YOUR ONE-STOP SOURCE OF ELECTRONICS INFORMATION

ICD 08559

MODERN ELECTRONICS

SEPTEMBER 1988 $2.50
CANADA $3.50

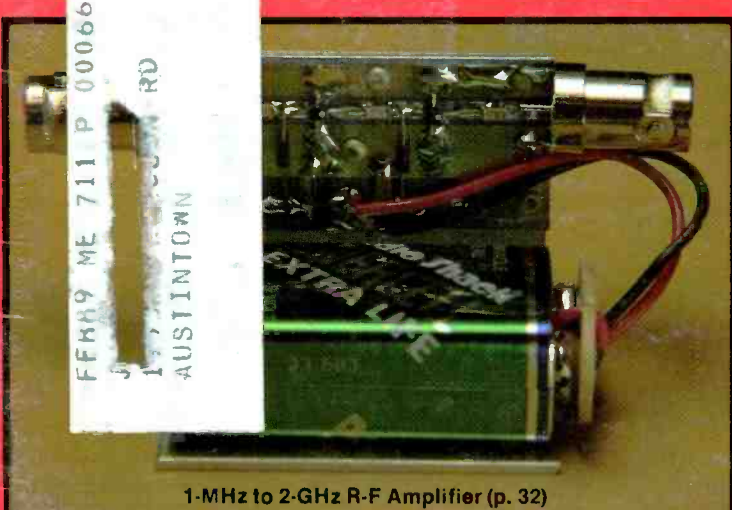
THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

- Wireless Data Link for Serial Computers/Peripherals
- Capturing Weather-Satellite Video Transmissions

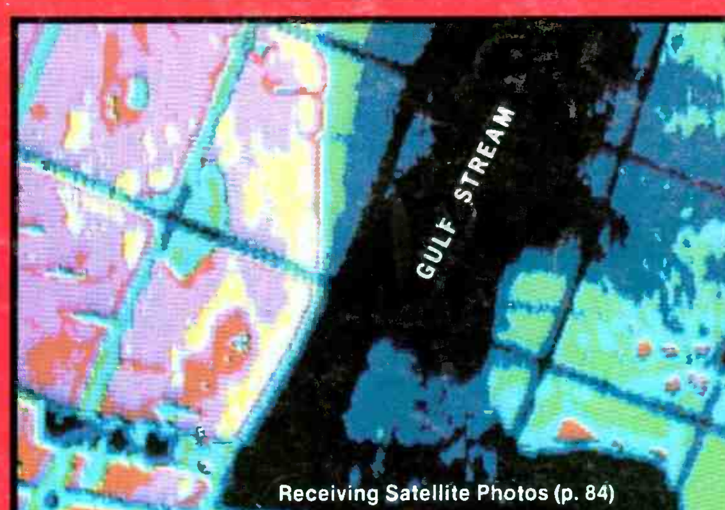
Full Construction Plans:

- A 1-MHz to 2-GHz R-F Amplifier
- Vehicle Back-Up Beeper ...destrians
- ...AC Outlet Box
- ...ault Circuit Interrupter ...r/Tester

Wireless Data Link (p. 18)



1-MHz to 2-GHz R-F Amplifier (p. 32)



Receiving Satellite Photos (p. 84)

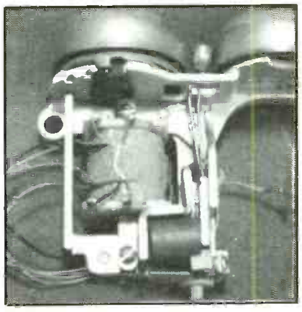
Bulk Rate
Permit No. 79
U.S. Postage Paid
Gordonsville, VA 22942

Plus: Forrest Mims Experiments With Photoresistors • New Developments in Op Amps • More on How to Read Oscilloscope Waveforms • Troubleshooting Telephones • Reviews of Salinon's "Special Days" & "Footprints in History" Software • Packet Radio Principles • Electronics & Computer News . . . more.

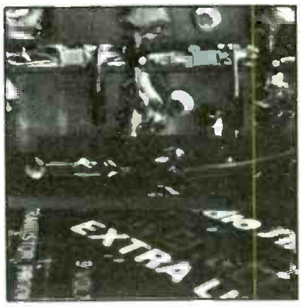
MODERN ELECTRONICS

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

SEPTEMBER 1988 VOLUME 5, NUMBER 9

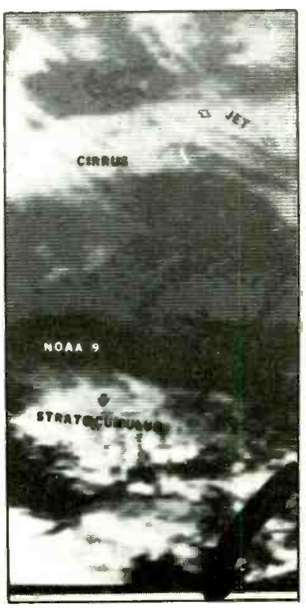


28



32

46



87

FEATURES

COLUMNS

DEPARTMENTS

EDITORIAL STAFF

Art Salsberg
Editor-in-Chief

Alexander W. Burawa
Managing Editor

Dorothy Kehrwieder
Production Manager

Elizabeth Ryan
Art Director

Barbara Scully
Artist

Pat Le Blanc
Florence V. Martin
Phototypographers

Hal Keith
Illustrator

Bruce Morgan
Photographer

Leonard Feldman, Harry Helms, Forrest Mims III, Ted Needleman, Curt Phillips
Contributing Editors

BUSINESS STAFF

Richard A. Ross
Publisher

Art Salsberg
Associate Publisher

Dorothy Kehrwieder
General Manager

Frank V. Fuzia
Controller

Arlene Caggiano
Accounting

Catherine Ross
Circulation Director

SALES OFFICES

Modern Electronics
76 North Broadway
Hicksville, NY 11801
(516) 681-2922

Advertising Manager
Peter Conn

Sales Assistant
Kathleen O'Lenahan

76 North Broadway
Hicksville, NY 11801
(516) 681-2922

Offices: 76 North Broadway, Hicksville, NY 11801. Telephone: (516) 681-2922. FAX (516) 681-2926. Modern Electronics (ISSN 0748-9889) is published monthly by CQ Communications, Inc. Application to mail at second class rates pending at Hicksville, NY and other points. Subscription prices (payable in US Dollars only): Domestic—one year $17.97, two years $33.00, three years $48.00; Canada/Mexico—one year $20.00, two years $37.00, three years $54.00; Foreign—one year $22.00, two years $41.00, three years $60.00. Foreign Air Mail—one year $75.00, two years $147.00, three years $219.00.

Postmaster: Please send change of address notice to Modern Electronics, 76 North Broadway, Hicksville, NY 11801.

EDITORIAL

Security

The electronic security business continues to grow by leaps and bounds. For consumers, it means that there are more devices and systems to choose from than ever before to prevent the possibility of burglary and theft, to alert one to fire/smoke and other hazards, for protection from bodily harm, and to automatically contact someone due to a medical emergency.

All manner of promotional material for security devices of one sort or another come our way, of course. They range from very simple ones to ultra-complex setups; from useful devices to some we would not consider using due to their apparent ineffectualness or to the possibility of harming someone (for example, we've turned down advertisements for stun guns).

With a plethora of products, it's no longer easy to choose which security product to buy, for whatever purpose, as it once was when, say, Chapman mechanical locks reigned supreme to prevent automobile theft. Now there are countless auto-theft-prevention systems to choose from, ranging from mechanical devices to elaborate digital-coded ones. Home security devices have similarly expanded, with sophisticated digital systems with automatic dialing to police and fire departments growing in popularity.

Installing many of these systems, however, is easier said than done. It depends on how handy you are with tools and how much time and effort you're willing to put into the task. The first-time installer almost always runs into problems due to inexperience. This invariably occurs whether it's installing a full home security system or some other installation challenge like, say, replacing a 29-cent automotive valve cover gasket that your friendly service station person wants $40 to do.

On the latter, my brother-in-law felt it was a snap to do himself. I watched him replace it, in fact. Firstly, he almost strangled the opening on a vacuum tubing while trying to remove the valve cover. He also learned later that the Perma-

LETTERS

Electronic Ups & Downs

• Electronic do-dads in homes and cars have driven up selling prices. What we need is electronics to drive *down* prices.

Ed Jones, Jr., WB2DVL
New Jersey

Expecting to see electronics driving down the cost of homes or cars in the foreseeable future is wishful thinking. If anything, homes and cars will probably demand premium prices with each new electronic addition. Not so all electronic devices, though. You can currently buy a digital wristwatch for as little as $1.99, a pocket calculator for $4.95, a VCR or color-TV receiver for $200, and a host of other everyday items for undreamed-of prices only 10 years ago.—Ed.

Owner Repairs

• It would be a nice idea if more articles on owner repair and "tuning" of compact-disc players were published. I have an early CD player that is beginning to exhibit signs of mechanical wear. I've taken the cover off the player and, from what I see inside, I believe that I could probably fix it if only I had a few hints to guide me. Do you know of books and/or service notes on *mechanical* repair of CD players that I can help me?

Les Shaw
Boulder, CO

Try Complete Guide to Compact Disc Player Troubleshooting and Repair *by John D. Lenk, published by Prentice-Hall.—Ed.*

Running Hot

• I just finished building the "Low-Cost Function Generator" featured in the January 1988 issue and have two questions regarding the circuit in Fig. 2. Filter capacitor C11 on the schematic calls for a 220-μF value, but the Parts List specifies it at 22 μF. Which is correct? My second question concerns the 8038 chip used for IC3. The chip I have runs excessively hot and shuts down after 30 minutes due to internal thermal cut-out. I note that the tex gasket "glue" he used was the type that dried hard instead of soft and pliable, so that if a new gasket ever has to be replaced, he'd have a frustrating job scraping off the old gasket instead of simply pulling it off. Then he had exclaimed derisively that the valve cover's head screws weren't even secured tightly in the first place, which he made sure he did when the job was completed. Only now the cover metal between screws is bowed a little, which will likely result in an oil leak, which was what he was trying to correct in the first place.

Without doubt, there are in's and out's in every trade, including the security equipment one. What you don't know can defeat you. For instance you might choose a heat detector that's activated when a preset temperature limit is reached at, say, 135 degrees. You'd be much safer, however, if you bought one that also responds to a quick temperature rise, which costs twice as much (about $11) If you're putting metallic foil on the windows, which is a chore unto itself to do neatly, would you know that you have to apply protective varnish over it?

The point here is that there are many jobs that a handy person can do well to save money. Plenty of them, though, can cause you grief in the long run. Sometimes it's worthwhile to pay the seasoned pro to do it right while you make a buck to pay for it by doing something extra in your field of specialty.

On the other hand, there are also many opportunities to put your work skills to bear on personal projects, including security systems. There are now wireless security systems, for example, that simplify even complicated home installations. With a burglary occurring every ten seconds in the U.S., it's something to consider.

Art Salsberg

maximum parameter for this chip is 30 volts. Therefore, my question is are the 15-volt bus rails set too high?

Howard L. Pemper
Roslindale, MA

The correct value for C11 is 22 μF, though a larger value would improve filtering efficiency and energy delivery from the supply. Assuming no faulty wiring, the cause of your difficulty may well be that the 8038 chip is marginal. If either the +15- or −15-volt regulator or both is operating on the high side of its tolerance range, the potential on either rail may be a bit too high for safe operation of the IC. You can take voltage readings and/or try a different 8038 chip to determine the culprit.—Ed.

Theory Wins

• I found the "$149 Digital Stereo Amplifier" featured in the December 1987 issue of *Modern Electronics* extremely interesting. However, I am confused with regard to the power supply. It appears that since the project calls for +32-volt rails, T1 should be a 70-volt center-tapped transformer to provide voltage under load. If one should use the power supply shown with a 50-volt center-tapped transformer, will the circuit run properly on the +22 volts the supply design delivers?

Edward Timothy Howell
Spartanburg, SC

The 50-volt center-tapped transformer specified will actually deliver 35.35 volts peak ac (25 volts rms × 1.414) to the rectifier circuit. Taking into consideration slight drops introduced by rectifiers, the peak potential delivered to the large filter capacitors will be very near the 32 volts specified. Since the capacitors charge up to peak value of the voltage, the power supply rails will actually register +32 volts or thereabouts. If you were to use a transformer that delivered +22 volts, the circuit would still work, but at considerably reduced output power.— Ed.

SIGHT & SOUND. Home TV receivers continue to move, in tiny steps, in the direction of enhanced video and audio. So-called "improved-definition TV" (IDTV) sets have been announced by a few TV-set makers, Philips Consumer Electronics and Toshiba, among them. The IDTV system improves television picture performance by using non-interlaced scanning, field memory-based noise reduction and field comb filtering, as well as including a picture-in-picture (PIP) feature. As a result, there are 525 scan lines per field that occur every 1/60th of a second instead of the conventional 262-1/2 lines...Philips claims that there's a 40% improvement in vertical resolution with these sets and that 480 lines of horizontal resolution is achieved. Moreover, Philips' system has two selectable levels of digital noise reduction to reduce extraneous video noise up to 10-12 dB, as well as a viewer choice of 1, 3 or 9 PIP images on screen simultaneously...Toshiba incorporates Carver Sonic Holography audio system to enhance sound reproduction of its MTS stereo TV models...A two-lb., 9-oz. combination battery-powered VCR/TV receiver, dubbed "Video Walkman," was introduced by Sony Corp. The hand-held record/playback/color LCD viewing machine uses 8-mm video cassette that can also store PCM stereo sound tracks.

FUN, GAMES, CONVENIENCE. Q-Link's on-line computer game, RabbitJack's Casino, which features color graphics and animation with real-time interactivity, accounted for over $1-million in connect time in its first year of operation. Designed by Interactive Productions for Quantum Computer Services, the game includes poker, black jack, slot machines and bingo. The game enables users to play against other players around the country. Software is set up for Commodore-64 or C-128 computers...An electronic learning aid for children "JC, The Junior Computer," introduced by INTEG, Inc. (San Jose, CA), looks like a laptop computer with a pop-up screen and carrying handle. The look-a-like portable has 16 learning activities, speaks instructions in a computerized voice, and runs on four C-size alkaline batteries. A RAM cartridge lets users create and store animations and music, as well as "play" plug-in ROM Activity cartridges. A touch-sensitive keyboard has 76 keys, 12 cursor control keys and 18 function keys. Left unattended for five minutes, it turns itself off to conserve batteries. Retails for $69.95; optional cartridges, $19.99. JC will sell through game, toy and consumer electronics retailers and also through computer stores...Eastman Kodak has entered the game field with an action-packed VCR sci-fi mystery gamed called "Isaac Asimov's ROBOTS." It's a futuristic game with 256 possible clue combinations that lead to 32 different solutions. $34.95 for the VHS tape, four photo clue card packets and an answer book...Northwestern Bell Phones has introduced a unique telephone that's both easy and fun to use. It has a flat, big-key dialing display that doubles as a photo collage for up to nine pictures or symbol cards. Users just insert photos of friends or relatives into the "window memory keys" and enter their phone numbers into the unit's memory. Then simply press the familiar face and you're dialing out. $69.99.

NEW MAC OPERATING SYSTEM. Apple Computer announced the newest version of its operating system for the Apple Macintosh computer family--Software Version 6.0. It features enhanced system and MultiFinder capabilities, a MacroMaker program, CloseView and Map utilities, as well as increased processing speed. CloseView enables users to magnify the Mac screen display up to 16 times its normal size, which can aid the visually impaired. The customizable utility, Map, is used to determine time and distance between locations worldwide. The $49 version is compatible with all Macintosh computers having at least one megabyte of memory.

RISCY BUSINESS. Reduced instruction set computer (RISC) processors get faster and faster. While Motorola's 88000 is rated at 14-17 MIPs, Cypress Semiconductor 's new RISC microprocessor (the CY7C600 family) claims 20 million instructions per second, with its 33-MHz performance. Such single processing workstation 32-bit chips have fewer instructions built in than the traditional Complex Instruction Set Computer microprocessors have, executing most in a single clock cycle. The fastest RISC draw in the West, however, belongs to McDonnell Douglas, which demonstrated its MD-484 gallium arsenide processor with 60-MHz clocking (for the military, of course).

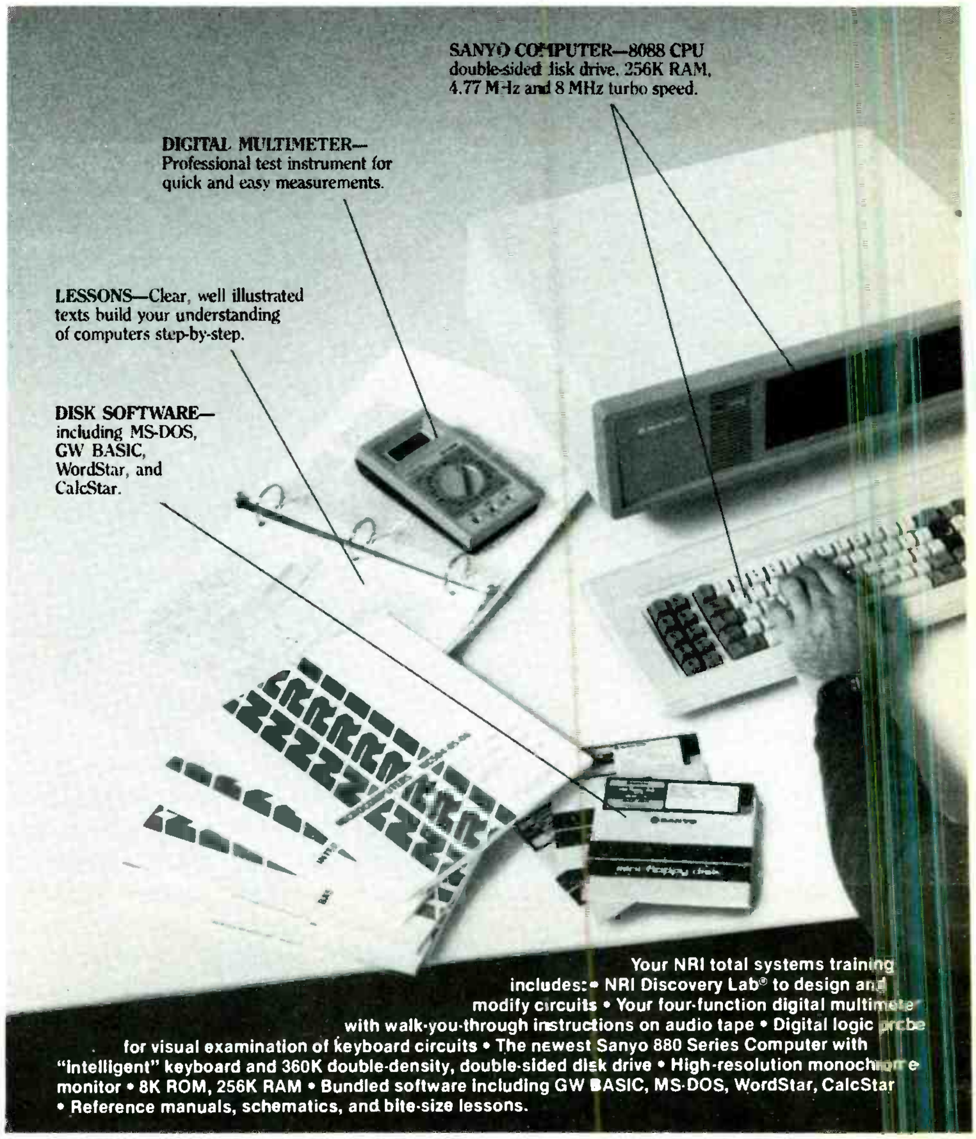
MUSIC & VOICE DEVELOPMENTS. Local libraries often carry audio recordings for check-out, but selections are quite limited. Now there's a National Music Library that permits anyone to check out recordings at no charge! Founded by Alan Foxx as a nonprofit organization to build music appreciation in all fields of music (including rock, country, jazz and classical), a large selection of compact discs, music cassettes, sheet music and books on tape are said to be available. For a list of the library's current circulation and for library-card information, contact National Music Library, 1994-A202 Woodward Ave., Bloomfield Hills, MI 48013, enclosing $1 to cover costs for the list...First there was the "follow the bouncing ball" singing in theatres; then Mitch Miller's sing-alongs. Now it seems that some manufacturers believe that sing-along is due for a resurgence. One, Pioneer Laser Entertainment, Inc. (a Pioneer Electronic Corp. subsidiary) announced three Laser Karaoke (means "empty orchestra" in Japanese) Systems to make available to us a popular sing-along format from Japan where people sing in groups or alone to recorded musical accompaniment, often in "karaoke" clubs where they can pick their tunes. The Pioneer systems show the lyrics on a TV set, as well as playing selected LaserDisc compositions. The current Karaoke library ranges from show tunes like "Hello Dolly" to old standbys like "Strangers in the Night" to "Peggy Sue" to "Over the Rainbow," and "Jailhouse Rock," among others, which include Christmas carols, nursery-rhyme tunes, etc. The self-contained machines incorporate various voice enhancement controls to support the music videos, such as a Voice Key Controller, Digital Echo, Voice Volume, Five-Band Graphic Equalizer, two microphone inputs and a built-in cassette recorder for recording purposes. Original vocals can be restored, too. The models can also play regular LaserDisc movies or video programs.

Train with NRI for a servicing

NEW!
20 Meg Hard Disk Included!

Get started now by building this fully IBM PC-compatible computer

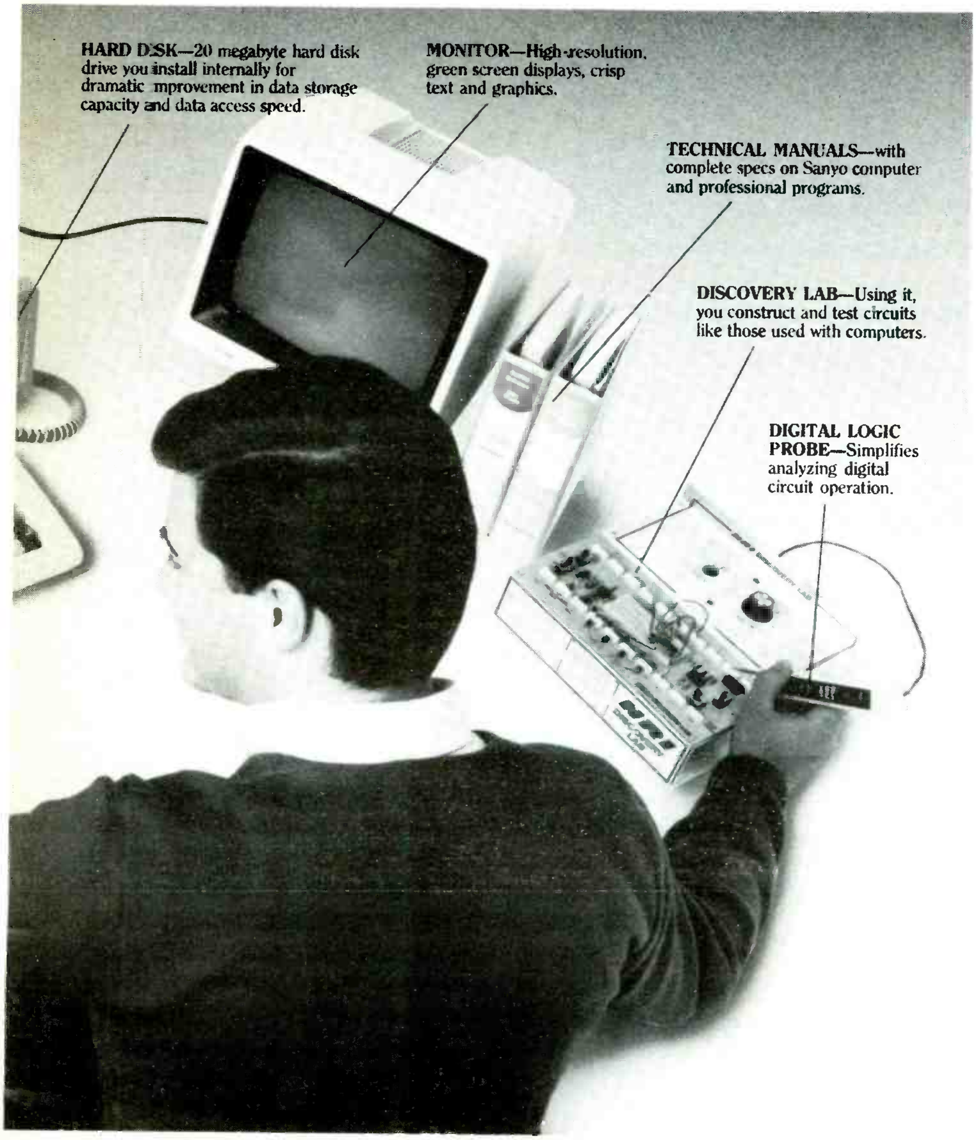
Now you get it all . . . training for one of America's fastest-growing career opportunities . . . training to service all computers . . . training on a total computer system, the Sanyo 880. Only NRI can give you the well-rounded training you need, because only NRI gives you a complete computer system . . . computer, monitor, floppy disk drive, hard disk drive, software, even test instruments like a DMM and logic probe to work with and keep. It all adds up to training that builds the knowledge and ability you need to succeed as a computer service specialist.



