP) and RF power amplifiers. A revised section on digital-logic ID timers will help you to improve the operation of your repeater continuous-wave ID circuit.

17294-0850; Phone: All Thumbs Guide to Home Security; by Robert W. Wood. Tab Books Inc., Blue Ridge Summit, PA 1-800-233-1128; $9.95.

This illustrated guide is offered with the claim that it will provide homeowners and renters with all the information they'll ever need to safeguard their homes against burglary and fire. Moreover, it is sold with a money-back guarantee that novices will be able to complete the projects successfully without outside help.

According to its author, Bob Wood, you don't need formal training in wiring and electricity to carry out the inexpensive security measures he discusses. Wood claims that, if organized effectively, the projects detailed in the book can reduce the risk of fire and intrusion significantly—and they might even help to reduce insurance rates.

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AUTOCOUPLER

Continued from page 79

does, LED1 will light up. Connect an audio source to the audio leads and try sending some audio down the line. Your calling party should hear it loud and clear. Next, connect an amplifier and speaker, to the audio port and listen to the calling party. Shortly after the caller hangs up, the coupler should automatically drop the line. With your amplifier still connected, pick up an extension phone; you should hear the dial tone through your off-line coupler. That confirms the audio pass-through from the MPC-2 section that makes the coupler caller-ID compatible.

The remote connections can be tested with a VOM. When the coupler first picks up, pin 5 of the DB-25 connector will go low for a moment. Depending on which way you set jumper JU2, the contacts of relay RY2 (available at J3, the DB-25 connector, pins 1–4) will close either momentarily or will latch as the unit picks up. A ring signal will produce a high output at pin 9 of J3.

You should be able to force the coupler to pick up by momentarily grounding pin 13 of J3 via switch S1. Be sure you don't ground pin 13 directly (R16 must be in place) or you might damage IC5. You can force the coupler to hang up by grounding pin 8 of J3 via S1. Test the external inhibit by connecting pins 11 and 12 of J3 together. Then remove JU1 and have someone call the coupler; it should not answer. Next, connect pin 10 of J3 to ground; the coupler should answer.

Conclusion

The couplers can send or receive audio signals and they have been used as outgoing message centers, listen lines, and remote-control interfaces, just to mention a few. You'll find that it is an excellent and versatile telephone-line interface suitable for automatically connecting your telephone line to a variety of projects. Ω

AURORA MONITOR

Continued from page 100

the sensing head is adjusted and working correctly, close the lower cap and fasten it with two non-magnetic stainless steel self-tapping screws to complete the assembly. Connect one end of the plug-terminated coaxial cable to the sensor head jack 1 and the other end to the control/display unit jack J2.

Turn on the power toggle switch of the control/display unit and turn SENSITIVITY potentiometer R18 full clockwise. *The meter should remain at zero.* Rotate ALARM ADJUST potentiometer R19 clockwise until the alarm just begins to sound. Then turn it back slightly so that no sound is heard to obtain the maximum sensitivity setting. Next, turn potentiometer R19 full clockwise.

There should be no sound from the speaker.

Position a small magnet or piece of metal next to coil L1, in the sensor head and the unit should now be activated: the speaker should emit sound, and the meter should read full scale. If everything checks out, you can now start observing magnetic field disturbances or anomalies.

Operating the monitor

In a quiet magnetic environment it might be necessary to adjust potentiometer R4 in the sensor head to the threshold of the meter movement. This fine adjustment eliminates any small dead zones in sensitivity. Test the instrument's ability to detect the Earth's magnetic field by rotating the sensing head with short, quick, snapping motions in a counter-clockwise direction.

The meter movement should jump off scale.

As rotation is continued, a direction will be found where the meter will have its lowest response. This nulling point is the north-south direction. Any objects containing permanent magnets such as speakers or meters that are brought into close proximity to the Aurora Monitor's sensing head coil L1 will affect the accuracy of the instrument's readings.

The Aurora Monitor can be connected to a chart recorder or it can pass signals to a personal computer with an analog-to-digital converter board. The recorder or PC can collect data for the study of magnetic fields, magnetic storms, and sunspot activity over long periods of time for futher analysis. A set of high-impedance (greater than 1 kilohm) headphones can be plugged into jack J3 if you wish to "hear" the changes in magnetic fields.

If you want a permanent installation, mount the sensing head assembly so that it is directed away from any large metal obstructions, oriented on a north-south axis, and pointed slightly upwards. It's aos a good idea to fasten it to a heavy wooden post to prevent wind-induced vibrations. Ω

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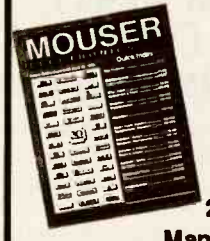