Get inside the newest, fully IBM PC-compatible Sanyo Microcomputer

As an NRI student, you'll get total hands-on training as you actually build your own latest model Sanyo 880 Series computer from the keyboard up. It's fully IBM PC-compatible and, best of all, it runs programs almost twice as fast as an IBM PC. As you assemble the Sanyo 880, you'll perform demonstrations and experiments that will give you a total mastery of computer operation and servicing techniques. You'll do programming in BASIC language—even run and interpret essential diagnostic software.

high paying career computers



Understanding you get only through experience

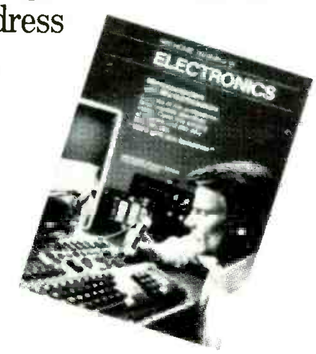
You need no previous knowledge to succeed with NRI. You start with the basics, rapidly building on the fundamentals of electronics with bite-size lessons. You perform hands-on experiments with your NRI Discovery Lab and then move on to master advanced concepts like digital logic, microprocessors, and computer memories.

Learn at home in your spare time

You train in your own home at your own convenience, backed at all times by your own NRI instructor and the entire NRI staff of educators and student service support people. They're always ready to give you guidance, follow your progress, and help you over the rough spots to keep you moving toward your goal.

Free 100-page catalog tells more . . . send today

Send the postage-paid reply card today for NRI's 100-page catalog that gives all the facts about computer training, plus career training in robotics, data communications, TV/audio/video servicing, and many other fields. If the card is missing, write to NRI at the address below.



NRI SCHOOLS

McGraw-Hill Continuing Education Center
3939 Wisconsin Avenue
Washington, DC 20016

We'll give you tomorrow.

For more information on products described, please circle the appropriate number on the Free Information Card bound into this issue or write to the manufacturer.

Hand-Held "Workbench"

B&K-Precision has just released a new instrument that has built into it test and measurement capabilities of a testbench full of gear. The Model 388-HD, appropriately called the Test Bench™, is a 41-range voltmeter, ammeter, ohmmeter, frequency counter, capacitance tester, logic tester, transistor/diode tester and continuity tester—all in a drop-resistant case the size of a conventional hand-held digital multimeter. It features a large-size LCD window for high readability under just about any viewing conditions.

Triple protection is provided for the new instrument, including reverse-polarity and overload protection and high-energy fusing. Dc accuracy is rated to be within 0.5%, while ac accuracy is rated to be within 1.25% from 40 Hz to 1 kHz. Input impedance on both dc and ac is 10 megohms. Currents up to 20 amperes ac and dc, resistance up to 2,000 megohms and capacitance (in five ranges) to 20 microfarads can be measured. The instrument can count frequencies up to 200 kHz and has a resolution of up to 1 Hz.

Diode junctions are tested with a maximum current of 1.5 mA and maximum open-circuit potential of 3.2 volts. Test results in this function are indicated in the LCD window and audibly through a built-in beeper, which is also used for continuity tests. Bipolar transistors can be tested for h_{FE} gain from 0 to 1,000. Finally, the logic tester indicates logic 0 and logic 1 states in TTL-level digital circuits. $139.

CIRCLE 1 ON FREE INFORMATION CARD

Upgradeable '286 Computer

Vendex's (Great Neck, NY) HeadStart PRO computer comes with a 16-MHz 80286 microprocessor but, with the addition of two chips and the flick of a switch, can be transformed into a 20-MHz 80386 machine without any additional boards or modifications to the hardware. Supplied as standard hardware are: 2M bytes of RAM (expandable to 8M bytes on the motherboard); 6-in-1 VGA graphics adapter (VGA, EGA, MCGA, CGA, Hercules and MGA compatible); 2,400-baud HeadStart Friend-Link Modem; mouse; hard-disk controller; 1.2-MB 5.25" and 1.44-MB 3.5" floppy drives; choice of hard-disk capacities. The basic system comes with a 32-MB hard drive.

Also featured is a unique six-slot upgrade bus that accommodates XT,

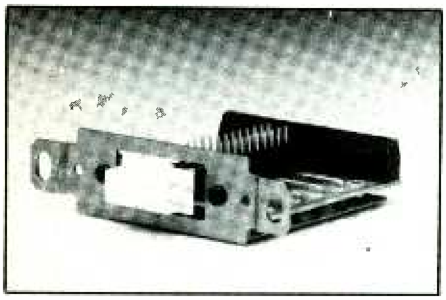
AT or 32-bit Compaq-compatible peripheral cards. Other hardware supplied includes a built-in clock/calendar with 2-year lithium batter back-up, one parallel port; separate 9- and 24-pin serial ports; an Arc-Network port; game port; mouse port; 101-key PS/2-compatible keyboard; and 200-watt 117/220-volt power supply. Available as options are a 13" VGA analog paper-white high-resolution monochrome ($249) and 13" high-resolution, 0.31 dot-pitch VGA color ($695) monitors, both with tilt/swivel bases.

Bundled at no extra charge with the computer is a software package that includes the OS/2 operating system, Ashton Tate's "Framework II," the HeadStart Advanced Environment (modeled after IBM's SAA specification by Executive Systems), Floppy Driver, an ATI tutorial, HeadStart 3D Graphics, Dynamic Publisher, XTREE PRO, LogiTech Paintshow and Chessmaster 2000. The software is designed to work in conjunction with the HeadStart Advanced Environment so that each program is completely menu-driven for ease of use. The HeadStart Advanced Environment also provides the user with new menus that offer a choice between beginner, intermediate and advanced skill levels. $3,995 with 80-MB, 28-ms hard drive.

CIRCLE 2 ON FREE INFORMATION CARD

Speaker/Source Switcher

Sonance's (San Juan Capistrano, CA) ABW1 in-wall high-fidelity speaker or source switcher fits into a light-switch box and can be covered with a conventional wall-type switch plate. It can handle on/off switching of a pair of speakers or selection between such signal sources as TV receiver and audio system. Operation is via a single push-push switch that is rated to handle up to 200 watts of power. This switcher can be used in conjunction with the company's Models VC50 and VC100 in-wall

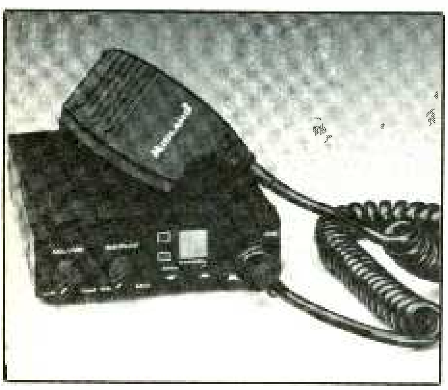


volume controls to provide the audio equivalent of a light dimmer. All three units can be installed in a standard light-switch housing that can be covered with standard wallplates to match or complement room decor. $26.50 to $30.00.

CIRCLE 3 ON FREE INFORMATION CARD

Mini Mobile CB Rig

Midland packs 40 channels of two-way mobile CB communications into a package that measures just $4\frac{1}{4}$"W × $4\frac{1}{4}$"D × $1\frac{1}{4}$"H in its new Model 77-099 transceiver. Claimed to be the world's smallest 40-channel mobile CB transceiver, it can be mounted in or on almost any vehicle, including motorcycles, snowmobiles and other recreational vehicles.

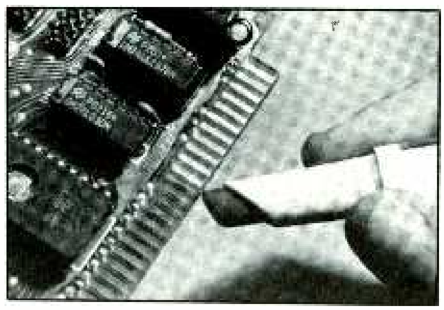


ETR frequency control is built into the mini transceiver for pinpoint channel tuning accuracy, and separate up/down channel scan controls are provided. The receiver section employs a dual-conversion superheterodyne design. Other features include: full-time ANL to eliminate background noise during receive; a ceramic filter for improved selectivity; enhanced modulation for more "talk" power; condenser microphone with front-panel locking mount; separate LEDs for transmit and receive; and a large high-intensity projection mask LED channel display. $89.95.

CIRCLE 4 ON FREE INFORMATION CARD

Quick Contact Repairs

Field service kit No. 4c3k from Micro-Circuits, Inc. (New Buffalo, MI) is said to eliminate a major cause of electronic equipment down time in bus-type systems that use connectors into which circuit-board edges plug. A technician simply unplugs a circuit



board from its connector and rubs onto its edge-connector contacts a thin layer 4c3m gold replacement from the 4c3k's shirt-pocket-size applicator. This permanently restores sound board-to-connector conductivity and eliminates the problem. The whole process takes about 6 seconds to complete, at an economical cost of approximately 12 cents per connector.

CIRCLE 5 ON FREE INFORMATION CARD

Calling/Alerting System

The Auto-Kall HF-Alert from Mo-Tron Electronics (Eugene, OR) is a selective calling or alerting system designed to be used with hf SSB/CW radio systems. The device eliminates the need for you to constantly monitor busy or noisy channels. According to the manufacturer, HF-Alert works with almost any radio system, including hf/vhf/uhf, SSB/CW/FM/AM, CB, marine hf/vhf, etc. It mutes the speaker until the correct calling sequence (225 combinations possible) is received from another

unit. A correct incoming sequence turns on a LED and enables an audible alarm. Calling/decoding codes are set with rotary switches on the front panel. The calling signal is sent either by directly keying a radiotelegraph transmitter or by placing the microphone next to the speaker.

The HF-Alert comes with a mobile mounting bracket, 117-volt ac power supply for base-station operation and an audio patch cord. A built-in speaker is provided, but an external speaker (not supplied) can also be used. $129.95.

CIRCLE 6 ON FREE INFORMATION CARD

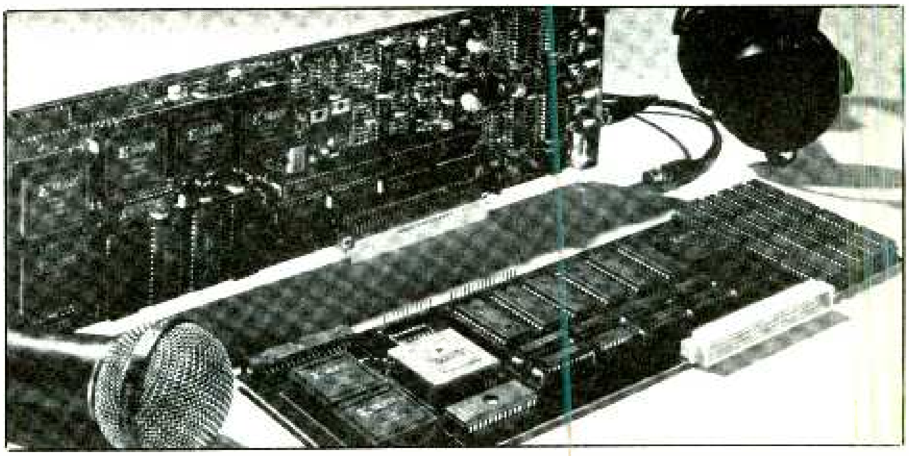
Auto-Scan Printer Switch

The Model PAS-41 parallel auto-scan printer switch from Tab Sales Co. (Pensacola, FL) switches up to four computers for sharing of a single parallel-feed printer (or plotter or other peripheral). Features include: all-electronic switching between

computers and peripherals; regulated and fused dc power; built-in 6-foot printer cable; switch-selectable, hardware generated form feed; and switch-selectable automatic or manual scan mode. On automatic, each computer is scanned ten times each second for an output signal. $189.95.

CIRCLE 64 ON FREE INFORMATION CARD

NEW PRODUCTS . . .



Macintosh II NuBus Audio Signal-Processing Cards

A series of signal-processing cards for Macintosh II NuBus systems has been announced by Southworth Music Systems (Harvard, MA) for audio A/D and D/A applications. The cards reproduce, analyze and synthesize digitally-stored audio with a fidelity claimed to be better than that of CDs. Each card uses parallel-processing Motorola 56000 processing chips.

The Max Audio Analog Card performs all A/D and D/A conversion using a proprietary 20-bit converter that provides 104 dB S/N on recording and 120 dB S/N on playback. It supports sample rates of 44.1 kHz (standard CD rate), 48 kHz (DAT and professional recorder rate), 96 kHz (2 × oversampling rate) and 192 kHz (4 × oversampling rate). Ultra-high-speed signal processing replaces nearly all of the analog components used in conventional converters. A/D conversion is performed by a custom ECL circuit that samples the input signal 24-million times per second and integrates the data to 192 kHz. By operating well above the audio range, the card is said to perform without the usual multitude of analog filtering components. $1,400.

The Max Audio Quad 56000 DSP Card provides additional signal processing, frequency-domain audio processing (such as pitch tracking and shifting), sample playing and additive synthesis. In addition to the RAM on each 56000 chip, this card provides facilities for 3MB more optional shared-memory RAM for storage of audio samples. It operates at 68 MIPS. $1,400.

The Digital Audio/SMPTE Card sends and receives audio data in AES/EBU Digital Audio format for recording CD or DAT recorder data in digital form and provides an SMPTE Time Code reader/generator that gives a means of locking the speed of playback or recording in the Macintosh to an external multitrack tape recorder or VCR. This card is able to trigger events to SMPTE Time Code with an accuracy of 1 microsecond. $995.

CIRCLE 7 ON FREE INFORMATION CARD

Intelligent Remote

Technics' new Model SH-R700 intelligent audio/video remote controller can replace the controller units for up to five infrared-controlled devices. It has a built-in learn capability that lets you store a total of 144 commands that are accessed by pressing a touch-sensitive LCD display panel that includes alphanumeric displays. The five display faces into which the LCD panel is segmented change to match the component in operation, keeping the number of physical keys and overall size of the unit to a minimum while contributing to simplified operation. Learning functions are programmed in just seven steps.

Of the 144 commands available, 46 are fixed for Technics audio equipment. The other 98 are capable of learning the major commands of most infrared remote controllers for a CD player (28 learning functions), TV receiver (22 functions), videocassette recorder (23 functions), and an

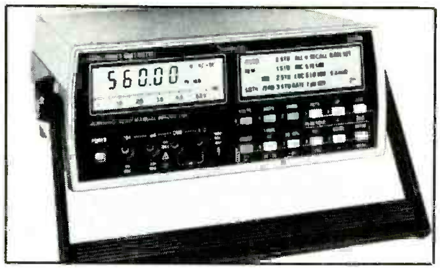
optional device (25 functions). It operates on four AA cells (not included) and, when the battery is too weak to operate the unit, a "Battery No" message is displayed. Whatever is stored in memory will be preserved for about a week after this message is displayed. The new controller measures $8\frac{1}{4}$"L × $3\frac{5}{16}$"W × $1\frac{13}{32}$"D and weighs 8.7 ozs. $200.

CIRCLE 8 ON FREE INFORMATION CARD

Menu-Driven Multimeter

The Simpson Electric Professional Series Model 560 digital multimeter's wide features and capabilities are accessible through menu-driven programming. The meter features ultra-fast auto-ranging; data-logging capability on any selected range with battery-backed measurement memory; frequency counting capability; continuity and diode check with audible beeper; pushbutton operation; and separate LCD windows that separately display measurements in a five-decade format and menu/programming in four lines.

The meter can measure rms ac + ac plus dc volts, true rms (TRMS) ac or ac + dc coupled amplifiers, dc volts, current, low and high resis-



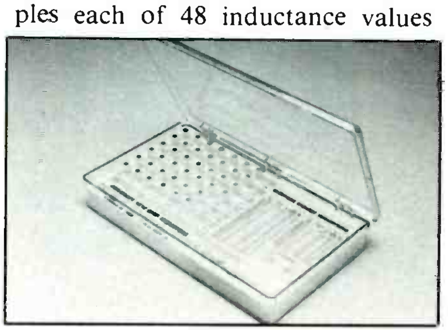
tance, dBm on any voltage range and frequency from 5 Hz to 500 kHz. Instrument integrity is rated at 1 kV dc + peak ac circuit to ground and all inputs are transient protected to 6 kV at 100 microseconds. Special functions include diode and continuity test, differential peak hold, REL and zero. Menu functions for selected measurements are: Store-all (inclusive or exclusive) Recall, Hi and Lo Limit, dB Ref and Rel Set. On-board battery-backed nonvolatile RAM retains last user selections and readings.

Available are an 8-bit (with strobe and ready) Centronics-compatible parallel printer port and an RS-232C serial port that can be set for 300 to 9,600 baud. Both are fully isolated. $2,195 basic instrument; $2,395 with optional serial or parallel interface.

CIRCLE 9 ON FREE INFORMATION CARD

Surface-Mount Inductor Kit

A low-cost Designer's Kit that contains 480 surface-mount inductors can now be obtained from Coilcraft (Cary, IL). The kit provides 10 samples each of 48 inductance values



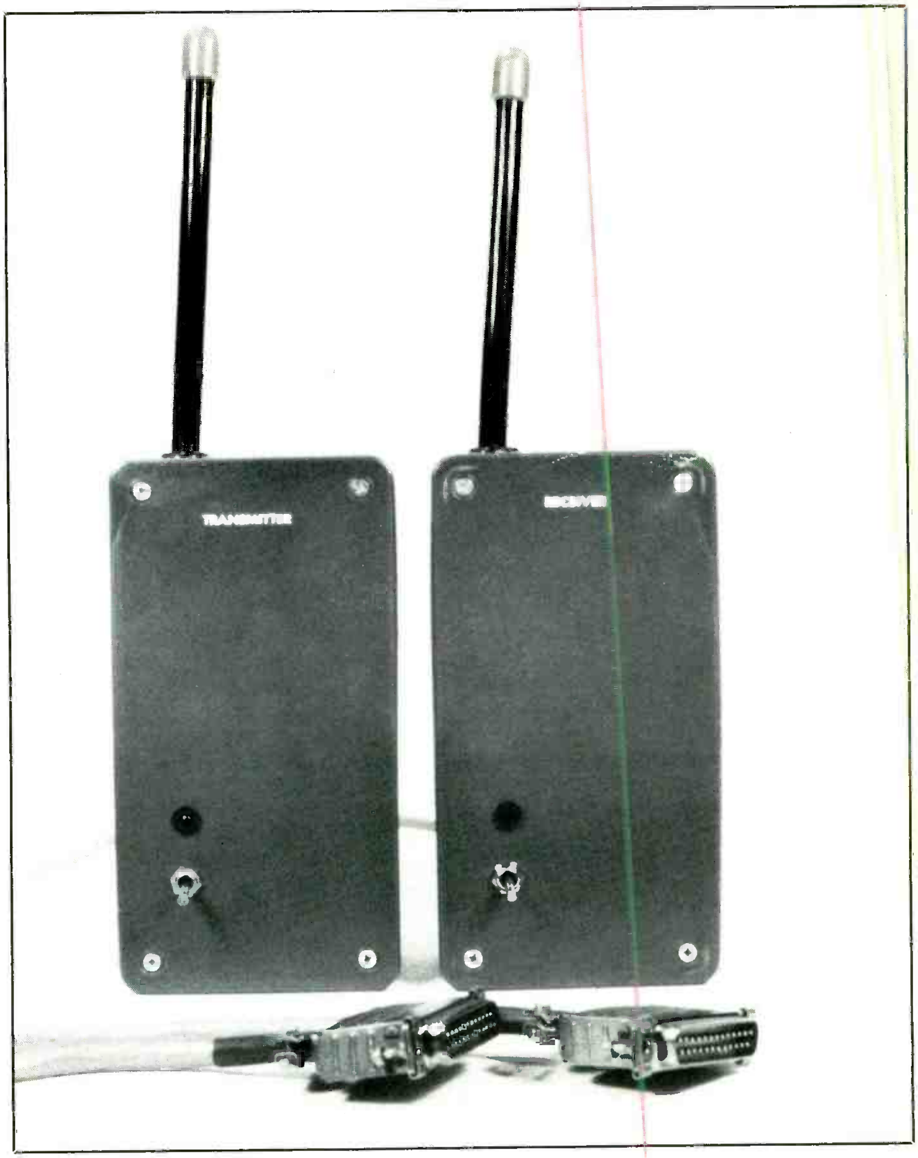
ranging from 4 nanohenrys to 33 microhenrys. The 10% and 20% tolerance inductors come in 1008 and 1611 body sizes. They are packaged in a reusable clear plastic box with hinged lid. $125.

CIRCLE 10 ON FREE INFORMATION CARD

A Wireless Data Link

This 300-baud accessory eliminates the need for long cable runs when connecting serial peripherals to a computer

By Jan Axelson & Jim Hughes



The RS232 serial interface has become a popular way to send data from a computer to another computer, remote terminal, printer, or other serial device. However, when the devices to be interconnected are located in different rooms or are on different floors, running a cable between them isn't always convenient or even practical. For situations like these, you need a device like the Wireless Data Link to be described. This handy device does away with the need for the connecting cable, using radio waves instead of physical cables to link together RS232 data transmit/receive devices. It operates at a transmission speed of 300 baud.

About the circuit

Design of the circuitry for this project was greatly simplified due to use of two convenient building blocks. One is National Semiconductor's 74HC943 single-chip modems that convert digital data into audio-frequency tones that can easily be transmitted on an r-f carrier and, at the receiving end, converts the tones back into digital data square waves. The other building block is Radio Shack's Space Patrol walkie-talkies that are used here as transmitters and receivers of the audio signals. These operate on the 49-MHz citizens band.

Portability isn't a criterion for this project. Therefore, the circuits are powered by ac-operated 9-volt dc power supplies or batteries. Whichever powering option is used, the system can accept and generate bipolar RS232-compatible signals, at a communication speed of 300 bits per second.

Shown in Fig. 1 is the schematic diagram of the very simple (in terms of component count) transmitter modem circuit. It is designed to reside between the computer's or other device's RS232 interface and the input to transmitting walkie-talkie. Regulated 5 volts dc for modem chip

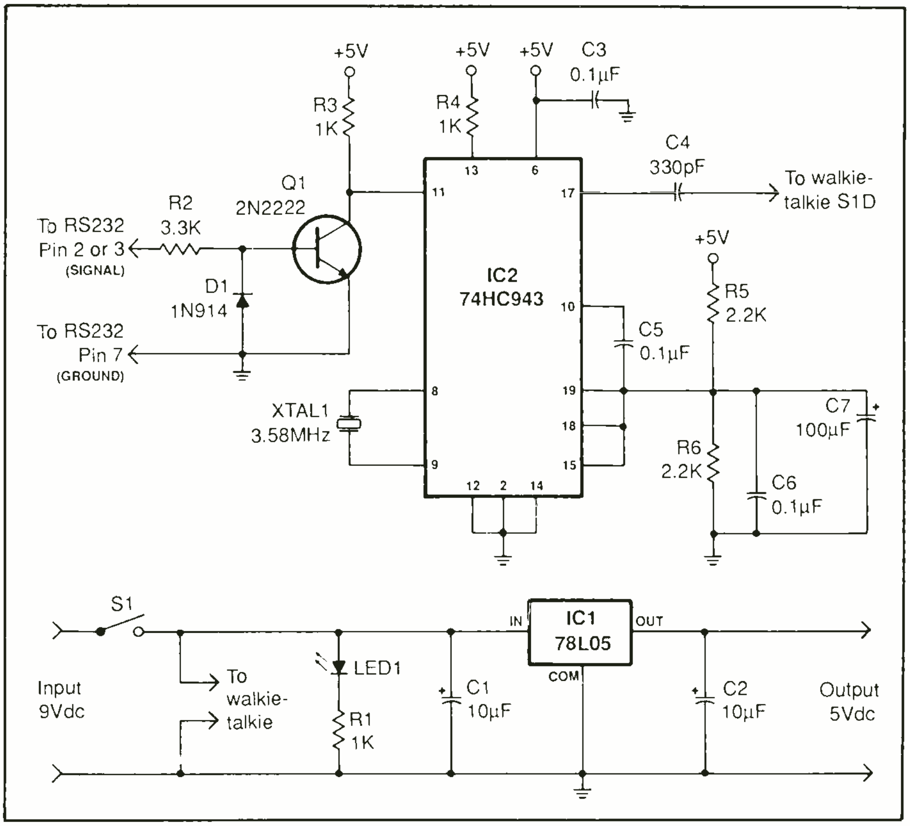


Fig. 1. Schematic diagram of the transmitter unit from the RS232 interface to the input to the walkie-talkie.

IC2 is provided from the 9-volt dc source by regulator *IC1*. Light-emitting diode *LED1* serves as a convenient POWER-on indicator.

Data to be transmitted is fed from the RS232 interface through resistor *R3* to the base of transistor *Q1* in the Fig. 1 circuit. According to the RS232 standard for bipolar data signals, a transmitted logic 1 is represented by a potential between −5 and −15 volts, a logic 0 between +5 and +15 volts. Transistor *Q1*, diode *D1*, and resistor *R3* convert the bipolar signal to the TTL-compatible levels required by *IC2*. The transistor also inverts the signal, converting negative inputs to high voltage levels and positive inputs to low voltage levels.

Modem chip *IC2* receives the digital signal at pin 11 and uses frequency-shift-keyed (fsk) modulation to code the digital information as an analog signal. Being a single-chip modem in the high-speed CMOS family of circuit devices, the 74HC943 is designed primarily for use in telephone communications. It contains on-chip analog-to-digital (A/D) and digital-to-analog (D/A) converters, as well as timing and control circuits. This is a sophisticated chip and, needless to say, our Wireless Data Link project uses only some of the chip's capabilities.

In fsk modulation, logic 1s and 0s are represented by different frequencies, rather than by different voltage levels. The frequencies used by *IC2* are those defined by the Bell 103 standard for modem transmission. To permit full-duplex (two-way) transmission over telephone lines, the Bell 103 standard specifies two sets of frequencies, one for transmitting in each direction. Figure 2 shows both sets.

The simplex (one-way) circuit presented here uses just one of these pairs. To select the "originate" frequencies for transmitting, pin 11 of *IC2* is tied high. When the input at pin 11 is low, pin 17 outputs a 1,070-Hz sine wave; when pin 11 is high, pin 17 outputs 1,270 Hz.

PARTS LIST

Semiconductors
D1—1N914 or similar silicon diode
D2,D3—1N270 germanium diode
IC1,IC3—78L05 +5-volt regulator
IC2,IC6—74HC943 300-baud modem (National Semiconductor)
IC4—555 timer
IC5—1488 quad line driver for RS232
LED1,LED2—Light-emitting diode (high-intensity recommended)
Q1—2N2222 or similar npn transistor

Capacitors (16 WV minimum)
C1,C2,C8,C9,C11,C12—10-µF electrolytic
C3,C5,C6,C13,C14,C15,C16—0.1-µF ceramic
C4—330-pF ceramic
C7,C17—100-µF electrolytic
C10—0.001-µF ceramic

Resistors (¼-watt, 10% tolerance)
R1,R3,R4,R7—1,000 ohms
R2—3,300 ohms
R5,R6,R9,R10—2,200 ohms
R8—68,000 ohms

Miscellaneous
XTAL1,XTAL2—3.579545-MHz crystal
S1,S2—Spst toggle or slide switch
Printed-circuit boards (2) or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware; two Archer Space Patrol walkie-talkies (Radio Shack Cat. No. 60-4015); DIP sockets for IC2, IC4, IC5, and IC6; suitable enclosures (2); two subminiature D-type RS232 connectors; rubber grommets; two 9-volt batteries and battery clips or two 9-volt dc power supplies and connecting jacks (see text); panel clips for LEDs (2); 2-conductor cable; machine hardware; hookup wire; solder; etc.

Figure 3 shows the square-wave input to the modem and the frequency-shift-keyed output that results. If you carefully examine the photo, you can see that the frequency of the sine wave changes slightly as the voltage of the square wave goes high and low.

The clock for the modem chip is provided by *XTAL1*, a 3.58-MHz crystal (a standard TV color-burst type). Resistors *R5* and *R6* and capacitors *C6* and *C7* provide an analog ground midway between the +5-volt supply and circuit ground rails. Capacitor *C4* couples the fsk signal to the audio input of the walkie-talkie, in place of the speaker.

The fsk input to the walkie-talkie consists of sine waves in the voice, or audio, frequency band. The walkie-talkie, which is designed for voice communication, can easily transmit such a signal. It uses FM (frequency modulation) to carry the signal over the 49-MHz radio band.

Unused pins on *IC2* are tied to ground as recommended by the IC's data sheet. Pins 14 (squelch transmitter) and 2 (analog loop-back) are grounded for normal operation. Pins 15 (receive analog #2) and 18 (external input) are tied to analog ground, and pin 10 (filter test input) is analog-grounded through a 0.1-microfarad capacitor.

On the other end of the data link, another walkie-talkie receives and demodulates the FM signal. A second modem chip converts the frequency-shift-keyed signal back to digital pulses, and an RS232 driver and 555 timer provide an RS232-compatible signal for the end receiving device. The receive unit also includes a 5-volt regulator like the one in the transmitter. The receiver's schematic diagram is shown in Fig. 4.

The speaker output of the receiving walkie-talkie is coupled to the input of receive modem chip *IC6* by capacitor *C14*.

The receive modem is configured much like the transmit modem, except that pin 13 of the modem chip is grounded to identify it as an "answer" device. The modem converts the fsk input at pin 17 back to digital pulses, which appear at pin 5. (These digital pulses should match those at pin 11 of the transmitting modem.)

	Originate	Answer
Space (logic 0)	1,070 Hz	1,070 Hz
Mark (logic 1)	1,270 Hz	1,270 Hz
Direction of Transmission →		
Space (logic 0)	2,025 Hz	2,025 Hz
Mark (logic 1)	2,225 Hz	2,225 Hz
← Direction of Transmission		

Fig. 2. In the Bell 103 standard for modem transmission, different frequencies are designated for communicating in each direction.

The pulses are inverted and level-shifted to a bipolar RS232-compatible signal by RS232 driver chip *IC5*. The negative voltage supply for *IC5* is generated at *C12* by timer *IC4*. In the timer circuit, adapted from a circuit in *IC Timer Cookbook* by Walter Jung, the 555 is configured as an astable oscillator, whose frequency of about 10,000 Hz is set by *C10* and *R8*.

Several oscillator cycles are required to fully charge *C12*. When power is first applied to the circuit and pin 3 of *IC4* goes high, *C11* charges through *D2* to approximately 7 volts, which is limited by the output characteristics of the 555 and the voltage drop across *D2*. When pin 3 goes low, *C11* "shares" its charge with *C12*, which charges to about −3 volts through *D3*.

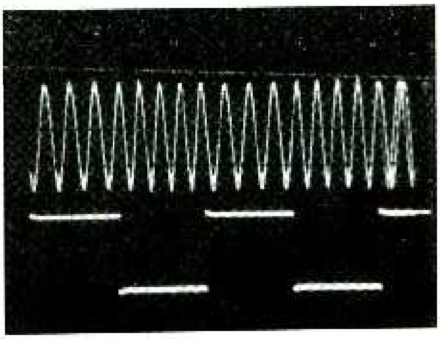


Fig. 3. The bottom trace shows the digital RS232 signal. The top trace is the frequency-shift-keyed output at the modem chip.

When pin 3 again goes high, *C11* recharges to 7 volts. Then when pin 3 goes low again, *C11* charges *C12* until the two are at equal potential once more, with about 5 volts across each. The potential across *C12* increases in this manner, cycle-by-cycle, until it levels out at about −6.5 volts. Use of germanium devices holds the limiting effect of the diode drops to a minimum.

The output at pin 3 of *IC5*, the RS232 driver, is a bipolar signal with positive peaks of about +7 volts and negative peaks of about −5 volts. These fall within the "legal" levels specified by the RS232 standard.

Construction

Since the two units are quite similar in design, you can build them side-by-side, following essentially the same procedures. Figure 5 contains the actual-size etching-and-drilling guides for both printed-circuit boards. Figure 6 shows component layout and orientations and off-board connections for both circuit-board assemblies.

Though printed-circuit construction is recommended for ease of assembly and virtual elimination of chance wiring errors, if you prefer, you can build the circuits on perforated board that has holes on 0.1-inch centers. If you do this, use suitable Wire Wrap or soldering hardware and arrange the components approximately the same as in Fig. 6, but refer to Fig. 1 for wiring the transmitter and Fig. 4 for wiring the receiver boards.

Begin construction by installing

EXPAND YOUR CAREER HORIZONS...

The CIE Microprocessor Trainer helps you to learn how circuits with microprocessors function in computers.

START WITH CIE.

Microprocessor Technology. Satellite Communications. Robotics. Wherever you want to go in electronics... start first with CIE.

Why CIE? Because we're the leader in teaching electronics through independent study. Consider this. We teach over 25,000 students from all over the United States and in over 70 foreign countries. And we've been doing it for over 50 years, helping thousands of men and women get started in electronics careers.

We offer flexible training to meet your needs. You can start at the beginner level or, if you already know something about electronics, you may want to start at a higher level. But wherever you start, you can go as far as you like. You can even earn your Associate in Applied Science Degree in Electronics.

Let us get you started today. Just call toll-free **1-800-321-2155** (in Ohio, 1-800-362-2105) or mail in the handy reply coupon or card below to:
Cleveland Institute of Electronics,
1776 East 17th Street, Cleveland, Ohio 44114.

CIRCLE 98 ON FREE INFORMATION CARD

CIE World Headquarters — AMO-115

Cleveland Institute of Electronics, Inc.
1776 East 17th Street • Cleveland, Ohio 44114

☐ Please send your independent study catalog.
For your convenience, CIE will try to have a representative contact you — there is no obligation.

Print Name ____________________

Address ____________________ Apt. ______

City ____________________ State ______ Zip ______

Age ______ Area Code/Phone No. ____________________

Check box for G.I. Bill bulletin on Educational Benefits
☐ Veteran ☐ Active Duty **MAIL TODAY!**

Just call toll-free **1-800-321-2155** (in Ohio, 1-800-362-2105)

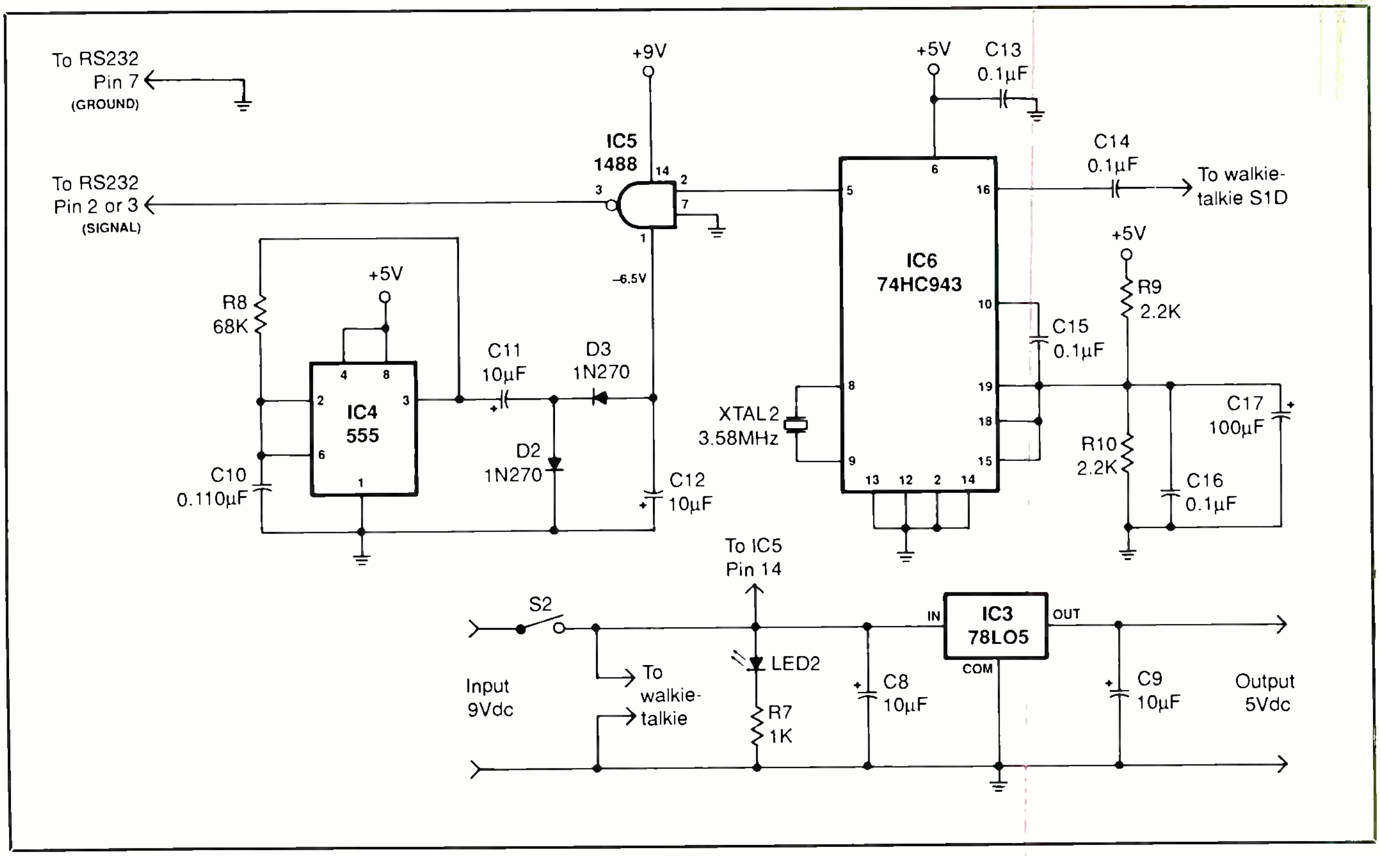


Fig. 4. Schematic diagram of the receiver unit from the output of the walkie-talkie to the RS232 interface.

and soldering into place DIP sockets for *IC2*, *IC4*, *IC5* and *IC6*. Do not install the ICs themselves at this time. Then install and solder into place all resistors, capacitors, diodes, the transistor, crystals and voltage-regulator ICs. Observe proper orientation for electrolytic capacitors, diodes, transistor and the three-terminal voltage regulators. Note that the positive (+) lead of *C12* connects to circuit *ground*.

Now prepare the walkie-talkies as follows. Begin by removing their back covers. Figure 7 is an interior view of one of the Radio Shack Space Patrol walkie-talkies specified for this project. Remove the screws that hold in place the printed-circuit assemblies and antennas in both walkie-talkies.

Cut off the red and black wires leading to the circuit boards at the battery snap connectors. Then cut

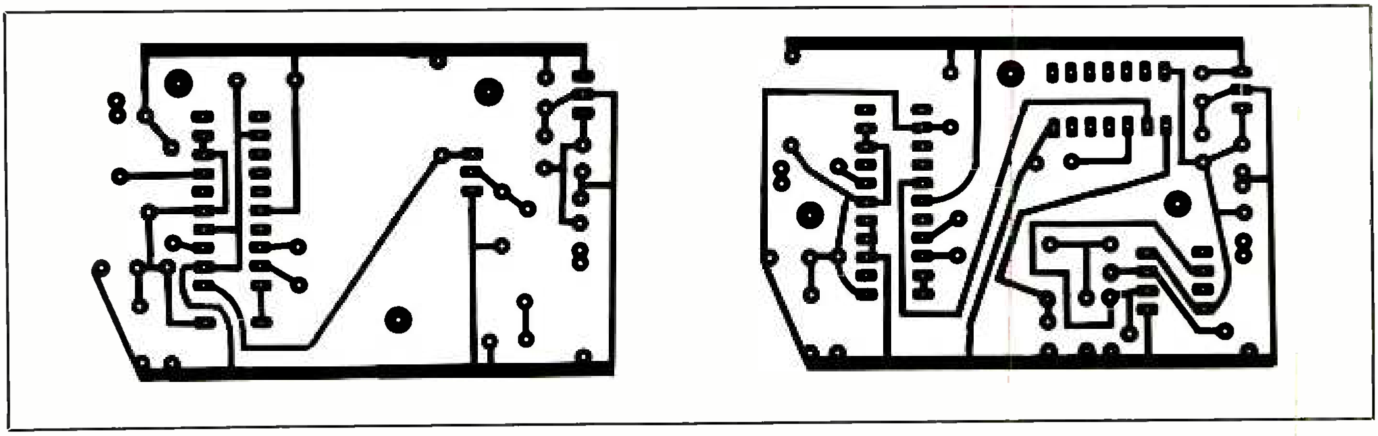


Fig. 5. Actual-size etching-and-drilling guides for the transmitter's (A) and receiver's (B) printed-circuit boards.

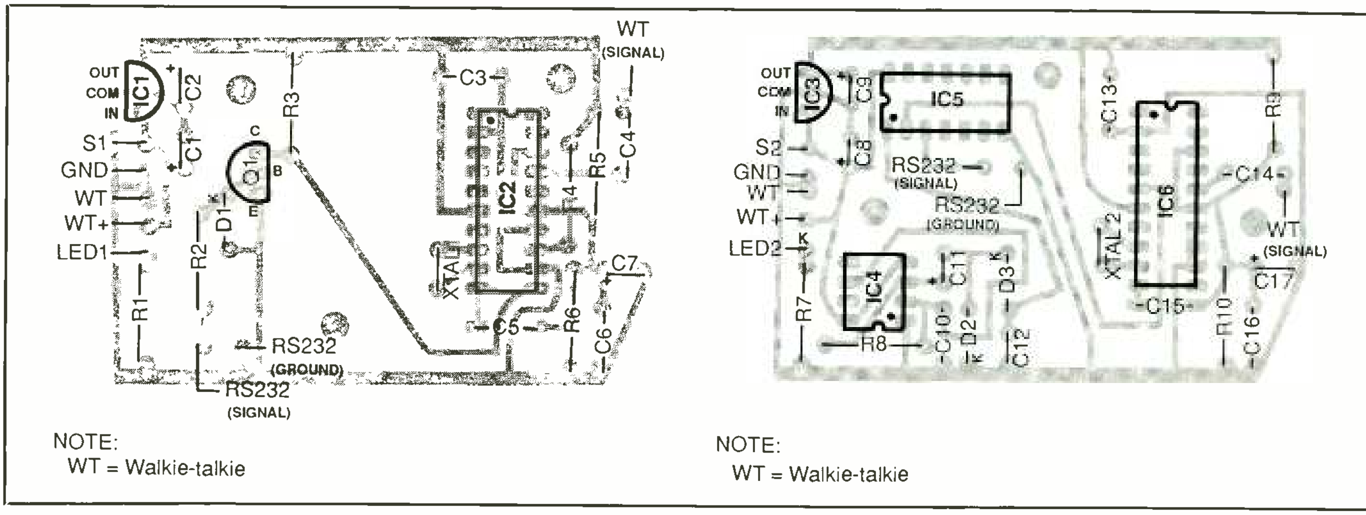


Fig. 6. Wiring guides for the transmitter (A) and receiver (B) pc boards. Use these as rough guides to component layout if you wire the circuits on perforated board.

the two speaker wires on each unit near the lugs of the speakers. Lift out of the cases the circuit-board assemblies and set the cases aside.

Unsolder and save the red battery wires that connect to the on/off switches in both cases. These switches and the orange transmit/receive switches on the walkie-talkies can now be unsoldered and removed. You will replace the on/off switches with a master switch for each unit; the transmit/receive functions will be hard-wired later.

Use a vacuum-type desoldering tool or wicking-type desoldering braid to remove the solder from the pins of the switches and carefully work the switches free. After removing the on/off switches, resolder one end of the red wires to the 9-volt trace on each board. This trace is located one pin up from where the wire was originally fastened. For double-checking locations on the walkie-talkie's circuit board, Radio Shack supplies schematic diagrams with its Space Patrol units.

After removing the transmit/receive switches, their functions can be wired at each walkie-talkie. Designate and so label one walkie-talkie as the transmitter, the other as the receiver, and use short jumper wires to solder the connections at the switch locations, as shown in Fig. 8. The removed switches and speakers can be saved for use in other projects.

Prepare 12 8-inch or so lengths of hook-up wire by stripping from each end ¼ inch of insulation. If you are using stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Use these wires for interconnecting the circuit-board assemblies and switches. Though the following instructions describe the procedure for wiring one unit, follow the same procedure for both transmitter and receiver.

First, solder a wire from the negative (−) terminal on the power supply connector or battery clip to GND on the circuit board. Figure 6 shows the circuit board connection locations. Next, solder a wire from the positive (+) terminal on the power supply connector or battery clip to one lug of *S1*. Then solder two wires to the other lug of *S1* and connect one to the anode of the LED and the other to the +9V pad on the circuit board. Solder a wire from the LED's cathode to the LED1 K pad on the circuit board.

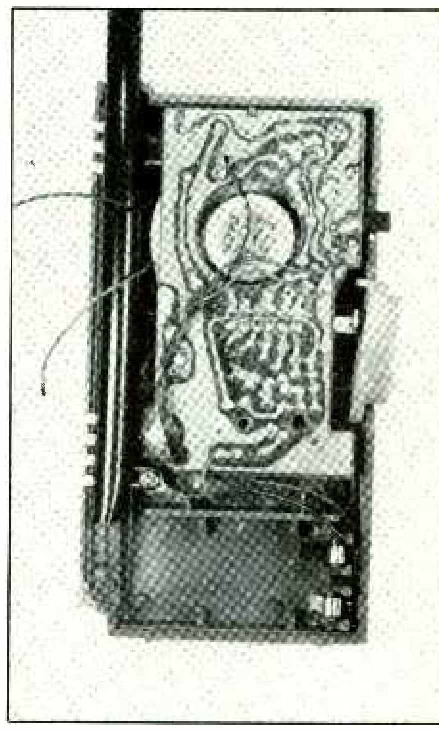


Fig. 7. Interior view of one of the walkie-talkies used in this project.

Solder a wire from the WT signal pad on the circuit board to the jumper at *S1D* on the walkie-talkie, as shown in 8. Solder the red- and black-insulated battery wires on the walkie-talkie to the WT+ and WT−

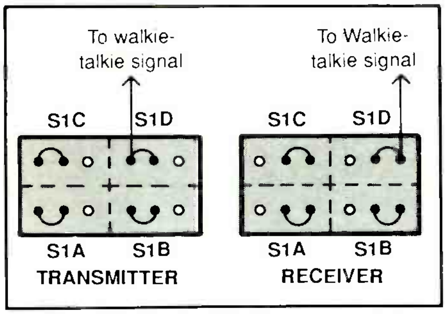


Fig. 8. Wiring guide for transmit/receive switch in walkie-talkies. Switch is shown in same orientation as in Fig. 7.

pads on the circuit board, making sure to observe proper polarity.

To prepare the enclosures used for the project, drill appropriate-size holes for the antenna, on/off switch, LED, and power supply jack (if used). The antenna should mount on one side of the enclosure at the rear. This way, its top will rise out of the case. Mount the walkie-talkie board at the bottom of the enclosure so it can easily connect to the bottom of the antenna. Use ½-inch spacers to provide clearance for the antenna when mounting the circuit boards.

Make a hole for inserting a two-wire cable for the RS232 interface and line the cable and antenna holes with rubber grommets. If you prefer, you can mount the RS232 connector directly on the enclosure and use a separate cable. If you do this, prepare an appropriate-size and shape cutout for the connector. Drill mounting holes for the circuit boards. Slide the antenna through its hole and insert and fasten the power supply jack, if used.

A few words about the RS232 standard might be helpful here. The standard specifies RS232 devices as being either DTE (Data Terminal Equipment) with male connectors, or DCE (Data Communications Equipment) with female connectors. Most RS232 interfaces use subminiature D-type connectors. The standard also specifies that DTE devices transmit data on pin 2 and receive on pin 3 at the connector, with DCE devices transmitting on pin 3 and receiving on pin 2.

For a working data link, the transmit pin of the sending device must connect to RS232 signal on the transmitting modem board, and RS232 signal on the receive modem board must connect to the receive pin of the receiving device. Figure 9 illustrates the wiring for different combinations of equipment. A transmitting computer with a DTE interface, for example, requires a female connector on the transmitter unit, with RS232 signal wired to pin 2 of the connector. A printer with a DCE interface needs a male connector on the receive unit, with RS232 signal again wired to pin 2.

Because not all equipment rigidly adheres to the specifications of the RS232 standard, you should double-check which pin is used as the transmit pin before wiring the connector. To do this, turn on the device and measure with a dc voltmeter or multimeter set to the dc voltage function at the connector from pin 2 (signal) to pin 7 (ground) and then from pin 3 (signal) to pin 7 (ground). When no data is being transmitted, the transmit pin should provide a reading of

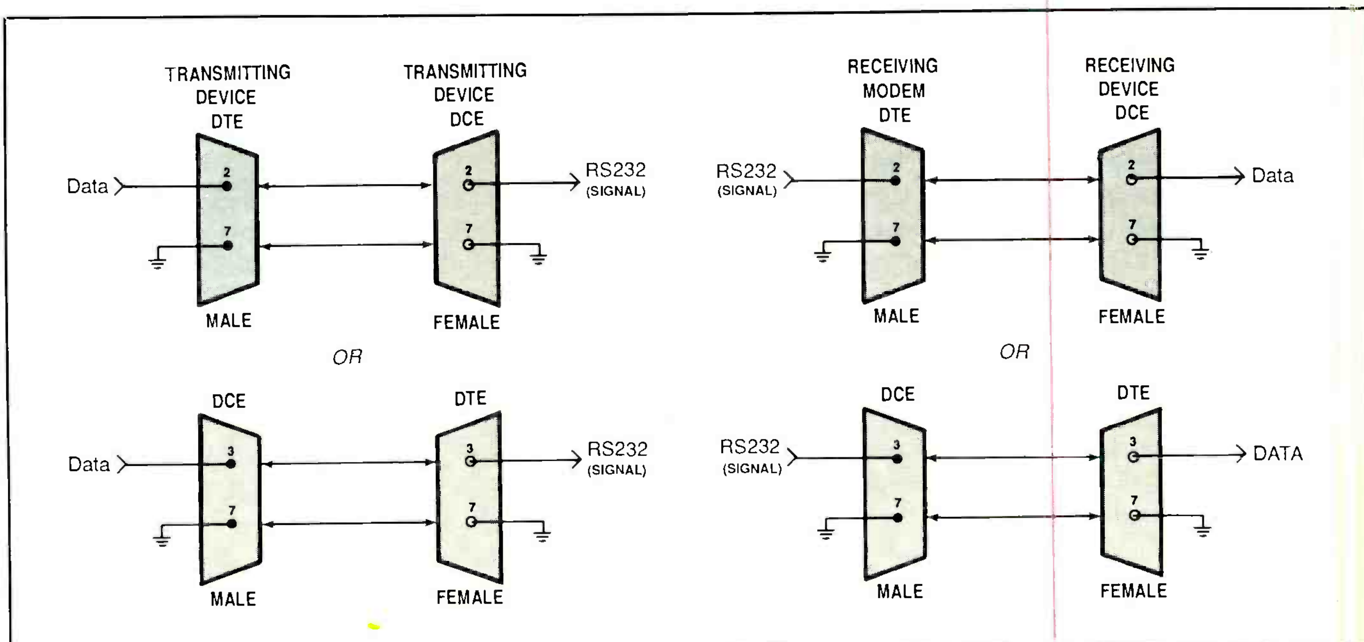


Fig. 9. The RS232 connectors must be wired to be compatible with the equipment they connect to. DTE devices have male connectors and transmit on pin 2. DCE devices have female connectors and transmit on pin 3. Pin 7 is signal ground.