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DTMF DECODER

Continued from page 104

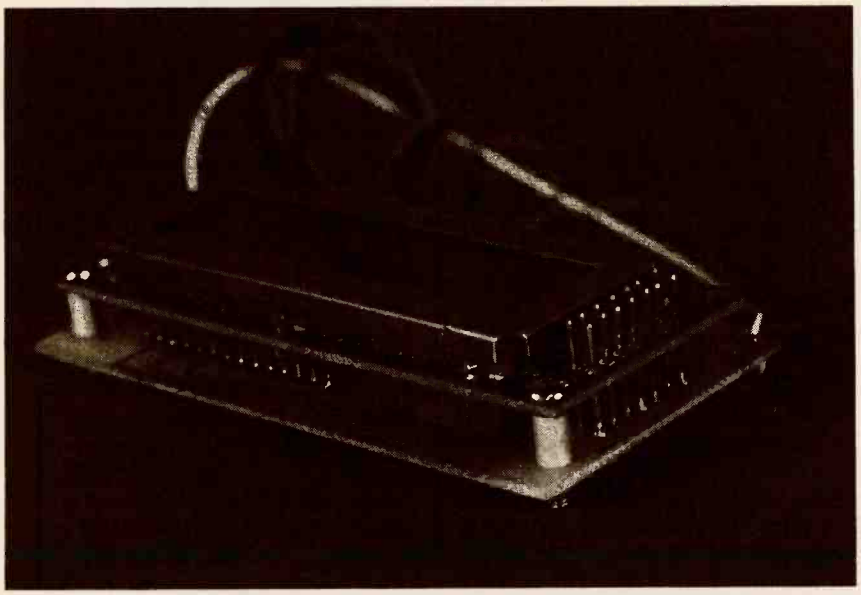

FIG. 5—AFTER MOUNTING the display module to the DTMF board with screws and spacers, electrical connections between the two boards are made with header pins or bits of wire.

can't be decoded. Cordless telephones are difficult to decode unless they emit a strong signal. For a successful decode, a tone pair must be present for 40 milliseconds with a 40-millisecond pause between digits.

Pressing switch S2 clears the display, and S3 clears the memory and displays "MEM CLEARED!" Switch S1 will redisplay the memory as four screens—one screen for each button press—of 16 characters; pressing S1 a fifth time displays "*READY*" and returns the display to normal operation.

Troubleshooting

If the power-up message does not appear, make sure R9 is adjusted properly. If the display is not functioning, the most likely cause is a wiring error. Check the board for solder bridges between the pins and traces. Pin 5 of IC1 should show a 1-megahertz sawtooth waveform that verifies the operation of the microcontroller. Ω

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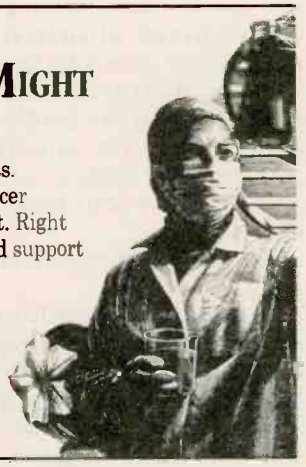

NOVEL AMMETER

Continued from page 94

whose temperature is to be determined. This instrument can be used to warn you that the temperature at the surface of equipment or within an enclosure exceeds 109.4°F.

You can also mount the tester on a 1 by 4 inch piece of circuit board to make a simple transition thermometer that you can move from place to place to determine if objects or spaces are above or below that temperature.

Applications precautions

Remember that the tester is a sensitive thin-film sensor-display that can be damaged by excessive heat or current. Here are some precautions to take that will assure good results in your experiments and projects:

- *Do Not* use the tester in direct sunlight or where the ambient temperature never falls below 42°C.
- *Do Not* mount the tester directly to heat-conducting material when making an ammeter. Heat conductors will degrade the tester's response time and sensitivity. A 1/16-inch thick insulating "cushion" will provide adequate thermal isolation.
- *Do Not* pass more than about 300 milliamperes through the resistive element. (See Figs. 2 and 3.) If higher operating currents are required, shunt the resistive element with a discrete resistor of the proper value.
- *Do Not* experiment with or use the tester where flammable or explosive gas or other materials are present. If overheated, the tester will act as a pyrotechnic fuze.
- *Do Not* make sharp bends or creases in the tester because the resistive element will be damaged. Ω

IRON-ON PATTERNS

Continued from page 51

IF YOU DON'T HAVE AN EPROM-BASED target system, you can buy this assembled 8048-based microcontroller system consisting of a microcontroller, UART, I/O ports, RAM and EPROM (see the Parts List).

icate the board to a specific application and do not wish to use a separate EPROM. See the parts list for ordering details.

When you have obtained a working target system, connect the 25-pin DB25 male-to-female cable, with the Static-ROM to either parallel port and apply power to the Static-ROM. If the circuit is functioning correctly, the POWER LED should be illuminated, and the LOAD LED can be off or on, depending upon the initial state of the parallel port STROBE line.

Next, connect the EPROM cable to your selected target system. Note that the author-supplied 8048 system uses the 2732 EPROM cable. Select either active-high or active-low reset, depending on your processor. The 8048-based system offered by the author uses active-low reset. Connect the reset probe to the reset pin of your target processor. When you start the Static-ROM terminal program, you will be prompted to select the parallel port that is connected to the Static-ROM. If the LOAD LED was on, it should now be off. Enter the name of the binary object file you want to download to Static-ROM.

After pressing the enter key, you should see the LOAD LED illuminate and a "sending" message with a byte count on the terminal display. The terminal program should indicate that the download has completed, and the target system processor has been reset. You should see immediately the downloaded program running on your target system. Toggle the reset select switch to reset your target system manually or run the Static-ROM terminal program again, and download and run another binary file.

The Static-ROM is designed as a debugging tool, not an EPROM eliminator or substitute. Disconnecting Static-ROM from the parallel port while emulating an EPROM will terminate the emulation if a randomly generated active level is presented to the PIC16C55 STROBE input. Recall that the PIC16C55 always wants to restart on an active STROBE from the parallel port while in EPROM emulation mode and, if an inadvertent strobe is encountered, the algorithm will cease looking for download data that is not forthcoming.

As you can see, you can transfer between your assembler and the terminal program quickly, testing your code until you obtain the desired results. Ω

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7	C&S Sales	C2
—	C.I.E.	17
6	Chenesko Products	7
8	Heath	7
—	Information Unlimited	101
9	Mouser	109
—	NRI	9
5	School of VCR Repair	8
10	Sescom	107
—	Smith Design	8
—	Tab Books	1, 105
11	Zentek	108

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