−5 to −15 volts, while the reading at the receive pin should should be 0 volt.

To wire the RS232 connector, cut a length of two-conductor cable long enough to conveniently reach from the end equipment to the wireless link. Remove 2 inches of the outer plastic jacket from both ends of the cable and strip ¼ inch of insulation from each conductor. Tightly twist together the fine wires at each conductor end and sparingly tin with solder.

Solder the conductors at one end of the cable to the GND and RS232 signal pads on the modem board. Tie a strain-relieving knot in the cable a few inches from the soldered end and pass the free end of the cable from the inside of the enclosure through its rubber-grommet-lined hole. At the free end of this cable, connect and solder the GND conductor to pin 7 of the RS232 connector and the RS232 signal conductor to pin 2 or 3 on the connector, which is used depending on your particular setup. (See Fig. 9 for wiring details.)

Mount the modem board in the enclosure. Then, with a screw and nut, connect the antenna to the antenna lug at the walkie-talkie board. Mount the walkie-talkie board in the case and insert and fasten the on/off switch and LED in its holder.

Finally, label the two enclosures according to function (transmitter and receiver). If you use dry-transfer lettering, spray onto them two or more light coats of clear acrylic to protect from scratching. The completed project, just before closing the enclosures, is shown in Fig. 10.

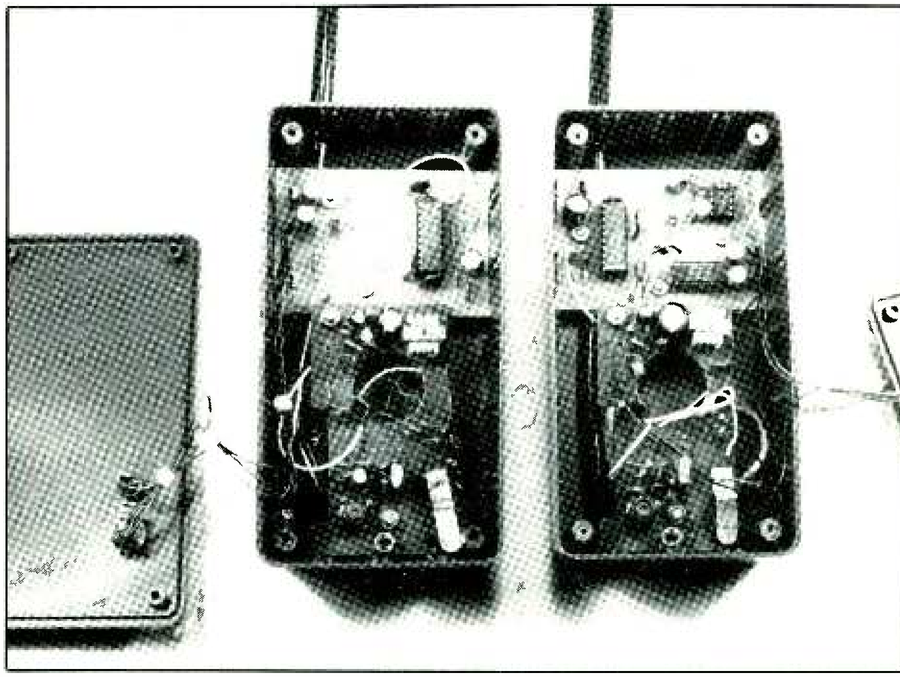


Fig. 10. Interior views of completed transmitter (left) and receiver (right) ends of project.

Checkout & Use

The first step in checking out the circuit is to make sure the power supplies are operating properly. Connect the power supply or 9-volt battery to and turn on the transmitter. (Note: The DIP ICs should still *not* be installed in their sockets at this time!) Now use a dc voltmeter or a multimeter set to the dc voltage function to take voltage readings as follows.

First, connect the meter's common probe to any convenient circuit-ground point and leave it there for the duration of the tests. Working on first the transmitter portion of the project, touch the meter's "hot" probe to the IN pin of *IC1* and note that the reading should be +9 volts. Then touch the "hot" probe to the OUT pin of *IC1* and socket pin 6 of *IC2*; this time, the readings should both be +5 volts. If you do not obtain the appropriate reading at any of these three points, power down the circuit and correct the problem before proceeding.

Repeat the tests for the receiving end of the project. This time, you should obtain the same readings at the IN and OUT pins of *IC3* as you did for *IC1*, and +5 volts should be available at socket pins 4 and 8 of *IC4* and pin 6 of *IC5*. Once again, if you do not obtain the proper reading at any point, power down the circuit and correct the problem before proceeding.

When you are satisfied that both boards have been correctly wired, power down both and carefully install the ICs in their respective sockets. Make sure that each is properly oriented and that no pins overhang the sockets or fold under between IC and socket as you push each home. Use safe-handling procedures for MOS devices when installing *IC2* and *IC6* in their sockets.

With the ICs installed in their sockets, power up the receiver portion of the project. Connect the meter's common probe to circuit ground and touch its "hot" probe to pin 1 of *IC5*. If all is okay, you should obtain a reading of about −6.5 volts.

If all looks okay, you're ready to proceed with system checkout. Connect the Wireless Data Link units to the devices that will be transmitting and receiving data in your system. As always, set up the communications protocol so it is the same at both

(Continued on page 91)

Telephone Technology

(Conclusion)

Troubleshooting and repair techniques

By Stephen J. Bigelow

Last month in Part I, we introduced major assemblies that make up the telephone instrument and detailed how these elements perform together with the Central Office. Also covered were typical techniques used in the installation of telephone instruments at a customer's location. In this concluding installment, we will discuss simple and proven techniques for isolating problems to the on-premises telephone instrument and wiring or the telephone line itself, as well as some steps you can take to correct a problem once you identify its cause. Also included is a quick reference troubleshooting chart that should simplify and speed problem solving.

Locating a Problem

Assume your telephone is not working. You lift the handset and listen for a dialtone only to hear nothing at all. There is a quick and simple procedure to follow to determine whether the cause of the problem is in the telephone instrument or at a point before the phone line from the Central Office enters your premises.

Perhaps the easiest way to isolate a problem is to use another telephone instrument that is known to be good in place of the instrument in question. If when you try this you still fail to hear a dialtone at the problem location, you know that the problem lies before the jack into which the instrument is plugged, whether in your on-premises wiring or from there back to the Central Office.

Many homes have one or more telephone jacks at various locations. It is a good idea to try a known-good instrument at each extension jack. If even *one* extension location provides the instrument with a dialtone, you know that your line to the Central Office is working properly and that the problem is within your on-premises extension wiring. Alternatively, if *all* locations fail to provide a dialtone when the instrument is taken off-hook, the problem is most likely from the Central Office.

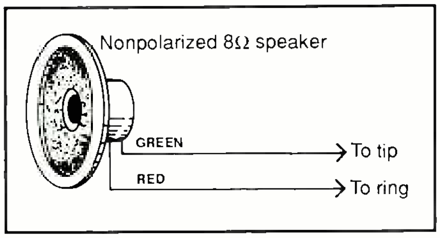


Fig. 13. Using an 8-ohm speaker to check out a phone line for dialtone.

An easy test you can make to determine whether or not the Central Office is at fault is to trace the wiring in your premises to the point at which the telephone line from the Central Office enters your location. There will be at this point a central connecting jack—the so-called "telco" jack—that will feed any other extensions that might be installed in your home.

Once you have located the telco jack, use an 8-ohm speaker with short lengths of wire connected to each lug to perform a "speaker test." To do this, touch one speaker wire to the "tip" (green) and the other to the "ring" (red) terminals of the jack (Fig. 13). The speaker's impedance is low enough to draw loop current to simulate an off-hook condition. If the incoming line is working, the Central Office will sense this off-hook condition and send down the line a dialtone signal that can be heard from the speaker. If you do not hear a dialtone, the problem is definitely outside your premises; to correct it, you must contact your local telephone company (from a working phone, of course) to request service.

Extension failures almost always are caused by an open circuit in part of the connecting cable or at the RJ11 or RJ14 modular connector into which they are plugged or terminated (Fig. 14). Always be suspicious of the

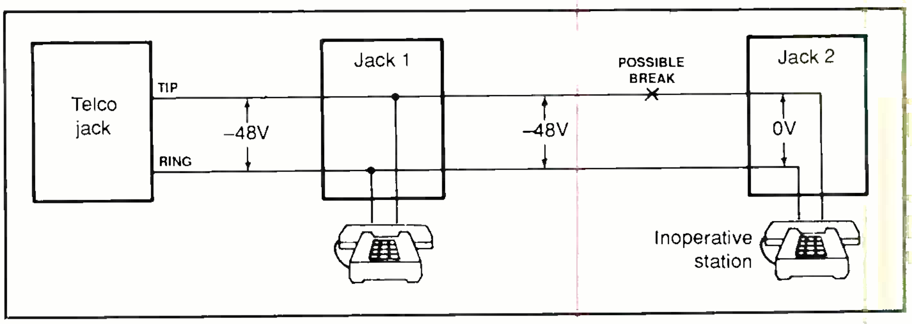


Fig. 14. A multiple-extension residential telephone wiring scheme showing location of possible failure.

the line that connects the telephone instrument to the RJ11 or RJ14 jack. That line is also part of the extension wiring and can just as readily be the source of the problem. Remove the cover from the modular connector and check the wiring at each of the screw terminals and repair any wires that are loose or broken.

If the wiring is secure at the connector, use a dc voltmeter or a multimeter set to the dc function to measure the voltage across the tip and ring contacts by touching the meter's probes to the tip and ring terminals (Fig. 15). If all is okay, you should obtain a −48-volt reading. If the meter indicates an absence of voltage (0 volt), there is a break somewhere in the cable. Trace the cable as far back as you can to determine if a break is visible. If you cannot locate a break just by looking, or even if you can but it is in an impossible to reach location, you may have to run a whole new cable.

If when you take a voltage reading the meter indicates presence of −48 volts across the tip and ring contacts and a known-good instrument does not work when plugged into the jack, the problem lies within the modular jack itself. In this event, you must replace the jack with a good one to restore service at that given location.

A note on service: Your local telephone company will repair any line problems that are outside your premises free of charge. However, if the problem is on-premises, you will be charged an hourly service fee to repair it. So make certain where the problem lies *before* you call for service.

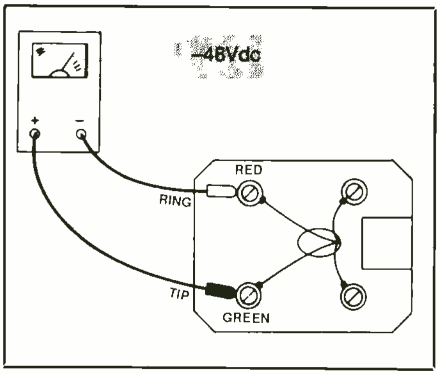


Fig. 15. Using a multimeter set to read dc voltage to check voltage across tip and ring contacts of telephone jack.

Instrument Problems

A wide variety of problems can and do surface in telephone instruments. In this section, we will discuss some of the most common troubles encountered in phones and how the major subassemblies of the instrument relate to each other. (Figure 1 in Part I depicts drawings of these elements; so you might want to refer back to it to refresh your memory of them.)

As pointed out last month, there are five major assemblies in *every* telephone instrument. Each has its own set of functions, as follows:

(1) *Hookswitch.* Activates the instrument and switches in the audio and dial portions of the circuit.

(2) *Network.* This is the interconnect point for all parts of the phone that filters and isolates the audio circuit and ringer and provides proper line balance and loss compensation. A wiring diagram of the network in a typical 2500-type telephone instrument is shown in Fig. 16.

(3) *Handset.* This assembly contains the transmitter and receiver (a speaker and microphone may also be present on more sophisticated "hands-free" telephone instruments).

(4) *Dial.* This can be either a rotary mechanism or an electronic Dual Tone Multi Frequency (Touch-Tone) keypad and its electronic circuitry whose purpose is to signal the Central Office the specific digits of the number being called.

(5) *Ringer.* This unit audibly signals you when a call is coming in.

Let us now discuss some possible trouble symptoms, their causes and what you can do to correct them.

• **Phone Totally Dead.** A telephone instrument is considered to be totally inoperative if it is unable to draw a dialtone in the off-hook condition. With a multimeter set to measure high dc voltage (say, 200 volts) across the tip (green) and ring (red) wires while the defective phone is *on-hook*, you should obtain an indication of −48 volts. When the handset is lifted *off-hook*, the reading should drop to about −6.5 volts.

If you obtain a −6.5-volt reading, the phone is drawing loop current and dialtone. In this event, try another handset assembly and handset cord to check for a defect in the receiver circuit. If the problem still persists, check the network for loose wires and breaks in the printed-circuit board's copper traces.

If the loop voltage across the tip and ring contacts remains at −48 volts when the phone is off-hook, the instrument is not activating. In this case, check the line cord into the phone to be sure it is in place, is connected properly at both ends and that continuity exists in all conductors.

Keep in mind that an open line cord is a very common problem. If this is not the source of the difficulty, check the contacts in the hookswitch assembly.

• **Low or No Ring.** Conventional electromechanical bells are nothing more than a coil wound around an iron core to form a simple electromagnet. As the ring signal from the Central Office reaches the telephone instrument, the fluctuating voltage varies the magnetic field in first one and then the other polarity. In one polarity, the electromagnet physically pulls a striker arm on the end of which is a ball-like clapper that strikes a gong-like bell to sound a ring tone. As the polarity of the ring voltage reverses, the polarity of the magnetic field also reverses and physically pushes the striker arm away to strike another bell. In some phones there is only one bell. Shown in Fig. 17 are examples of both single- and double-gong bells.

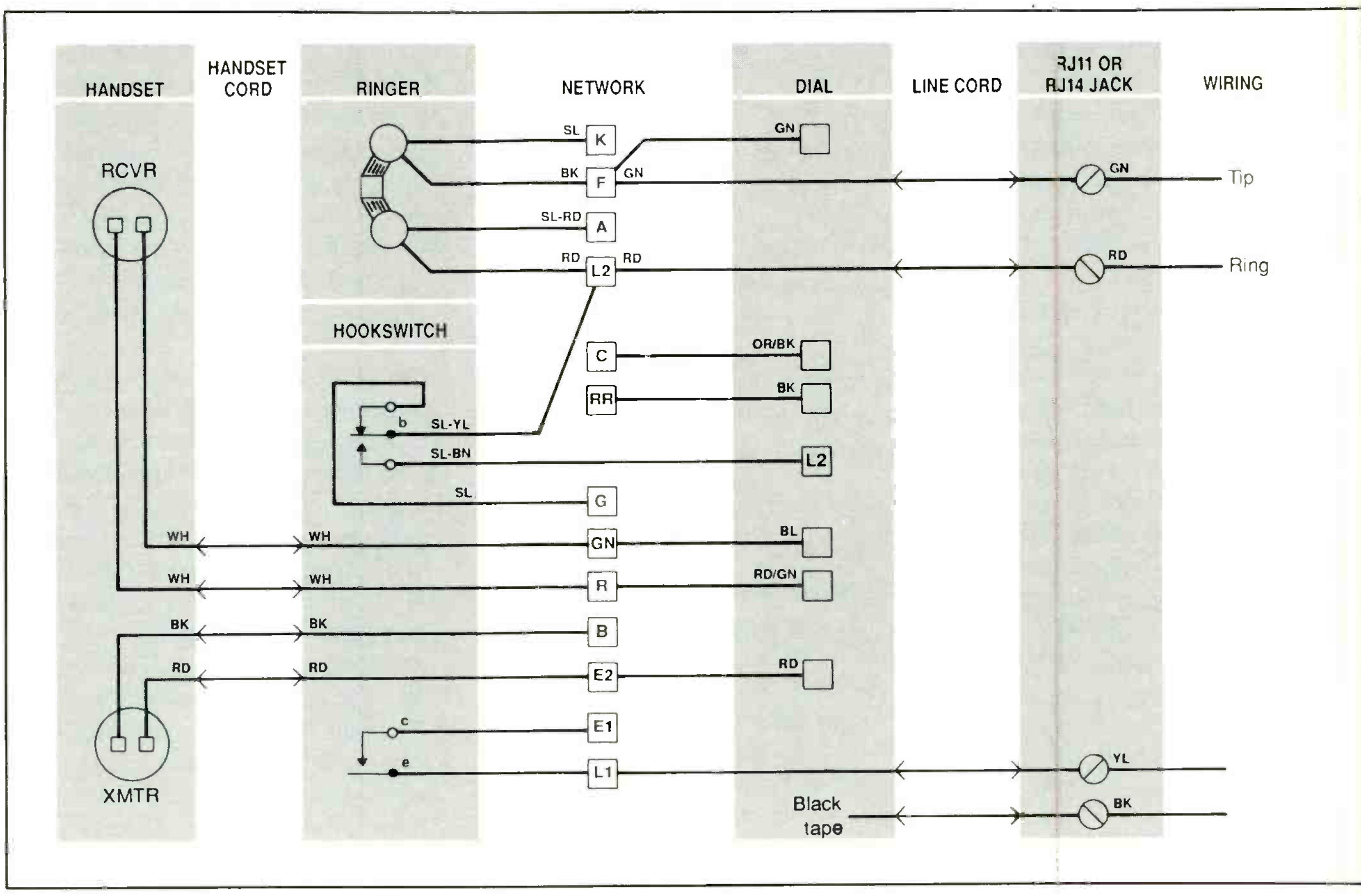


Fig. 16. Network diagram of a typical 2500-type telephone instrument.

Typical standards for ring signals are 90 volts ac rms at a frequency of 20 Hz. There is also a capacitor in series with the coil that blocks dc while passing the ac signal (Fig. 18). Thus, the low impedance of the coil across the tip and ring contacts will not draw dialtone.

Ring failures are almost always confined to the ringer coil itself. It is possible for several windings in the coil to short together such that the coil becomes a less powerful electromagnet. If only a few turns are short-circuited, the incoming ring signal will result in a low ringing of the bells. More severe shorting can result in very low bell-ringing volume or even a barely audible hum or buzz in the most severe short-circuiting cases.

A winding in the coil might also be open (no continuity). In this event, there will be no current-flow path and the ringer will be totally inoperative. Also, the dc blocking capacitor may become open-circuited so that it will not even pass the ac ring signal.

In more modern telephone instruments, an integrated circuit is used to sense presence of the ring signal and drive a piezoelectric buzzer that audibly alerts you to an incoming call. Very often, the IC fails and will have to be replaced.

• **Noise and Intermittent Operation.** The most common cause of "static" noise in the telephone circuit is in the handset cord. Constant flexing, stretching and twisting of this cord eventually fatigues the internal wiring and connectors. This results in poor and intermittent contact that appears as static in the receiver whenever the handset is moved. Replacing the handset cord will usually cure this condition.

Noise and intermittent operation can be caused by the network assembly as well if any of the soldered points have deteriorated or been damaged. This is usually caused if the telephone instrument has been dropped or subjected to any other sudden severe mechanical shock. You may be able to hear this noise by tapping the body of the instrument.

It is also possible that the network might be slightly cracked. Fortunately, conventional telephone networks are simple assemblies that are very easy to inspect by simple visual means. Thus, it is a simple matter to resolder any questionable connections and bridge any cracks or breaks with a jumper wire.

Another possible contributor to noise can be the hookswitch. The contacts used in a hookswitch are generally very reliable. However, after years of usage, especially in adverse environments where humidity is high and dust and other airborne contaminants are present, the contact points can corrode and build up oxides and dirt that can cause static noise.

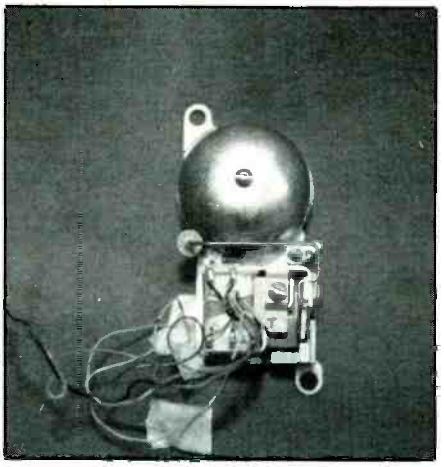
• **Rotary Dial Problems.** Rotary dial mechanisms are prone to wear in all moving parts. When a rotary dial is rotated from its rest position, a set of contacts close to shunt the audio to the receiver. After the dial is released, a spring-driven rotary cam opens and closes another set of contacts at a constant speed of 10 pulses per second (pps).

The pulse ratio, or the ratio of time that the pulse contacts are open to the time they are closed, is 60 percent. For a 100-millisecond pulse length, the contacts are open for 60 milliseconds and closed for 40 milliseconds. Where the wear of the cam or cam shaft may cause the dial to change its pulse ratio, which can cause pulses to be sent that the Central Office cannot interpret correctly.

Wear in the tension spring that returns the dial to its rest position may cause the dial to pulse too fast or too slow during return. Fortunately, pulse speed is not as critical a parameter in proper telephone operation as is the pulse ratio.

• **DTMF Dial Problems.** Dual Tone Multi Frequency dial units used in Touch Tone phones consist of two parts: the mechanical pushbutton keypad assembly and the circuit-board assembly that contains the tone-generating integrated circuit and a frequency base crystal that hold the proper frequencies. DTMF dialers must remain within a *very* tight tolerance, typically 1.5 to 2 percent, for all types of environments and for the entire life of the dialer. The reason that a dual tone is used is so that the Central Office can easily distinguish a dialed digit from speech or other audio that might be fed into the transmitter mouthpiece.

Very little ever goes wrong with a DTMF dialer. The most common type of problem is encountering a column or row of buttons that fail to work, caused by one or more bad contacts in the keypad's switch matrix. The next most frequent problem is a total failure in the dial pad such that there is no tone output at all whenever any button is pressed, usually due to a complete failure of the tone-generating IC. In both cases, the DTMF dial unit must be replaced.



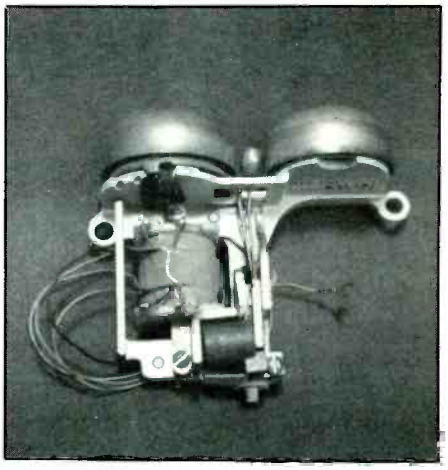


Fig. 17. Examples of single- (A) and dual-gong (B) electromechanical ringers.

Older DTMF dialers use a transistor oscillator with two slug-tuned, multiple-tapped coils to generate the required tones (Fig. 19). When a key is pressed on such a dialer, a set of mechanical contacts along the outside of the dial closes to select the proper taps on each coil to produce the tones for the needed digit.

Mechanical contacts along the outside and in the rear of the DTMF dialer can corrode, eventually resulting in a single-tone or no tone output. The solution to this type of problem is simple: clean the contacts. Use a solvent cleaner designed for electronics use. *Never* use any type of abrasive to clean the contacts; to do so will *destroy* the contacts and accelerate future corrosion.

• **Will Not Break Dialtone.** This is a problem that is inherent in rotary dialers. When the phone is taken off-hook, the Central Office senses loop

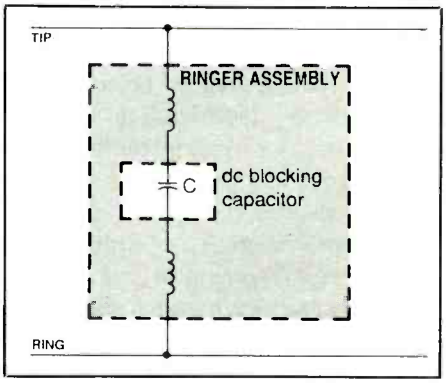


Fig. 18. Typical ringer with dc blocking capacitor.

current and sends a dialtone signal to inform the user that it is ready to receive digits. The moment the Central Office receives the first pulse, it removes the dialtone signal to indicate that it is responding.

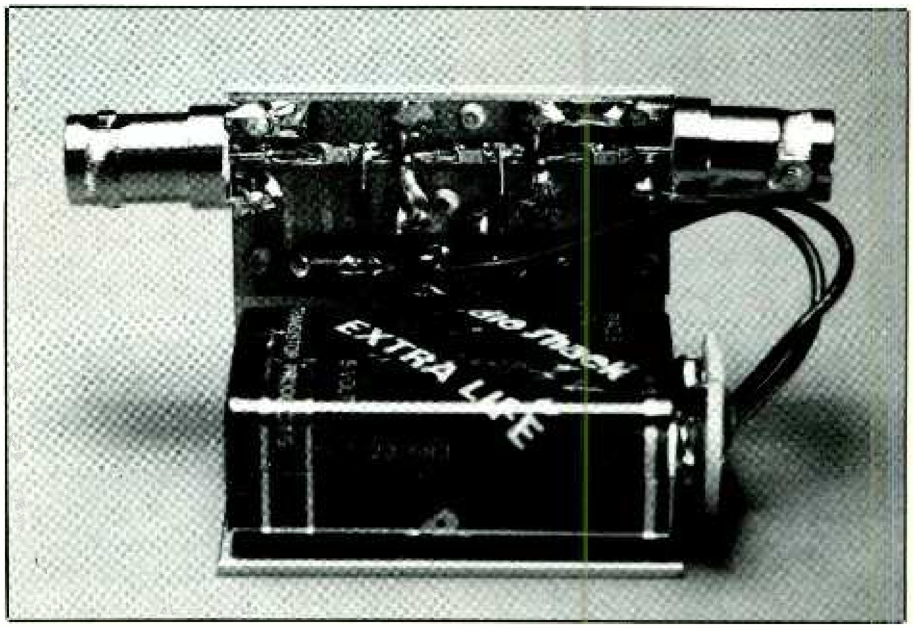
If the pulse contacts on a rotary dialer are not making proper contact, no pulses may ever be sent to the Central Office. An easy way to tell if a rotary dialer is not pulsing is to take the instrument off-hook, draw dialtone and briefly tap on the hookswitch. If the dialtone disappears, the Central Office has sensed the pulse sent by the hookswitch. If you obtain this indication, the dialer is probably bad. Cleaning and adjusting the pulse contacts should restore operation.

(Continued on page 98)

1-MHz to 2-GHz Amplifier

Miniature 50-ohm cascadable monolithic ICs provide up to 40 dB of gain for a host of applications

By Bill Owen



What can you do with a tiny circuit assembly that measures only a couple of square inches and can provide up to 40 dB of gain over a whopping frequency range of from 1 MHz to 2 GHz? Some of the things you can do with this tiny device include: low-power r-f transmission, receive signal boosting, front-ending a frequency counter with preamplification for solid counting on low-amplitude signals, detecting r-f "bugging" equipment, boosting the output level from a signal generator, amplifier buffering and much, much more. In fact, the uses to which this handy device can be put are almost limitless.

In building this device, you will be introduced to two technologies that may be new to you: surface mounting of components and microwave strip-line layout of components. Power for the project can be any 9-volt regulated dc source, including a transistor battery if expected use is to be for brief periods, though you will want to use an ac-operated 9-volt supply for continuous or long periods of use. Whatever your application for this project, it is fun and informative to build. Better still, you can build it for about $20, not counting power supply and enclosure.

About the Circuit

The specific IC amplifier used in this project was selected from the MAR series of monolithic integrated-circuit r-f amplifiers from Mini-Circuits (P.O. Box 350166, Brooklyn, NY 11235-0003). As revealed in the Table, there are six devices in this family, each of which has an extremely wide r-f bandwidth. All operate from a single-ended 5-volt dc power supply, which makes it very easy to incorporate them into circuit designs. Differences among the MAR devices are in levels of gain and output power, as well as features.

We chose for this project the MAR-6 Mini-Circuits device for its low-noise, fairly flat 2-GHz bandwidth and high gain across its frequency spectrum. Some applications may require a device with a different set of characteristics, If you are interested in experimenting with the MAR series of devices, Mini-Circuits offers a complete designer's kit, No. DAK-2. This kit contains five each of the MAR-1 through MAR-8 devices. For more information and to order the kit, you can contact the company at the above address, or you can telephone 718-934-4500.

Mini-Circuits' MAR series of devices are actually tiny four-lead integrated circuits. When you consider the extremely small package in which these devices are housed are only about half the size as that used for the popular MRF901 r-f transistor of the same configuration, it is difficult to believe that the MAR device is not a simple discrete transistor. You can get some idea of just how small these devices are from the lead photo, in which the ICs themselves are the tiny black dots. A size comparison is provided by the 9-volt battery used to power the project in the same photo.

Technically speaking, the MAR device is a bipolar monolithic inte-

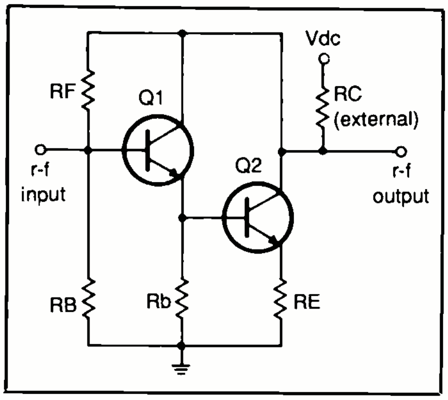


Fig. 1. Internal details of the MAR series of monolithic r-f amplifier devices from Mini-Circuits.

grated circuit that is fabricated with nitride self-alignment, ion-implanted for precise control of doping and passivation. Only a few years ago, small r-f amplifiers were thick- or thin-film hybrids that cost 10 to 100 times as much as the MAR devices.

Contained inside the MAR-6's package is a Darlington-connected transistor pair with a relatively simple resistive biasing scheme, as shown in Fig. 1. In this circuit, *RE* is the series feedback element that adjusts the base voltage of *Q2*. Resistor *RF* provides shunt feedback that adjusts the base voltage of *Q1*. The net effect of this feedback arrangement is that the amplifier is virtually immune to the effects of the variations in gain in the two transistors.

Bleeder resistor *RB* permits the emitter of *Q1* to be different from the base current of this transistor. External resistor *RC* also provides some feedback by dropping the voltage to the amplifier as more current is drawn by the transistors.

The values of the biasing resistors match the input and output impedances of the device to 50 ohms. This permits easy physical design of the circuit using 50-ohm micro-strip-line procedures.

The complete schematic diagram of the r-f amplifier circuit used in this project is shown schematically in Fig. 2. As you can see, this is a very simple circuit in terms of component count, consisting of just two each MAR-6 ICs, two resistors, a handful of capacitors and input and output connectors. In this circuit, the two MAR-6 devices used for *IC1* and *IC2* are cascaded to provide a reasonable amount of gain across the amplifier's entire 1-MHz to 2-GHz bandwidth. As you can see in Fig. 3, the amplifier's gain is roughly 40 dB at the lowest frequencies and gradually drops to 5 dB between about 1.8 and 2 GHz, which is which is quite respectable at these frequencies.

Inductance in the circuit becomes an increasingly serious problem as operating frequencies increase. With this project designed to operate at frequencies up to 2 GHz, it is extremely important to maintain the least possible inductance to assure such a wide bandwidth and respectable gain. To this end, all capacitors must be leadless chip types for the simple reason that they have less series inductance than do leaded capacitors. Too, the two resistors must be carbon-composition units because they have less inductive effects than do metal-film and other types.

Another consideration that must be kept in mind to assure proper operation of the circuit is input and output impedances. These must be held as uniform as possible throughout the project's frequency bandwidth. To achieve a constant 50-ohm input and output impedance, INPUT and OUTPUT connectors *J1* and *J2* must be coaxial BNC devices.

As mentioned above, the project can be powered by a common 9-volt transistor battery if you are planning to use it as an experimental device or for only brief periods at a time. However, current drain, though modest, dictates use of an ac-operated 9-volt regulated supply when it is used for extended periods.

Construction

Special precautions must be exercised when building this r-f amplifier. One of these is that you *must* use a printed-circuit board on which to mount and interconnect the components that make up the circuit. The copper traces of the board itself must rigidly adhere to strip-line techniques to assure proper operation. The actual-size etching-and-drilling

Summary of MAR Family Device Characteristics

No.	Dot Color	Bandwidth	Typical Gain at 1 GHz	Output (dBm)	Power Supply	Features
MAR-1	Brown	dc-1 GHz	15.5	0	5V, 17 mA	high gain, medium noise
MAR-2	Red	dc-2 GHz	12.5	+3	5V, 25 mA	Flat to 2 GHz
MAR-3	Orange	dc-2 GHz	12.5	+8	5V, 35 mA	Flat to 2 GHz, high power
MAR-4	Yellow	dc-1 GHz	8.0	+11	5V, 50 mA	Flat gain, high power
MAR-6	White	dc-2 GHz	16.0	0	5V, 16 mA	Low noise, flat to 2 GHz, high gain
MAR-7	Violet	dc-2 GHz	12.5	+4	5V, 22 mA	Medium noise
MAR-8	Blue	dc-1 GHz	23.0	+10	5V, 36 mA	High gain, low noise, high power

*Not unconditionally stable

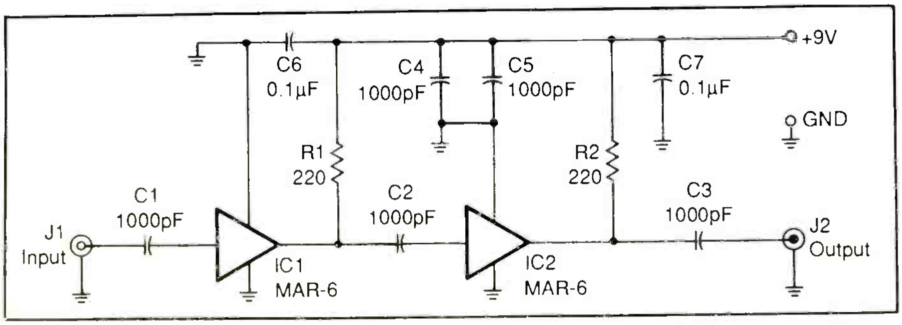


Fig. 2. Complete schematic diagram of the 1-MHz-to-2-GHz r-f amplifier.

guide for this printed-circuit board is shown in Fig. 4(A).

If you are not used to radio-frequency pc designs, the layout shown in Fig. 4(A) may appear to be very different from what you are used to. The reason for the odd appearance of the conductor pattern is that as frequency increases, odd things begin to happen in ordinary circuit elements, such as the inductance capacitors and resistors exhibit at superhigh and above frequencies pointed out above. So care must be taken not only in the selection of components but in the pc pattern itself.

With an amplifier that is designed to operate into the gigahertz range, ground connections that may appear to work at lower frequencies may or may not work at the higher and highest frequencies. Simply getting an r-f signal to flow through a pc-board trace can be a challenge at the higher frequencies. Therefore, r-f layouts, like the one shown in Fig. 4(A), employ strip-line techniques in which the width of the conductors is carefully chosen to assure constant-impedance conduction. If the impedance is not fixed or if a pc trace goes through sharp turns or any discontinuities, the signal may be attenuated or be reflected back into its source.

The pc traces shown in Fig. 4(A) are 0.1-inch-wide on G10 glass-epoxy pc board material. The characteristic impedance of this layout is nominally 50 ohms, which matches the MAR-6 ICs. The bottom of the board must be a solid ground plane. The widths of the conductive traces on the pc board would have to change for different blank thickness or/and dielectric material other than G10 glass-epoxy.

You can easily fabricate the printed-circuit board whose conductor pattern is shown in Fig. 4(A) from a single-sided G10 blank. Once you have etched and thoroughly cleaned the board, drill 1/16-inch-diameter holes in all locations shown circled in the Fig. 4(B) wiring diagram. Do *not* drill holes through the circular pads.

Once the pc board is ready, place it on an aluminum L bracket that has one leg that is at least deep enough that the entire board area can be accommodated by it and whose other leg is deep enough to accommodate the battery. Align one end of the bracket with one end of the board and scribe or mark a line on the bracket along the other edge of the board. Remove and set aside the board and then cut the L bracket to length along the line. If you cannot find suitable aluminum L-bracket material, cut to size any other piece of 1/16-inch or so thick piece of aluminum and bend it as needed to form the board and battery legs. Whichever way you go, smooth the cut edges with a fine file.

Place the board back on the L bracket, conductor pattern up and narrow portion of the surrounding copper pattern near the outside edge. Align the board with the edges of the bracket. Then use a sharp metal instrument (awl or large needle) to mark the location of each hole previously drilled in the pc board.

Now drill 1/16-inch holes through the L bracket at all marked locations. Replace the pc board on the L bracket and align all holes. Use eight or more 1/16-inch soft-aluminum rivets to solidly secure the pc board to the bracket. If you cannot locate aluminum rivets, No. 2 machine screws and nuts will work as well.

The reason for securing the pc board to an aluminum L bracket is to provide a groundplane for the circuit, which is critical to proper operation of the project. You could use G10 glass-epoxy pc blank that is clad on both sides for the board, etching copper from only the conductor side of the board to provide a good groundplane. However, you would still have to use rivets or machine hardware to make the ground connections for the circuit.

Make absolutely certain that you tightly clinch down the rivets or hardware to assure that the board is solidly secured to the L bracket.

PARTS LIST

C1 thru C5—1,000-pF leadless-chip capacitor
C6,C7—0.1-μF leadless-chip capacitor
IC1,IC2—MAR-6 r-f amplifier (Mini-Circuits; see text)
J1,J2—BNC connector (see text)
R1,R2—220-ohm, 1/8-watt, 5% tolerance resistor
Misc.—Printed-circuit board; aluminum L bracket (see text); 1/16" soft aluminum rivets or No. 2 machine hardware (see text); 9-volt transistor battery and snap connector or other dc power source (see text); double-sided foam tape.

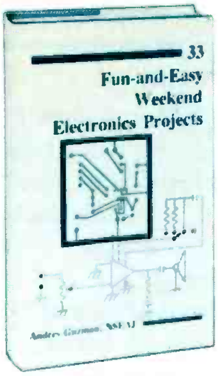
Note: A complete kit of parts, less battery and connector, is available for $19.95 + $3 P&H (Florida residents, please add state sales tax) from NRG Electronics, P.O. Box 24415, Ft. Lauderdale, FL 33307.

SELECT 5 BOOKS

for only $3.95

(values to $132.70)

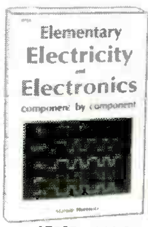
and get a Free Gift!



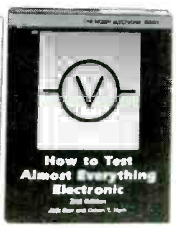
2861 $14.95

2705P $16.95

1367 $17.95

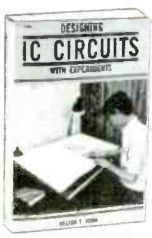


2753P $16.95

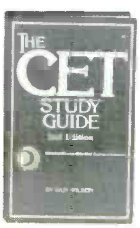


2925 $15.95

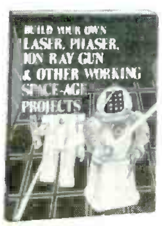
1897P $13.95



1925P $16.95

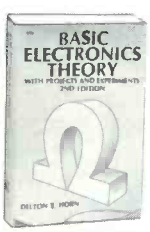


2941 $21.95



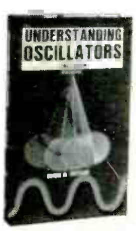
1604P $16.95

2790 $18.95

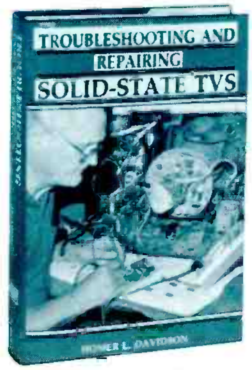


1775P $18.95

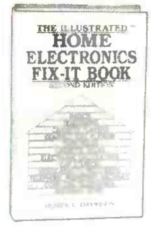
2912 $23.95



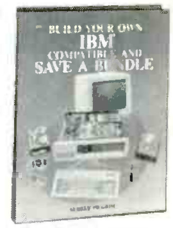
2715 $16.95



2707 $26.95
Counts as 2

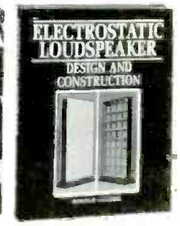


2883 $25.95

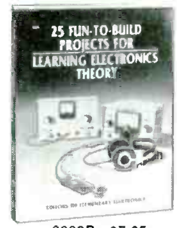


2831 $22.95

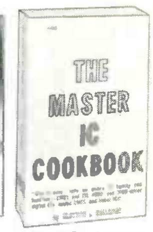
1341P $14.95



2832 $23.95

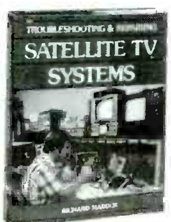


2839P $7.85

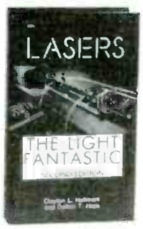


1199P $18.95

Electronics projects . . . ideas . . . the latest technology all at up to 50% off publishers' prices!

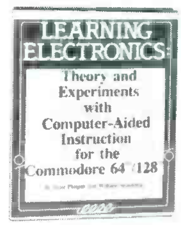


1977 $26.95
Counts as 2



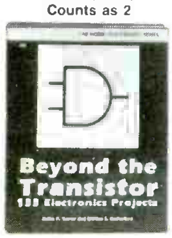
2905 $19.95

2731 $21.95

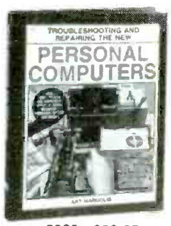


2882 $24.95

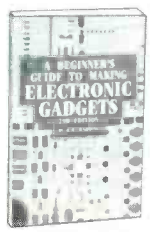
2613 $23.95



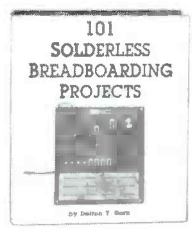
2887 $16.95



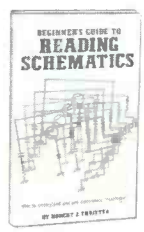
2809 $26.95
Counts as 2



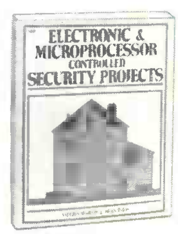
1793P $9.95



2985 $24.95

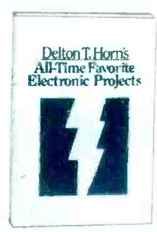


1536P $8.95



1957P $14.95

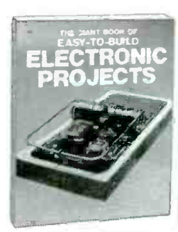
FREE when you join!



Here's 15 Best Electronic Projects From Delton T. Horn

Projects you can build—some unique, some old favorites—from the author's vast treasury of electronics know-how.

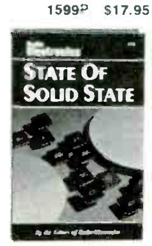
(a $7.95 value!)



1599P $17.95

2617 $17.95

Membership Benefits • **Big Savings.** In addition to this introductory offer, you keep saving substantially with members' prices of up to 50% off the publishers' prices. • **Bonus Books.** Starting immediately, you will be eligible for our Bonus Book Flan, with savings of up to 80% off publishers' prices. • **Club News Bulletins.** 14 times per year you will receive the Book Club News, describing all the current selections—mains, alternates, extras—plus bonus offers and special sales, with hundreds of titles to choose from. • **Automatic Order.** If you want the Main Selection, do nothing and it will be sent to you automatically. If you prefer another selection, or no book at all, simply indicate your choice on the reply form provided. As a member, you agree to purchase at least 3 books within the next 12 months and may resign at any time thereafter. • **Ironclad No-Risk Guarantee.** If not satisfied with your books, return them within 10 days without obligation! • **Exceptional Quality.** All books are quality publishers' editions especially selected by our Editorial Board.



2733 $14.95

2724 $24.95

All books are hardcover unless numbers are followed by a "P" for paperback. (Publishers' Prices Shown)

MDNE-988

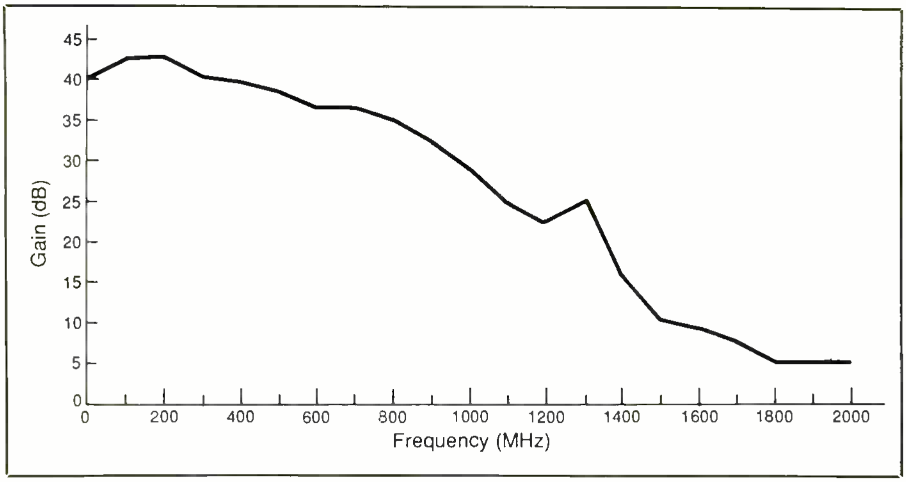


Fig. 3. Plot of actual gain results from tests performed on author's prototype.

Pretin all copper lands on the pc board to which component tabs or leads are to be soldered. Use a medium-heat soldering iron and the finest quality solder available for electronics work. Do not "blob" excessive solder onto the lands, but by the same token, do not just "wet" the lands, either. When you are finished, you want enough solder on each land that you can reflow what is already there to make the needed connection without having to add to the solder at any connection point.

Start populating the board with the smaller chip capacitors (*C1* through *C5*). You must use surface-mount techniques throughout. That is, set the chip capacitor in its location with its solderable edges against the solder-tinned connections at each end. Then hold the chip capacitor in place with the eraser end of a pencil as you reflow the solder on the land until it wets first one and then the other end of the capacitor. Apply soldering heat only long enough to be certain that each land-to-component-terminal connection is electrically secure. Allow the solder to completely solidify before removing the pencil hold-down from the capacitor. Repeat for all remaining capacitors, including *C6* and *C7*.

Next, lay the resistors on the circuit board in the locations shown and clip their leads to length. Use the same technique to "tack solder" the leads of both resistors to the indicated lands, using only the solder used for pretinning the lands. (Note: A good power rating for the 220-ohm resistors is ⅛ watt when powering the circuit from a 9-volt battery. If you use a dc source with a higher voltage, substitute ¼-watt resistors for *R1* and *R2*).

Now examine the MAR-6 ICs. You will note that each has four "pins" and that near one is a small white dot. The dot identifies the input pin. Directly opposite the identified input pin is the device's output pin. The other two pins are used for connection to ground. Before attempting to solder the pins of these two devices into place on the pc board, make sure that the copper lands have adequate solder on them. Place one MAR-6 device in the IC1 location with its pins symmetrically contacting the indicated lands. The input pin must be on the left land with the board viewed as shown in Fig. 4. Again, use the eraser end of the pencil to hold the IC in place as you reflow the solder on one land to make the pin-to-land connection. Now do the same for the other MAR-6 in the IC2 location. This done, go back to *IC1* and solder another pin to its land, go back to *IC2* and do the same there. Repeat until

(Continued on page 91)

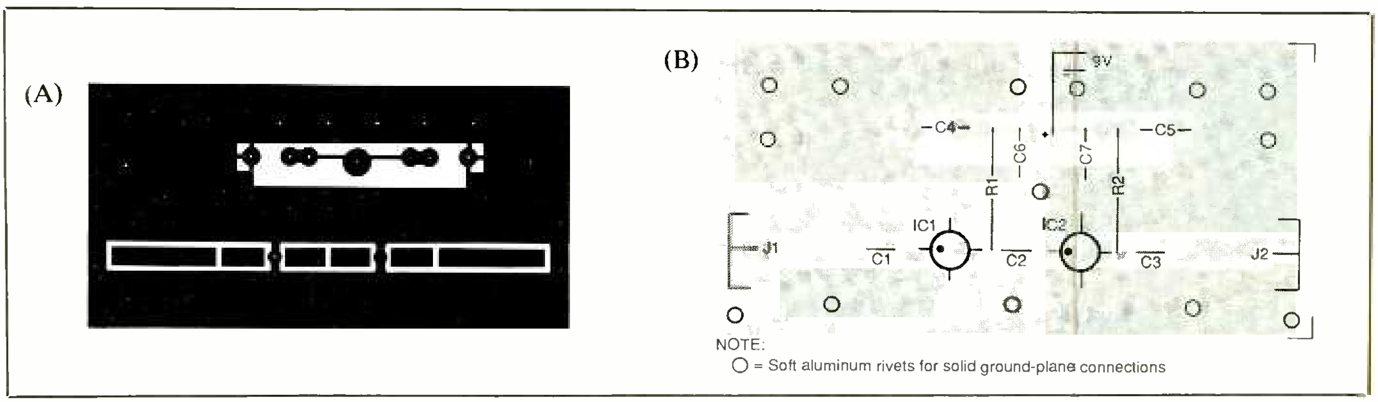


Fig. 4. Actual-size etching-and-drilling guide for fabricating printed-circuit board (A) and wiring details for board (B). Note that, ICs are surface-mount devices, as are leadless-chip capacitors.

OPTOELECTRONICS INC.

NEW POCKET SIZE FREQUENCY COUNTERS TO 2.4 GHZ

SIZE: 4" H x 3.5" W x 1" D
MADE IN USA

8 LED DIGITS · 2 GATE TIMES
ALUMINUM CABINET
INTERNAL NI-CAD BATTERIES INCLUDED
AC ADAPTER/CHARGER INCLUDED

EXCELLENT SENSITIVITY & ACCURACY

AC-DC · PORTABLE OPERATION

#TA-100S

Small enough to fit into a shirt pocket, our new 1.3 GHz and 2.4 GHz, 8 digit frequency counters are not toys! They can actually out perform units many times their size and price! Included are rechargeable Ni-Cad batteries installed inside the unit for hours of portable, cordless operation. The batteries are easily recharged using the AC adapter/charger supplied with the unit.

The excellent sensitivity of the 1300H/A makes it ideal for use with the telescoping RF pick-up antenna; accurately and easily measure transmit frequencies from handheld, fixed, or mobile radios such as: Police, firefighters, Ham, taxi, car telephone, aircraft, marine, etc. May be used for counter surveillance, locating hidden "bug" transmitters. Use with grid dip oscillator when designing and tuning antennas. May be used with a probe for measuring clock frequencies in computers, various digital circuitry or oscillators. Can be built into transmitters, signal generators and other devices to accurately monitor frequency.

The size, price and performance of these new instruments make them indispensible for technicians, engineers, schools, Hams, CBers, electronic hobbyists, short wave listeners, law enforcement personnel and many others.

STOCK NO:

#1300H/A	Model 1300H/A 1-1300 MHz counter with preamp, sensitivity, < 1mV, 27MHz to 450MHz includes Ni-Cad batteries and AC adapter	**$169.95**
#2400H	Model 2400H 10-2400 MHz microwave counter includes Ni-Cad batteries and AC adapter	**$299.95**
#CCA	Model CCA counter/counter, for debugging, ultra sensitive, < 50 micro volts at 150MHz! 1-600 MHz with adjustable threshold, RF indicator LED. Includes Ni-Cad batteries and AC adapter	**$299.95**

ACCESSORIES:

#TA-100S	Telescoping RF pick-up antenna with BNC connector	**$12.00**
#P-100	Probe, direct connection 50 ohm, BNC connector	**$20.00**
#CC-12	Carrying case, gray vinyl with zipper opening. Will hold a counter and #TA-1000S antenna.	**$10.00**

AVAILABLE NOW!

ORDER FACTORY DIRECT

FLA (305) 771-2050 **1-800-327-5912**

MasterCard VISA

OPTOELECTRONICS INC.
5821 N.E. 14th Avenue
Ft. Lauderdale. Florida 33334

Orders to US and Canada add 5% of total ($2 min, $10 max)
Florida residents add 6% sales tax. COD fee $2.
Foreign orders add 15%

An Automotive Back-Up Alarm

Sounds an audible alert to pedestrians and other motorists when you put your vehicle in reverse

By Charles Shoemaker, D.Ed.

Heavy industrial and construction vehicles nowadays usually have beeping alarms that alert people that they are about to back up or go into reverse motion. This safety device compensates for poor visibility from the operator's location. Though sanitation (garbage) trucks, payloaders, fork lifts and other such vehicles use beepers to signal their presence, other vehicles can benefit from their use as well. A pickup truck with cargo cap that limits visibility to the rear is a prime candidate. Actually, even the family chariot can benefit from a Back-Up Beeper like the one to be described.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the basic Automotive Back-Up Beeper. In this circuit, two of the four 2-input NOR gates inside the CD4001 chip used for *IC1* are cross-coupled to form an oscillator. The output from this oscillator arrangement is a square wave whose repetition rate is about 1 cycle in 1.6 seconds. The oscillator's "on" time (the period during which the output at pin 4 of *IC1* is at a logic high) is about 0.6 second, while its "off" time (the period during which the pin 4 output is at a logic low) is about 1 second, as illustrated in Fig. 2(A).

The output at pin 4 of *IC1* is coupled directly to the pin 4 ENABLE input of 555 timer *IC2*. During the 0.6 second that *IC1*'s output is high, *IC2* is enabled and provides a "beep" signal that is heard from the speaker for this length of time. Then when pin 4 of *IC1* goes low, *IC2*'s pin 4 input is also low and the timer is disabled for 1 second and no sound is heard from the speaker. This on/off cycle repeats for as long as power is applied to the circuit through regulator *IC3*.

Repetition rate of the *IC1* oscillator is determined by the values of *C1* and *R1*. Increasing the value of the capacitor or resistor will slow the repetition rate of the timer circuit. With the values specified for these components, a one-beep-per-second rate results, which is just about right to draw attention to the alarm.

Light-emitting diode *LED1* and its companion current-limiting resistor, *R2*, provide a visible means of monitoring the "on" time of the circuit. When the LED is on, the circuit is enabled and an audible alert is sounded, and when it is off so is the audible alarm. These two components are optional and can be eliminated without affecting operation of the basic circuit.

Timer *IC2*, a common 555 chip, is

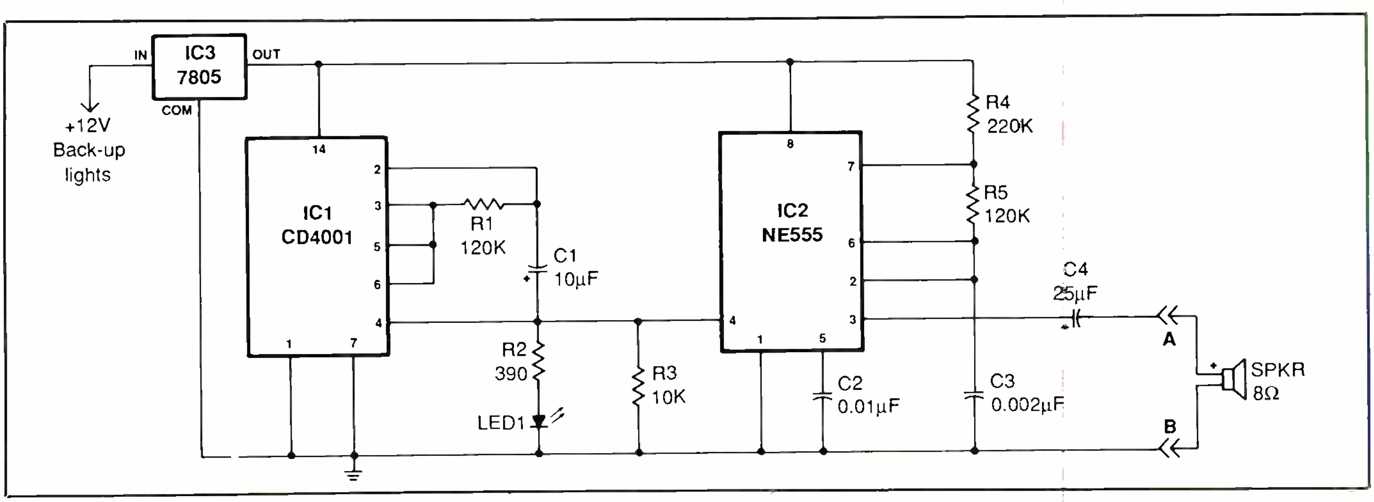


Fig. 1. The complete schematic diagram of the basic project.

PARTS LIST

Semiconductors
IC1—CD4001 quad 2-input NOR gate
IC2—NE555 timer
IC3—7805 +5-volt regulator
IC4—LM386 audio power amplifier (optional—see text)
LED1—Red light-emitting diode (optional—see text)
Capacitors (16 WV or greater)
C1,C5—10-μF electrolytic
C2—0.01-μF disc
C3—0.002-μF disc
C4—25-μF electrolytic
C6—500-μF electrolytic (optional—see text)
Resistors (¼-watt, 10% tolerance)
R1,R5—120,000 ohms
R2—390 ohms (optional—see text)
R3—10,000 ohms
R4—220,000 ohms
R6—25,000-ohm, audio-taper potentiometer (optional—see text)
Miscellaneous
SPKR—8-ohm outdoor-type speaker
Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware; suitable enclosure; 4-position screw-type terminal strip or barrier block; ¼- or 1-ampere fuse (see text) and in-line fuse holder; panel clip for LED1 (optional—see text); sockets for DIP ICs; small heat sink for IC3 (see text); medium-duty spade and ring lugs; rubber grommets; self-adhesive foam-rubber strips; silicone adhesive; heat-shrinkable tubing; lettering kit; ½" spacers; machine hardware; heavy-duty stranded hookup wire and speaker zip cord; solder; etc.

BASIC Program for Determining On, Off and Overall Times

```
10 REM TIME CONSTANT IN RESISTIVE-CAPACITIVE NETWORK BY SHOEMAKER
20 INPUT"ENTER VALUES OF R4 AND R5 IN MEGOHMS";R4,R5
30 INPUT"ENTER VALUE OF C3 IN MFD";C3
40 T1=.693*(R4+R5)*C3
50 T2=.693*(R5*C3)
60 T=.693*(R4+(R5))*C3
70 F=T/1
80 PRINT"VALUE OF T1 AND T2";T1,T2
90 PRINT
100 PRINT"VALUE OF T";T
110 PRINT
120 PRINT"VALUE OF F";F
130 STOP
```

operated as an astable multivibrator at a frequency of approximately 1,570 Hz, which is the frequency of the "beep" tone heard from the speaker. The output waveform from *IC2* has an on, or logic-high, time of about 0.5 millisecond, calculated from the formula $t_1 = 0.963(R4 + R5) \times C3$. Plugging values into this formula, we get $t_1 = 0.963 \times (220K + 120K) \times 0.002\ \mu F$, which yields 0.4712 or approximately 0.5 millisecond. Similarly, the off time, which is the time during which the oscillator is disabled and the speaker is silent, is calculated using the formula $t_2 = 0.693R5C3$, which becomes $0.693 \times 120K \times 0.002\ \mu F$ = approximately 0.166 millisecond.

Results of the calculations are depicted graphically in Fig. 2(B). Full-cycle time T is calculated using the formula $T = 0.693(R4 + 2R5) \times C3$, or $T = 0.693\ [220K + (2 \times 120K)] \times 0.002\ \mu F$. The result of the calculation is approximately 0.638 millisecond. Now, frequency can be derived by taking the reciprocal of T: f = 1/0.738 ms = 1,567 Hz, or approximately 1,570 Hz.

You can perform the above calculations with the aid of a calculator. Alternatively, you can key into your computer the short BASIC program listed elsewhere in this article, RUN it and plug in the various component values as you are prompted for them.

Timer *IC2* is disabled by pin 4 being forced low to ground via *R3*. When a positive pulse of about 0.6 second duration from *IC1* reaches pin 4 of *IC2* and enables the timer, *IC2* turns on and outputs the beep tone to the speaker for that length of time. The timer is then disabled by the negative pulse from pin 4 of *IC1* and silences the speaker for 1 second.

Though the basic circuit shown in Fig. 1 is complete in itself and will suffice for most applications, you may want its "beep" tone to be louder in noisy situations or if the speaker you choose requires more power than the modest amount the 555 timer can directly deliver. If so, you can incorporate the add-on circuit shown in Fig. 3 to the basic circuit. This circuit uses LM386 audio power amplifier *IC4* to deliver considerably more power to the speaker without significantly increasing the load on the vehicle's electrical system.

When the Fig. 3 circuit is added to the one shown in Fig. 1, points A and A tie together, as do points B and B. Potentiometer *R6* then provides a means for adjusting the volume of the beep tone heard from the speaker.

Power for the circuit is provided from your vehicle's electrical system. The incoming 12 volts dc from the vehicle's electrical system is regulated down to 5 volts dc by *IC3*. With the power taken from the vehicle's electrical system at a point in the back-up light circuit that is at +12 volts only when the transmission is placed in reverse gear, the beep tone is on only when the back-up lights are on. Putting the transmission in any other position disables the circuit.

Construction

This is a simple, straightforward circuit that requires no special component placement or conductor routing. Therefore, you can build it using any traditional wiring technique. If you wish, you can fabricate a printed-circuit board for it, using the actual-size etching-and-drilling guide shown in Fig. 4. This guide includes

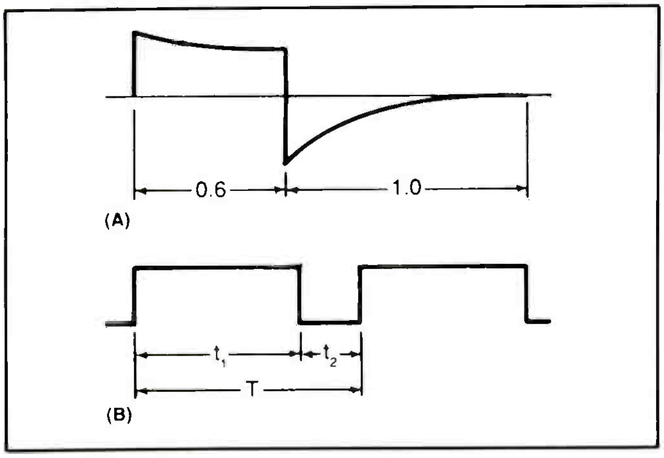


Fig. 2. Waveforms generated by IC1 slow-speed oscillator stage (A) and IC2 audio oscillator stage (B).

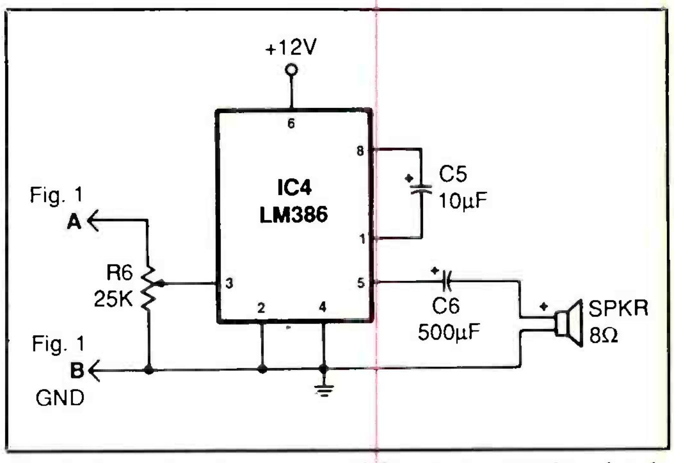


Fig. 3. An optional power-amplifier stage provides a louder output from the speaker.

wiring locations for the optional Fig. 3 circuit. If you prefer, however, you can use perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware in place of the printed-circuit board.

Whichever wiring technique you choose, it is a good idea to use sockets for all DIP ICs, installing them in the appropriate locations on the board, as shown in the Fig. 5 wiring diagram. (Note: If you decide on perforated-board construction, use Fig. 5 as a rough guide to component location and orientation.)

Start wiring the board by installing the sockets in the IC1, IC2 and IC4 (if used) locations. Do *not* install the ICs in the sockets until after initial checkout. Then install and solder into place the resistors and capacitors. Make sure the electrolytic capacitors are properly oriented before soldering their leads to the pads on the bottom of the board.

Now install the +5-volt regulator in the IC3 location. Make sure the pins of this chip are plugged into the appropriate holes in the board before soldering them into place. If you are using the optional power-amplifier IC, bolt to the regulator a small heat sink. Otherwise, no heat sink is needed because the basic circuit draws only a small current.

Next, strip ¼ inch of insulation from both ends of six (nine if you incorporate the optional Fig. 3 power-amplifier circuit into the project) stranded hookup wires cut to a length of about 6 inches. Tightly twist together the fine conductors at both ends and sparingly tin with solder. Plug one end of these wires into the holes labeled +12V, GND and LED1 and solder into place.

Now, if you do not use the power-amplifier circuit, plug two more wires into the holes below *IC2* labeled SPKR and solder them into place. Alternatively, if you *are* using the power amplifier, plug these wires into the SPKR holes in the lower-right of the board and solder into place. Then install the remaining three wires in the R6 holes and solder these into place. Temporarily set aside the circuit-board assembly.

You can use any type of enclosure to house the project that will comfortably accommodate the circuit-board assembly and any items that are to install on its walls. Just make sure that the one you choose can be environmentally sealed to prevent mud, rain, dirt and other contaminants from entering it.

Machine the enclosure to mount the circuit-board assembly, a four-position screw-type terminal strip or barrier block on one wall and the light-emitting diode in any location where it will be readily visible. (If you decided to omit the LED, there is no need to drill a hole for it.) Also, if you built onto the circuit board the optional power amplifier, drill a hole for mounting potentiometer *R6*. Also, drill two holes for mounting the project. If the enclosure is a metal utility box, deburr all holes.

When the enclosure is ready, temporarily mount the barrier block or terminal strip in place and mark its various hook-up locations on the box. Remove the block or strip and set it aside. Then use a dry-transfer lettering kit or tape labeler to label the marked locations with the legends +12V, GND, SPKR+ and SPKR− from left to right. If a dry-transfer kit is used spray two or more light coats of clear acrylic over the labels to protect them from scratching.

Remount the terminal strip or barrier block and secure it in place with suitable machine hardware. Then mount the potentiometer in its hole and the circuit-board assembly, using ½-inch spacers, ¾-inch machine screws, nuts and lockwashers.

Locate the free ends of the +12V, GND and SPKR wires and crimp and solder them to the appropriate lugs on the terminal strip or barrier block. Do the same with the free ends of the R6 wires. Place a control knob on the shaft of the potentiometer.

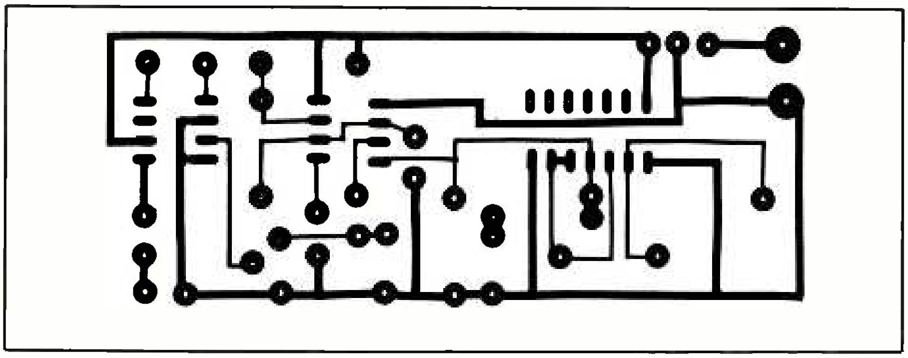


Fig. 4. The actual-size etching-and-drilling guide for the project's printed-circuit board. Included are mounting locations for the optional power-amplifier stage's components.

Cut the cathode lead of the light-emitting diode to a length of ½ inch and form a small hook in it. Slip a ¾-inch length of small-diameter heat-shrinkable or insulating plastic tubing over the free end of the LED1 K wire. Crimp the wire to the cathode lead of the LED and solder the connection. Do the same with the anode lead of the LED and remaining wire. Then push the tubing up over the connections until it is flush with the bottom of the LED's case and, if heat-shrinkable, shrink into place. Plug the LED's panel clip into the hole drilled for it and follow with the LED itself.

Checkout & Installation

If you have a bench-type power supply capable of delivering 12 volts dc, you can use it for initial checkout. If not, use the battery in the vehicle in which you plan to install the project.

Prepare two 10-foot lengths of heavy-duty stranded hookup wire, preferably with red insulation for one and black insulation for the other, by removing ½ inch of insulation from both ends. Tightly twist together the conductors at both ends of both wires and sparingly tin with solder. Then, cut through the red-insulated wire about 10 to 12 inches from one end and prepare both cut ends in the same manner. Install an in-line fuse holder (available from any automotive supply outlet) between the cut ends. Loosely twist together the two wires. Place a ¼-ampere fuse (1-ampere fuse if you are using the optional power-amplifier circuit) in the holder.

At the fused end of the cable, attach medium-duty spade lugs. Solder the lugs to the conductors to make mechanically and electrically secure connections. Temporarily connect the end of the red-insulated wire opposite where the fuse holder is installed to the + 12V contact on the terminal strip or barrier block and the black-insulated wire at this end to the GND contact.

If you are using a bench-type dc power supply for test purposes, turn it on and set it for an output of between 12 and 13.5 volts and then turn it off. Connect the other end of the two-conductor cable to the power supply or vehicle's battery, red-insulated wire to + terminal and black-insulated wire to − terminal. Turn on the power supply.

Connect the common probe of a dc voltmeter or a multimeter set to the dc volts function to the SPKR − contact on the terminal strip or barrier block. Touching the meter's "hot" probe to the IN pin of *IC3* should yield a reading of approximately + 12 volts. Moving the "hot" probe to the OUT pin of *IC3* should yield a reading of + 5 volts. If all is okay up to this point, touch the meter's "hot" probe tip to the pin 14 contact on the *IC1* socket, pin 8 contact of the *IC2* socket and pin 6 contact of the *IC3* socket. In all three cases, the reading should be + 5 volts.

If you fail to obtain the proper reading at any of the points indicated above, disconnect the project from the dc source and carefully check all component installations. Double check your wiring and soldering. With regard to the latter, check to make sure that all points are soldered and that the connections are bright and smooth. Reflow the solder on any connection that appears to be suspicious. Also, check to make sure that there are no solder bridges between the closely spaced IC pads. Do not proceed until you have corrected the problem.

When you are certain that every-

(Continued on page 88)

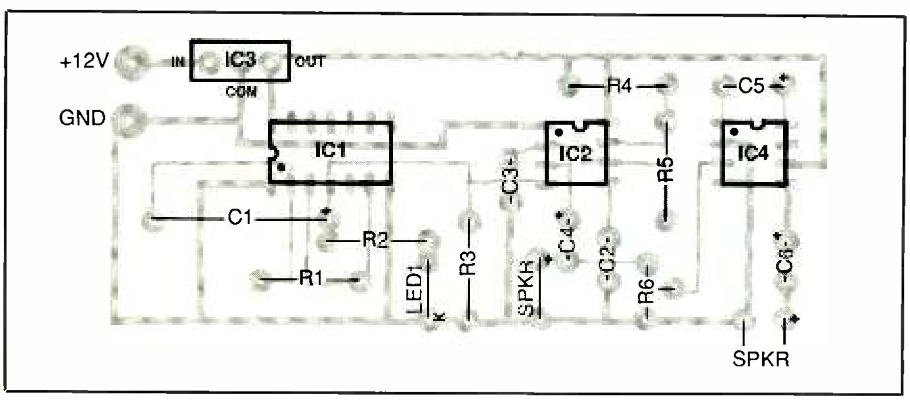


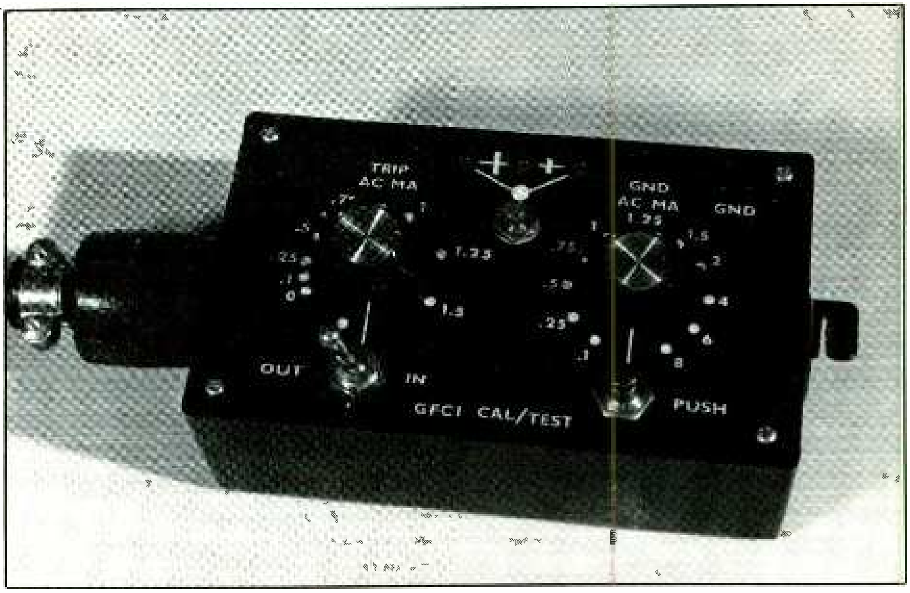
Fig. 5. The wiring diagram for the pc board. Use this as a rough guide to component layout on perforated board.

A GFCI Calibrator/Tester

Accessory provides true testing of ground-fault interrupter circuits as well as application enhancement

By Adolph A. Mangieri

Ground-fault circuit interrupters (GFCIs) replace standard ac power receptacles in the vicinity of swimming pools and other wet locations to minimize the possibility of severe electric shock. For all ac receptacles rated at 15 to 20 amperes, the National Electrical Code now mandates ground-fault protection in bathrooms, at all outdoor receptacles, on all electrical equipment used with outdoor swimming pools and all ac outlets located within 10 to 15 feet of a swimming pool. It makes sense to extend this protection to your kitchen, laundry room and your workbench as well.



Our GFCI Calibrator/Tester is designed to supplement the basic GFCI devices commonly available from hardware stores, department stores and other outlets. It provides several useful enhancements to the basic GFCI device. For example, it has a range of true ground-fault currents for GFCIs (TEST buttons on some GFCI devices do not apply an actual ground-fault test current). Additionally, light-emitting diodes on the project indicate if a three-conductor receptacle is wired properly and operating correctly. Also, the unit permits operating a GFCI at selectable trip currents instead of the usual single fixed trip current. It does this to as low as 0.1 milliampere without impairing trip time. Finally, it checks leakage currents of electrical appliances and tools without requiring you to rig the usual test circuit.

Technical Details

In residential ac wiring, though the neutral conductor of the ac power line is solidly grounded, inadvertent contact with the "hot" conductor with leakage currents subjects you to a potentially lethal ground-fault current that passes through your body to ground. A GFCI device guards against such an occurrence by sensing ground-fault current. When the GFCI trips as a result of a leakage current in excess of 5 milliamperes ac rms, it disconnects the power.

A 5-milliampere trip current threshold is a good compromise for a GFCI device because it is well below the "let-go" current range of from 10 to 25 mA. The let-go current is the current level at which one loses control over his muscle action and "freezes" onto an electrically live conductor. Research has revealed that currents of up to 9 mA ac rms are safe for the vast majority of people, though it is theoretically possible that "freezing" and even fatalities can occur at smaller currents.

Currents greater than the let-go range are regarded as potentially lethal. The 5-mA threshold is well above the 0.5-mA allowable leakage current for TV receivers, VCRs and home appliances.

Most of us have experienced the "startle effect" of an electric shock, which causes us to suddenly withdraw a hand from a source of electricity, sometimes violently enough to cause injury or even death. The shock itself is basically harmless, but the reaction to it can be damaging. As you withdraw your hand from a current-carrying conductor you might strike a sharp edge and gash yourself or even break a bone. If you are on a ladder, scaffold or other high place when this occurs, you can overbalance and fall off.

The severity of an electric shock depends on the level of the current encountered and its duration, among other factors. The Woods Guardian Model 1651 plug-in GFCI, for exam-

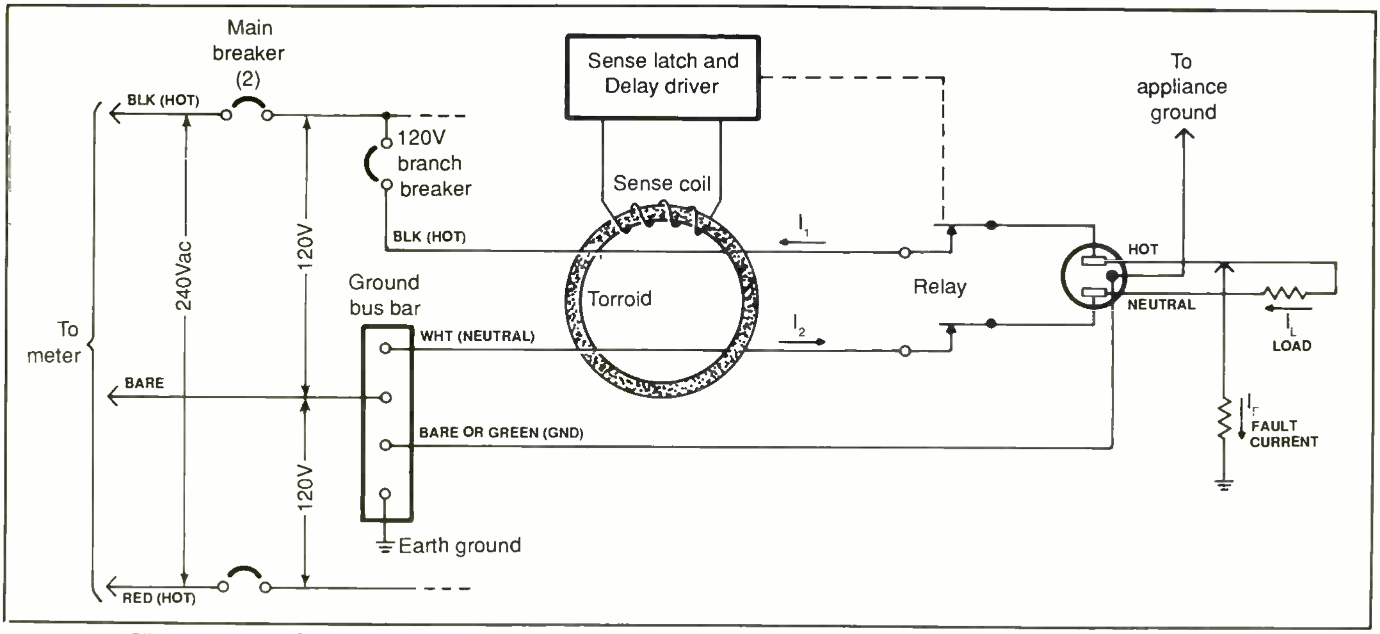


Fig. 1. Internal details of a typical ground-fault interrupter circuit designed for residential use.

ple, limits the severity of a shock by tripping at a 5-mA leakage current within 25 milliseconds (if the current is at 4 mA, the GFCI will not trip). Fortunately, the average person's let-go reaction time is probably 250 milliseconds at best, so a 25-millisecond delay should be much more than adequate for the Woods GFCI.

No actual tests were performed with the GFCI alone or in combination with our Calibrator/Tester to compare physiological effects. However, a shock with the Calibrator/Tester set to a 0.1-mA trip current and a GFCI clearing in 25 milliseconds is expected to be far less startling when compared to a 5-mA shock that lasts at least 250 milliseconds.

GFCI Operation

Most private residences are serviced with a 120/240-volt, 60-Hz, single-phase, three-conductor power line with a grounded neutral conductor. Shown in Fig. 1 is a simplified schematic diagram that illustrates operation of a GFCI in relationship with the grounded power-line system. The power line entering a home originates at a large 120/240-volt, center-tapped power transformer located somewhere in the vicinity. The center-tap conductor is connected to ground at the transformer.

The incoming power line's conductors feed current through the in-home electric meter and into the home itself via a service panel that contains a pair of main high-current circuit breakers in the red- and black-insulated lines. The incoming grounded neutral conductor connects to a large, heavy-duty ground bus bar inside the panel. The entrance-panel ground bus connects to a grounded water pipe or separate ground rods.

A branch circuit from the service panel to a 120-volt, three-conductor grounded wall receptacle has three conductors. The black-insulated "hot" conductor connects to a 117-volt branch circuit breaker that, in turn, connects to one of two "hot" buses in the panel. The white-insulated neutral conductor connects to the panel's ground bus, as does the bare ground conductor. At the wall receptacle, the black-insulated conductor connects to the brass-colored screw, the white-insulated conductor to the silver-colored screw and the bare conductor to the hex-head green-colored screw.

A pair of toroidal coils (only one is shown in Fig. 1) and a relay are contained inside the GFCI unit. The hot and neutral conductors pass through the toroid coil, through the relay's contacts and to the GFCI's output receptacle. The coils have windings that connect to the sense, latch and relay-driver circuit. Load current I_L flows in only the hot and neutral lines of this arrangement.

When load current flows, currents I_1 and I_2 are equal and opposite in phase and cancel out. The sense coil, therefore, "sees" no difference in the currents and, thus, keeps the relay's contacts closed. In the event of a ground-current flow (I_F), however, current I_1 increases while current I_2 remains unchanged. The sense coil now senses this difference and trips and latches the relay in a few cycles of the ac-line waveform.

Shown in Fig. 2 are plug-in and wall-mount GFCI units. The Woods Model 1651 plug-in adapter discussed earlier trips at 5 mA ±1 mA of ground-fault current in $\frac{1}{40}$th second, or 1.5 ac cycles. This device is rated at 125 volts and 15 amperes,

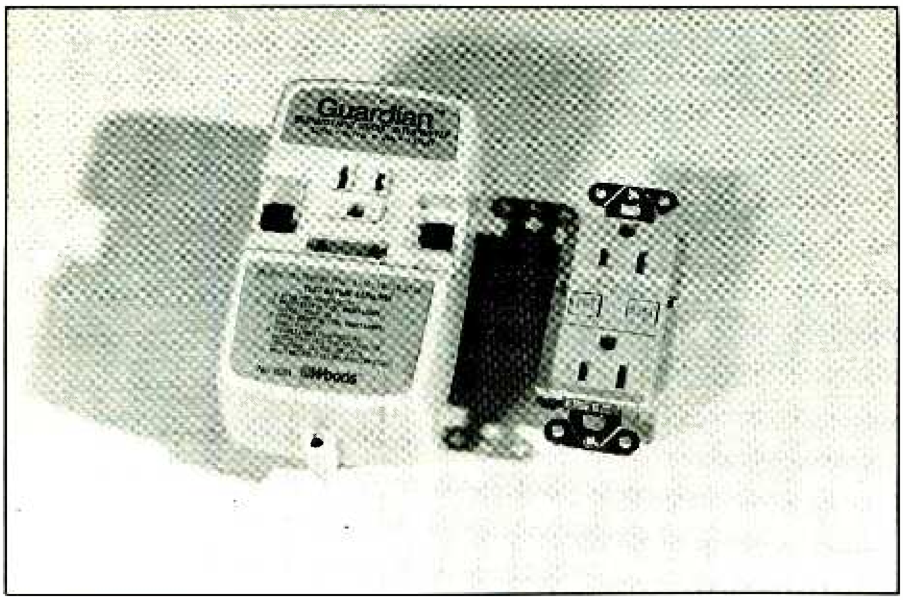


Fig. 2. Two typical GFCI units. Woods Model 1561 (left) is designed to plug into an ac receptacle and has LED status indicators, while Slater S-I-R series (right) replaces existing ac wall outlets and features two protected receptacles.

which is typical for GFCIs designed for use in private residences. It includes TEST and RESET pushbuttons and associated red and green LEDs. Once tripped, the Woods GFCI can be restored to operation simply by pressing the TEST button.

The Slater Model S-I-R series GFCI interrupter receptacle has voltage, current and trip-current ratings similar to those of the Woods model. This duplex-outlet device fits into a standard wall-type electrical box. When it trips, the RESET button pops up to indicate this condition. Trip time was not stated, but tests revealed it to be between three and four cycles of the ac power-line waveform.

Our GFCI Calibrator/Tester was tested with both of the above GFCI units and performed essentially the same in both cases. The 5-mA trip current of both GFCIs revealed very little change in trip current with line-voltage and load variations.

Typically, the GFCI affords no protection from electric shock resulting from touching the hot and neutral lines simultaneously. The current through your body in such a case is viewed by the GFCI as a legitimate "load"—not a ground-fault current. Fortunately, such occurrences are highly improbable in the home environment and are easily avoided on a workbench by observing common-sense safety precautions.

About the Circuit

Shown in Fig. 3 is the complete schematic diagram of the GFCI Calibrator/Tester. Three-prong plug *PL1* goes into the receptacle on the GFCI unit and carries ac line power directly to three-slot receptacle *SO1*.

The first section of the project comprises three light-emitting diodes that check for and indicate correct wiring of three-conductor grounded ac receptacles. Green *LED2* checks for normal voltage from the hot to the neutral ac lines and doubles as a power-on indicator for the project. Red *LED1* checks for erroneous voltage from neutral to ground, and green *LED3* checks for normal voltage from hot to ground.

Each LED has a rectifier diode connected across it in opposing polarity to prevent voltage breakdown, as well as a 6,800-ohm limiting resistor. Rectifier diodes *D4*, *D5* and *D6* absorb reverse voltage when the voltage on the ac line reverses. The diodes also reduce heating in the resistors and perform current steering service. Switch *S4* disconnects *LED3* from the circuit to prevent the GFCI from tripping as a result of LED current flow.

In the next section of the circuit, the GFCI is tested or its trip point is set. This section consists of ground-fault current selector switch *S1* and pushbutton switch *S2*. When *S2* is pressed (closed), ground-fault current flows through whichever *R1* through *R11* resistor has been selected by *S1* to ground.

Fault currents listed along the right side of the Fig. 1 schematic diagram in line with *R1* through *R11* are based on an ac line potential of 120 volts and standard resistance values with four exceptions. The calculated values for *R2*, *R6*, *R7* and *R8* are, respectively, 480K, 96K, 80K and 60K ohms instead of the 470K, 100K, 82K and 72K values (standard values all) shown and specified in the Parts List. High accuracy is not essential in this application, but you can improve the accuracy of the resistor bank if you wish by using precision resistors that have the actual calculated values or ones that are very close to them.

The final section of the circuit allows you to set the GFCI's trip current to a point between 0.1 and 1.5 milliamperes via potentiometer *R17*. When *S3* is closed, head-to-head zener diodes *D7* and *D8* receive current through limiting resistor *R15*. The diodes clip the ac sine wave at 51 volts. The resulting waveform is well-regulated against line-voltage changes, thus stabilizing the pre-load current and making it possible to operate the GFCI at trip currents as low as 0.1 milliampere.

The clipped sine wave is applied to TRIP ADJUST control *R17*, resistor *R16* and ZERO ADJUST control *R18*, from which it is returned to ground.

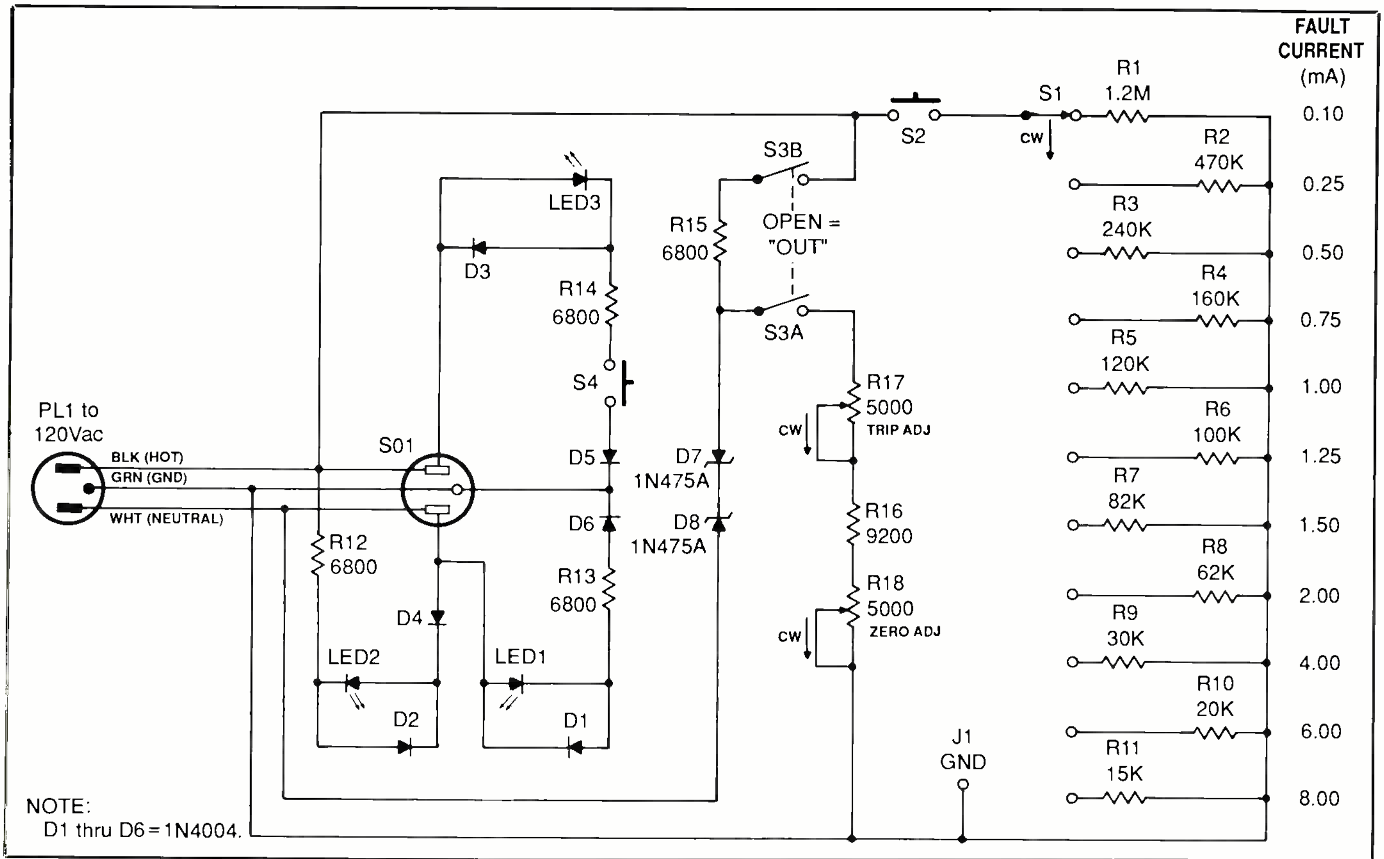


Fig. 3. Complete schematic diagram of GFCI Calibrator/Tester.

Current flowing through *R17* pre-loads the GFCI with a fault current. If the GFCI is pre-loaded with a 4-mA fault current, the trip current is then 5 mA minus 4 mA, or 1 mA. With *S3* open, the GFCI trips at its normal 5-mA fault current.

Construction

Before we get into construction, it is important to point out the following. Always exercise extreme caution when working around ac line power. This applies to building and working on the GFCI Calibrator/Tester. Observe the usual safety precautions when working with hazardous voltages:

- Stand on a dry nonconductive rubber floor mat placed in front of your workbench.
- Keep one hand clear—like in your pocket—at all times when probing or adjusting a "hot" circuit.

PARTS LIST

D1 thru D6—1N4004 rectifier diode
D7,D8—1N475A or similar 51-volt, 1-watt zener diode (see text)
J1—Black 5-way binding post or banana jack
LED1—Red light-emitting diode
LED2,LED3—Green light-emitting diode
PL1—Chassis-mount 3-conductor male ac plug
R1—1.2-megohm, ¼-watt, 5% tolerance carbon resistor
The following are 1-watt, 5% tolerance metal-film resistors:
R2—470,000 ohms
R3—240,000 ohms
R4—160,000 ohms
R5—120,000 ohms
R6—100,000 ohms
R7—82,000 ohms
R8—62,000 ohms
R9—30,000 ohms
The following are 2-watt, 5% tolerance metal-film resistors:
R10—20,000 ohms
R11—15,000 ohms
R12 thru R15—6,800 ohms
R16—9,200 ohms
R17—5,000-ohm, 2-watt, linear-taper panel-mount potentiometer (preferably wire-wound—see text)
R18—5,000-ohm, 2-watt, linear-taper pc-mount trimmer potentiometer (preferably wire-wound—see text)
S1—12-position nonshorting rotary switch
S2,S4—Spst normally open pushbutton switch
S3—Dpst toggle switch
SO1—Chassis-mount 3-conductor female ac receptacle
Misc.—Suitable all-plastic enclosure; perforated board for subassemblies (see text); panel clips for LEDs; metal spacers or sheet aluminum (see text); pointer-type control knobs for R17 and S1; dry-transfer lettering kit; clear spray acrylic; machine hardware; 16-gauge stranded wire; solder; etc.

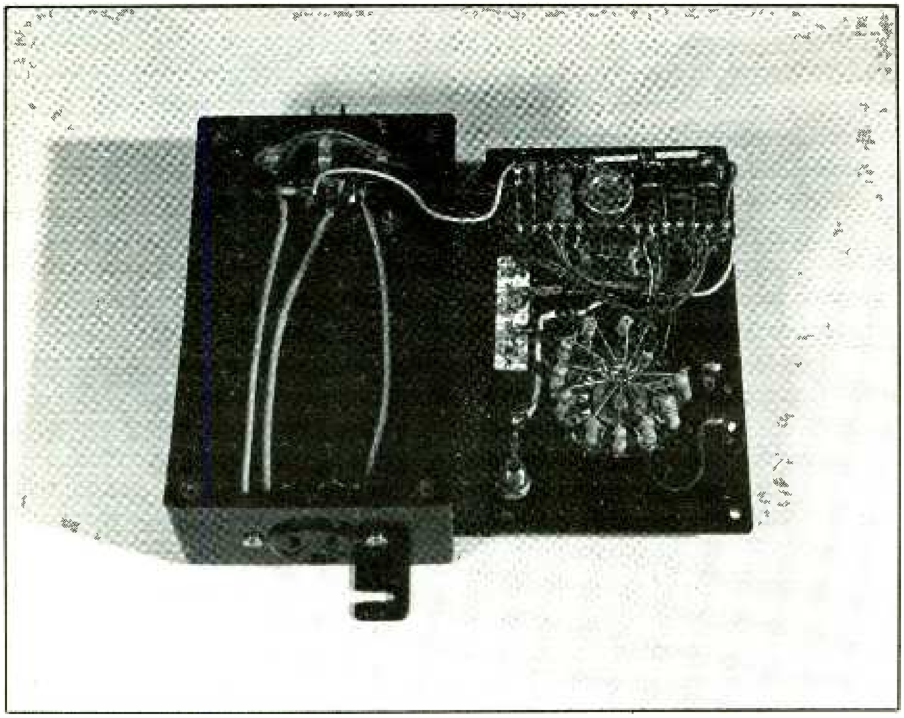


Fig. 4. Interior view of author's prototype shows modular construction.

• *Never* work on a metal workbench.
• Stay clear of grounded instruments and metal objects.
• These are just a few of the common-sense precautions you should observe.

Now on to construction.

Shown in Fig. 4 is an interior view of the assembled project built into an all-plastic project box that measures 6 × 3¾ × 2 inches. As you can see, there is nothing critical about component layout. Also, owing to the fact that the circuitry is basically passive, no printed-circuit board is needed. Construction can be performed in subassembly stages.

First, make cutouts for and mount *PL1* and *SO1* in the center of the walls at opposite ends and as near to the bottom of the box as possible. The half-round ground contacts on each should be nearest the bottom of the box. Then cut to 8 inches long three 16-gauge or larger stranded wires and strip ⅜ inch of insulation from both ends. Tightly twist together the fine conductors at all six ends and sparingly tin with solder. Use these wires to interconnect the same lug contacts on the plug and socket. Drill at least two dozen ⅛-inch-diameter holes through the rear wall of the enclosure to serve as vents to allow heat to escape from the project while it is operating.

Strip ⅜ inch of insulation from one end and ¼ inch of insulation from the other end of two 5-inch and one 8-inch lengths of hookup wire. Crimp and solder the end of the 8-inch wire from which ⅜ inch of insulation was stripped to the lug of the short rectangular contact on *PL1*. Then crimp and solder the ends from which ⅜ inch of insulation was stripped of the other two wires to the other two lugs on *PL1*. The other ends of these wires will be connected later.

Wire resistors *R1* through *R11* directly to the lugs of rotary switch *S1*. First trim one lead of each resistor to a length of about ½ inch and form a small hook in each lead stub. Next, crimp and solder the stub lead of *R1* to the position 1 lug, *R2* to the position 2 lug and so on, finishing up with the stub lead of *R11* connected to the position 11 lug. There will be nothing connected to the position 12 lug of the switch. Position the resistors as shown in Fig. 4.

Now bend the remaining resistor leads at 90-degree angle to the bodies of the resistors and pointing toward the center of the switch. If necessary, trim the resistor leads so that their ends just meet over the center of the switch. Form a small hook in the end of each lead. Now crimp all leads around the perimeter of a No. 6 solder lug and solder each connection as it is made.

Strip ¼ inch of insulation from both ends of two 3½-inch hookup wires. Crimp and solder one end of one wire to the solder lug and one end of the other wire to the wiper lug on the rotary switch. Temporarily set aside the switch assembly.

Next cut a piece of perforated board that has holes on 0.1-inch centers to a size that gives 16 full holes horizontally by four full holes vertically. Starting two holes from one end of this board plug flea clips into the two middle holes. Count up six holes and plug flea clips into the two center holes at that point. Then count up another six holes and plug flea clips into the two center holes.

Plug the leads of the three LEDs into the open ends of the flea clips so that the cathode leads are all in the *same* direction. Space the LEDs so that the bottoms of their cases are ¼ to ⅜ inch away from the surface of the perforated board. Identify and mark the cathode-lead clips. Draw three small diode symbols on self-stick paper, cut these out and stick them to the perforated board in the appropriate orientations near each LED so that you know which leads are which when it comes time to wire the assembly into the circuit. When you are finished, red *LED1* should be on the left and green *LED2* and *LED3* should be in the center and at the right.

Now prepare six 4½-inch lengths of hookup wire by stripping from each end ¼ inch of insulation. Crimp and solder one end of these wires to the stubs of the flea clips protruding from the board on the side opposite where the LEDs are mounted. Solder each connection and clip any excessive LED lead lengths flush with the ends of the flea clips. Temporarily set aside the LED assembly.

Most of the remainder of the components (except the switches, potentiometer *R17* and ground jack *J1*) mount on a tag strip, as shown in Fig. 4. Use perforated board for this strip, and mount the components in place using flea clips driven into its holes. Size the board as needed to accommodate all components to be mounted on it.

Before mounting any components in place on the tag strip, form a U-shaped bracket out of a strip of aluminum measuring ½ to ¾ inch wide as follows. First cut the strip to a length of 5 inches. Mark Xs at the exact center of the strip and ¼ inch from each end, centered between the long edges. Measure 1 inch to each side of the center X and strike pencil lines across the width of the strip at both locations. Then measure ⅜ inch from both ends of the strip and strike lines across the width at both locations.

Drill a ⅛- to ³⁄₁₆-inch hole at both marked locations at the ends of the strip and a hole in the center sized to accommodate the threaded mounting bushing of potentiometer *R17* without binding. Then bend the strip at 90-degree angles along the struck lines to form a U bracket with "ears."

Plug the shaft of *R17* into the hole in the center of the U bracket, with its body in the channel and loosely secure it in place with the supplied hex nut. Place the bracket against the perforated board that will be used for the tag strip so that its ears are flat against its surface and centered all around. Use a pencil to mark the outlines of the holes in the bracket's ears on the perforated board. Remove the bracket and drill the same-size holes at both marked locations. Mount the tag-strip board to the bracket with ¼-inch machine hardware.

Drive the flea clips into the tag-strip board and mount the components in place, with screwdriver-adjust potentiometer *R18* centered on it. Then, referring back to Fig. 3, wire together the components on the tag strip. Make certain that the diodes are properly oriented before soldering their leads into place. Also, install zener diodes *D7* and *D8* and resistor *R16* in such a way that they can easily be removed from the circuit.

When all subassemblies have been put together, proceed to panel-machining layout. The best way to do this is to set the components and assemblies temporarily in place and check for adequate clearances among them. Then carefully measure the mounting locations of each and mark the panel. Remove and set aside the components and assemblies and drill the various mounting holes needed. Size each hole according to the mounting requirements of the component or subassembly.

The lead photo shows a suggested layout for the panel. The LEDs mount in a line centered along the top of the panel and spaced 0.6 inch apart. After drilling the holes for the LEDs, test-fit the LED panel clips in them. If the clips will not seat properly in the thick panel, carefully countersink the holes a bit through the rear of the panel until they do.

Just below the LEDs is where to mount pushbutton switch *S4*. Potentiometer *R17* (along with its tag-strip assembly) mounts on the left side of the panel, with toggle switch *S3* far enough below it to clear the mounting bracket on the pot. On the right side of the panel is where rotary switch assembly *S1* mounts with pushbutton switch *S2* far enough below it to clear the rotary-switch wafers on the rear side of the panel. This arrangement groups controls and indicators by interrelated functions.

Drill all mounting holes in the panel and test-fit the components and assemblies into them. When all is okay, place pointer-type control knobs on the shafts of *R17* and *S1* and use a soft pencil to scribe onto the panel the outlines of the knobs. Next, rotate the knob on *S1* fully counterclockwise. If the pointer on the knob does not fall on the 7 o'clock location on the panel, remove the knob, loosen the mounting nut and reposition the switch until it does. Then place a small pencil mark at each location the pointer index on the knob stops as you rotate the knob clockwise.

Remove from the panel and set aside the components and assemblies. Then use a dry-transfer lettering kit to label the panel as shown in the lead photo. Rub on rectangular bars between the left and center and the center and right LED holes, making the latter a bit shorter than the former, per plug/socket arrangement. Directly below the center LED hole, rub on a solid dot. This arrangement shows a stylized representation of the three-contact plug/receptacle arrangement.

Proceed with labeling the panel, applying appropriate legends that identify the various switches and control on the panel and their positions. At this time, you will not be able to label the positions of the potentiometer. These will be determined later during calibration.

When you finish labeling the panel, spray on two or more light coats of clear acrylic to protect the lettering from scratching. When the spray acrylic has completely dried, mount the components and assemblies in their respective locations. Adjust the positioning of *S1* as described above and mount *R17* so that its lugs point directly toward the center of the panel. Replace the knobs on the shafts of *S1* and *R17*.

Now, referring back to Fig. 3, interconnect all components and assemblies. Make certain that when

(Continued on page 92)

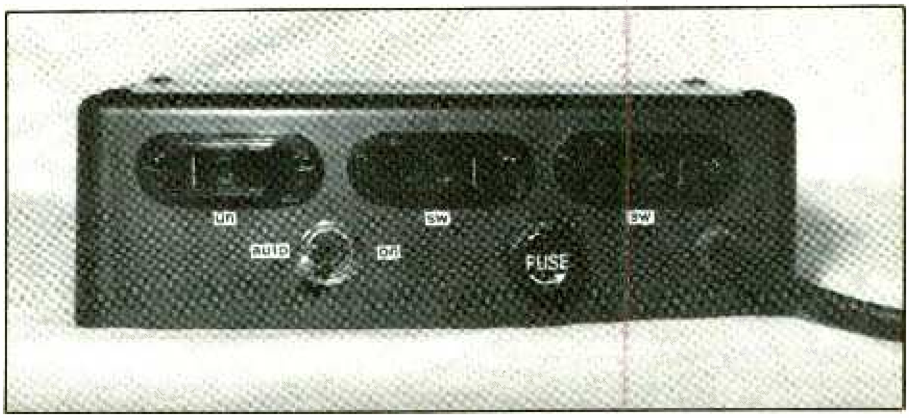
A "Smart" AC Outlet Box

Turning on one controlling device automatically powers up two others

By Dennis J. Eichenberg

It is often desirable for a piece of electronic equipment to have switched ac receptacles that simultaneously power up and down whenever the device is turned on and off. This is usually a requirement in laboratories for equipment associated with a given process. In the consumer area, some hi-fi preamplifier/control centers provide this capability as a standard feature, and power in some compact audio systems is controlled entirely by the record player. Unfortunately, some equipment—notably personal computers and audio/video systems—that could benefit from switched ac receptacles lack this feature. For such situations, the "Smart" ac Receptacle Box described here may be just what is needed.

Inexpensive and relatively easy to build from commonly available components, our "Smart" ac Receptacle Box features a "control" receptacle into which the main electronic device is to be plugged and two switched receptacles. Any device plugged into the unswitched receptacle automatically turns on/off whatever devices are plugged into the switched receptacles. For example, in a computer system, the computer would be the controlling device that also turns on/off a printer and any other peripheral.



About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the "Smart" ac Outlet Box. It is built around optical isolator *IC1*, which contains an infrared GaAs light-emitting diode and a light-activated bilateral switch. The latter operates with the same bidirectional action as a triac. In fact, the MOC3010 optoisolator mimics a common triac, with pins 4 and 6 acting like the main terminals and pin 1 acting like the gate terminal of a triac. The bilateral switch can directly drive 117-volt ac loads at currents up to 100 milliamperes. The LED inside the optoisolator requires between 10 and 15 milliamperes to turn on the bilateral switch and can withstand currents of up to 60 milliamperes.

The "hot" side of the ac line is routed through 5-ampere fuse *F1* to provide protection for the controlling circuitry. The project has one unswitched and two switched outlets. Though unswitched outlet *SO1* is part of the fuse-protected circuit, no fusing is used for switched outlets *SO2* and *SO3*. Instead, the "hot" side of the 117-volt ac line is brought directly to the contacts of relay *K1* and AUTO/ON switch *S1*. Depending on setting, switch *S1* permits *SO2* and *SO3* to be controlled automatically or manually. With *S1* set to ON, the relay contacts are shorted out and control is manual. Setting *S1* to AUTO gives the relay contacts control of ac power switching to *SO2* and *SO3*.

Following *F1*, the incoming 117-volt ac line is brought to one of the ac terminals of bridge rectifier *RECT1*. After passing through the bridge rectifier, the resulting pulsating dc is routed from the positive (+) output of *RECT1* to the negative (−) terminal of bridge rectifier *RECT2*. The other ac terminal of *RECT1* goes to the "hot" side of unswitched *SO1*, which is the socket into which the controlling equipment is to be plugged.

The neutral side of *SO1* ties to the neutral side of the ac line and switched receptacles *SO2* and *SO3*. For this application, bridge-rectifier assemblies *RECT1* and *RECT2* must be rated to handle at least 200 peak inverse volts at not less than 6 amperes. (If you wish, you can substitute individual rectifier diodes of the same ratings for the rectifier assemblies).

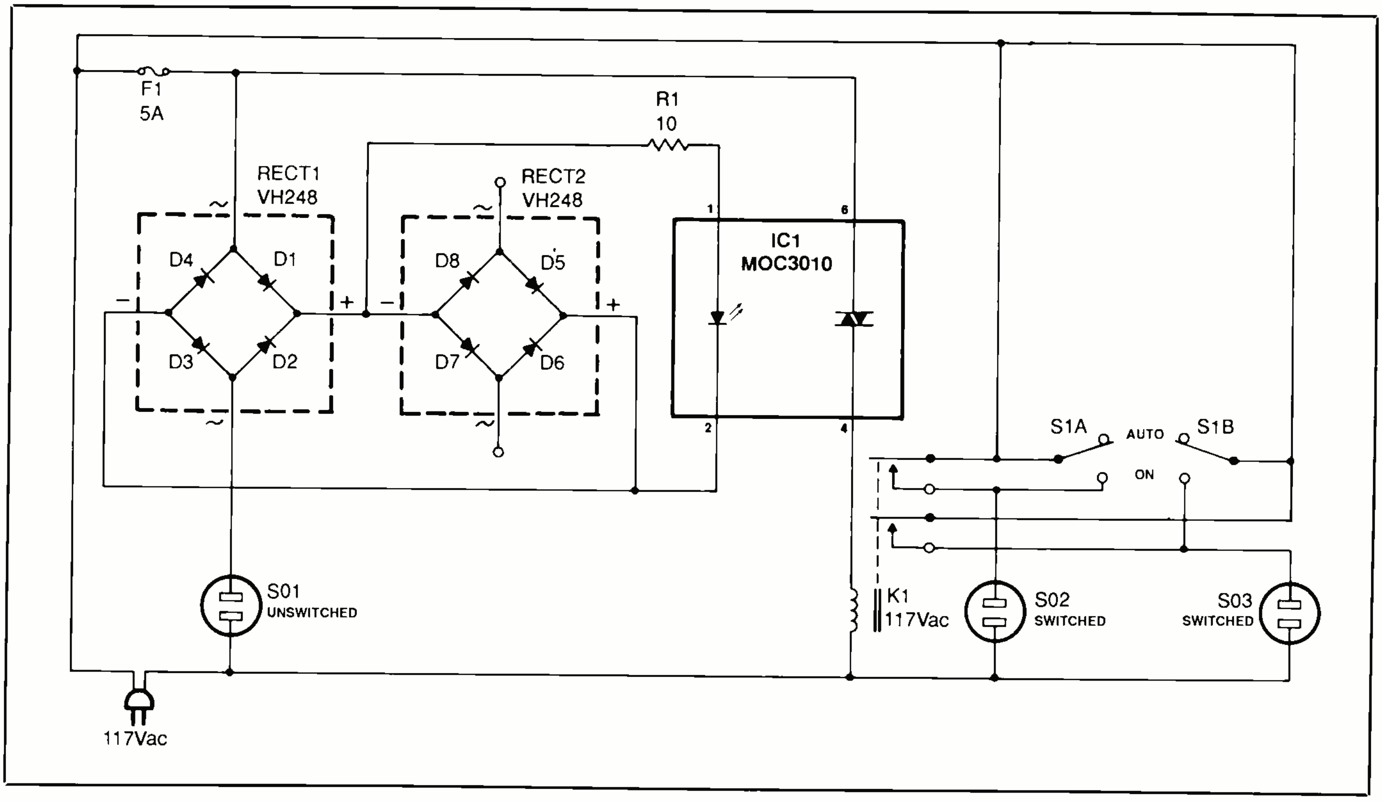


Fig. 1. Complete schematic diagram of the "Smart" ac Outlet Box shows a two-conductor power scheme. If a three-conductor system is needed, as for computer systems, simply tie together the "extra" ground conductors.

PARTS LIST

F1—5-ampere slow-blow fuse (see text)
IC1—MOC3010 optical isolator
K1—117-volt ac relay (see text for coil/contact ratings)
R1—10-ohm, ¼-watt, 10% tolerance resistor
RECT1,RECT2—VH248 or similar 200-PIV, 6-ampere bridge rectifier (or individual 200-PIV, 6-A rectifier diodes—see text)
Misc.—Suitable enclosure; bayonet-type fuse holder for F1; three (or more—see text) chassis-mount ac receptacles; socket for IC1; ac line cord with plug; machine hardware; spacers; heavy-duty stranded hookup wire; solder; etc.

With 117 volts ac applied to the circuit through the line cord, turning on the controlling device plugged into *SO1* causes current to flow through the diodes in the *RECT1* and *RECT2* circuits. Current flow is through diodes *D1*, *D3* and *D5* through *D8* on the positive alternation of the ac line and through *D2*, *D4* and *D5* through *D8* on the negative alternation. The rectifier diodes have a characteristic drop of 0.7 volt. Thus, approximately 1.4 volts is developed between the negative (−) and positive (+) terminals of *RECT2* when the controlling device plugged into *SO1* is turned on.

The LED inside *IC1* requires at least 10 milliamperes of current to turn on the internal light-activated bilateral switch. The LED, which has a forward voltage drop on the order of 1 ohm, is connected across the + and − terminals of *RECT2*, with resistor *R1* limiting current flow to a safe level. The value of *R1* is derived as follows:

$$R1 = (V_{BRIDGE} - V_{LED})/I_{LED}$$
$$= (1.4\ V - 1.0\ V)/40\ mA$$
$$= 10\ ohms$$

From this, you can calculate the amount of power drawn by the LED as follows:

$$PR1 = (I_{LED})^2 \times R1$$
$$= (40\ mA)^2 \times 10\ ohms$$
$$= 0.016\ watt$$

Therefore, a 10-ohm, ½-watt will suffice for *R1*.

As mentioned above, the bilateral switch inside *IC1* can handle up to 100 milliamperes of current, which is not sufficient to directly drive the switched receptacles. Therefore, this current is used to drive relay *K1*, which has contacts that are rated for the expected loads. Of course, the relay's coil rating should be less than the 100-milliampere maximum from *IC1*. A safe rating would be 50 milliamperes. For a 117-volt ac coil potential, the coil's resistance should be at least 2,400 ohms. Contact rating should be at least 10 amperes to accommodate just about any reasonable loads that will be plugged into *SO2* and *SO3*.

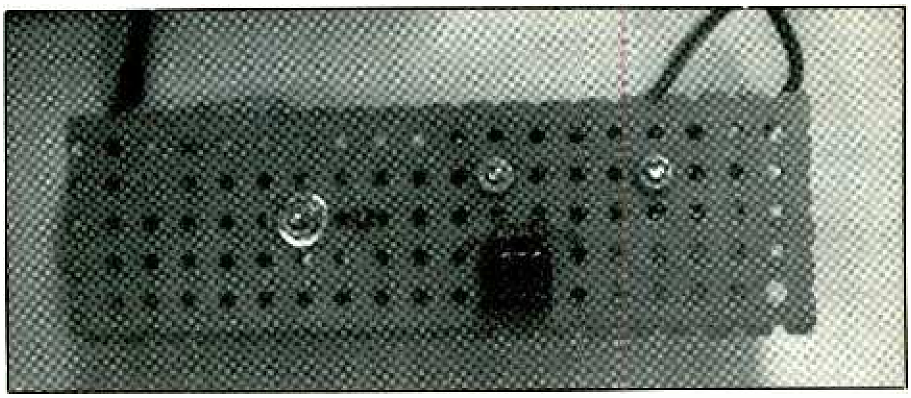
Figure 1 shows an arrangement for switching two auxiliary receptacles on and off from one "control" receptacle. If you wish, you can switch more receptacles, up to a maximum of six, assuming you can find a relay that has an appropriate number of contacts and you beef up the gauge of the wiring used. Additionally, you can make the system operate with three-conductor power schemes. To do this, use three-contact ac receptacles and a three-conductor ac line cord and wire together all socket ground contacts and the ground conductor of the line cord.

Construction

There is nothing critical about component layout for this project. Therefore, you can assemble it using any traditional wiring technique that suits you, including on a printed-circuit board of your own design and perforated board. Perhaps the simplest and fastest approach is to mount and wire together the rectifier assemblies (or individual rectifier diodes), resistor, optoisolator and relay on perforated board, as shown in Fig. 2. Whichever method you decide to use, it is a good idea to use a socket for the optoisolator.

Once you have mounted the components on the board, refer back to Fig. 1 and wire them together. Use heavy-duty stranded hookup wire for all interconnections, preferably 16-gauge or larger. After cutting the wires to length, strip ¼ inch or so of insulation from both ends, tightly twist together the fine conductors at both ends and sparingly tin with solder. At this stage make only the interconnections between the rectifier assemblies, resistor, optoisolator and relay coil.

Prepare four 6-inch lengths of 16- or heavier-gauge wire. Crimp and solder one end of these wires to the appropriate contact lugs on the relay. The other ends of these wires will be connected later to the lugs on the chassis-mounted ac receptacles. Temporarily set aside the circuit-board assembly.



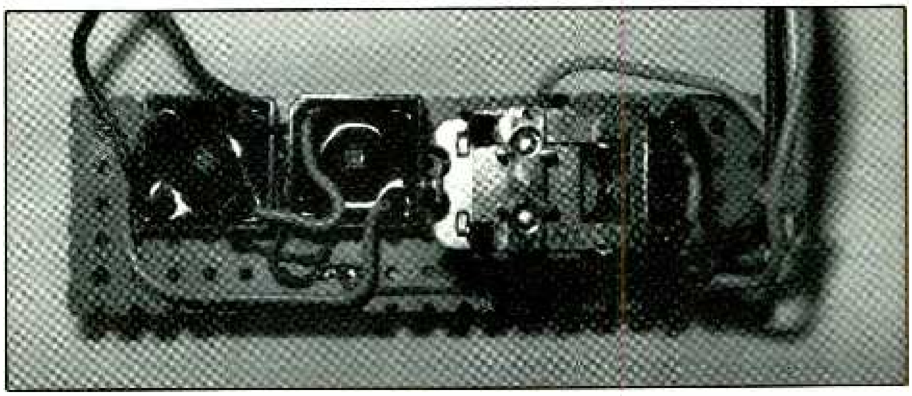


Fig. 2. Author's prototype was built using perforated board, with optoisolator in a socket and the resistor on top (upper photo) and rectifier assemblies and relay on the bottom (lower photo).

Now machine the enclosure in which the project will be housed. You can use any enclosure that will accommodate all components without crowding. Because of the need to cut rectangular or square openings for the receptacles, a good choice would be a plastic project box that has a metal panel. The plastic is relatively easy to cut and trim without specialized tools. Of course, if you have a chassis punch of suitable size and shape or a nibbling tool, you can quickly machine an all-metal utility box instead.

Start machining the enclosure by drilling mounting holes for the circuit-board assembly. Then drill the large hole in which to mount the bayonet-type holder for *F1* and the smaller holes for the switch and entry for the ac line cord. Finally, cut the slots for the chassis-mount ac receptacles.

Line the entry hole for the ac line cord with a small rubber grommet. Tightly twist together the fine wires at the free end of the line cord's conductors and sparingly tin with solder. Pass the free end of the cord through the grommet and tie a knot in it about 6 inches from the end inside the enclosure.

Mount the circuit-board assembly in place with ½-inch or so spacers and suitable machine hardware. Then mount the ac receptacles, switch and fuse holder in their respective locations.

Locate the free ends of the wires connected to the lugs of the relay contact pairs. Crimp both wires and one ac line cord conductor to one lug of the fuse holder and solder the connection. Then crimp and solder the

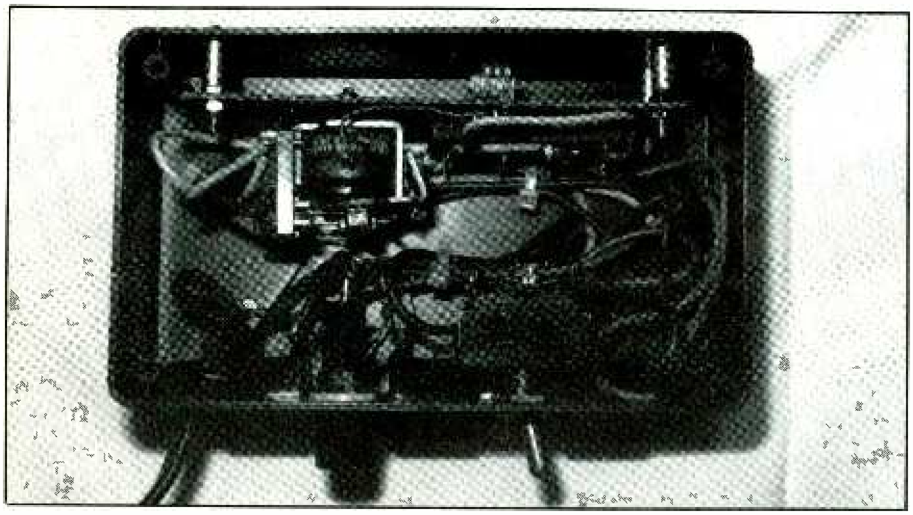


Fig. 3. Interior view of author's completed project prototype built into a plastic project box.

ends of the remaining two relay wires to one lug of switched receptacles *SO2* and *SO3*.

Prepare five 6-inch lengths of wire as you did for the relay wires. Crimp and solder one wire between one ac input lug of *RECT1* and one lug of unswitched ac receptacle *SO1*. Then crimp and solder another wire from the other ac lug of *RECT1* and the unused lug on the fuse holder.

Crimp and solder one end of a third wire to the unoccupied lug on *SO3* and crimp the other end of this and a fourth wire to the unoccupied lug on *SO2* and solder the connection. Connect and solder one end of the fifth wire to the unoccupied coil lug of *K1*. Finally, crimp and solder the free ends of both the fourth and fifth wires and the remaining ac line cord conductor to the unoccupied lug of *SO1*. This completes the wiring of the project. The author's completed prototype is shown in Fig. 3.

Label *SO1* with the legend UNSWITCHED or CONTROL and *SO2* and *SO3* with the legend SWITCHED or AUX. Then label the positions of *S1* with the legends AUTO and ON or MANUAL. Also, label the fuse holder with the legend 5A MIN. If you use a dry-transfer lettering kit, spray two or more light coats of clear acrylic over the labels to protect them from scratching.

Before putting the project into service, it is a good idea to go over it carefully, checking your wiring against Fig. 1. Make certain that all connections are electrically and mechanically secure.

Checkout & Use

Plug lamps into the three receptacles on the project. Turn on both lamps plugged into switched outlets *SO2* and *SO3*, but leave the one plugged into unswitched outlet *SO1* turned off. Make sure the project's switch is set to AUTO.

Plug the "Smart" ac Outlet Box's line cord into an ac outlet. At this point, none of the lamps should be on. Set the switch to MANUAL (or ON). The lamps plugged into the switched receptacles should immediately come on. If they do not, check the switches on the lamps themselves. If this does not turn on these lamps, power down the project, disconnect it from the ac outlet and recheck all wiring. Do not proceed until you have rectified the problem.

Once you have the project working in the manual position of the switch, set the toggle to the AUTO position once again. Turn on the lamp plugged into the unswitched receptacle. Now all three lamps should turn on simultaneously. Turning off the "control" lamp plugged into *SO1* should cause all three lamps to turn off.

You can now put your "Smart" ac Outlet Box into service. Before you do, however, make certain that the relay contacts and switch can handle the expected loads plugged into the switched ac receptacles. Also, if the equipment to be plugged into control receptacle *SO1* draws more than 5 amperes, replace *RECT1*, *RECT2* and *F1* with suitably rated components.

Use of the "Smart" ac Outlet Box is as simple as flipping a switch. Just keep in mind that the device plugged into the unswitched "control" receptacle controls power to the switched receptacles. Therefore, always make sure that the devices plugged into the latter have their power switches turned on at all times. **ME**

How to Read Oscilloscope Waveforms

(Conclusion)

Finishing up with our series on useful tricks of the trade for getting the most out of your oscilloscope

By Robert G. Middleton

Concluding this three-part series on the basics of interpreting oscilloscope waveforms, our focus here is on sawtooth waveform characteristics, common distortion factors and analysis of abnormal waveshapes. In future issues, we will present more advanced techniques that will considerably expand upon what we have already covered and are about to cover here.

Sawtooth Waveform Relationships

Sawtooth waveforms are widely encountered in many types of electronic equipment, including test instruments. The ideal sawtooth waveform is functionally related to the square wave, as shown in Fig. 1. A sawtooth waveform is called a ramp, as used in digital voltmeters and the voltage functions of digital multimeters.

Distortion of a sawtooth waveform results in various trouble symptoms whose nature depends on the circuit action involved. Elementary sawtooth waveform distortions are illustrated in Fig. 2. Convex sawtooth distortion in a TV receiver, for example, causes compression of the picture on the right-hand end of the picture screen, and concave sawtooth distortion causes compression of the picture on the right-hand end of the screen.

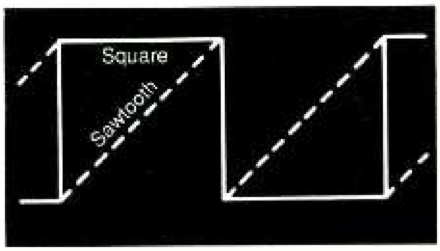


Fig. 1. The sawtooth or ramp waveform is functionally related to the basic square waveform.

Similarly, convex sawtooth distortion causes cramping of the waveform displayed on the right-hand end of an oscilloscope's CRT screen, as shown in Fig. 3. This is a common type of sawtooth waveform distortion because the sawtooth is often generated by integrating a square wave. This circuit action provides an exponential waveshape, as illustrated in Fig. 4. The practical consideration here is that although an exponential waveform is curved throughout its complete course, this curvature is negligible over its initial 5 percent interval. However, if 50 percent of the exponential waveform in Fig. 4 is employed, the resulting "sawtooth" is highly convex.

If a deflection waveform or ramp is produced by less than 5 percent of the exponential waveform shown in Fig. 4, the resulting sawtooth will approximate the linear waveshape depicted in Fig. 1. On the other hand, if the "sawtooth" waveform is produced by 20 percent of the exponential waveform, for example, the resulting semi-sawtooth resembles the distorted waveform in Fig. 2(A).

In the case of a TV receiver that develops compression of the picture on the right-hand end of the screen, the person doing the troubleshooting will look for a circuit fault that causes objectionable exponential curvature in the horizontal-deflec-

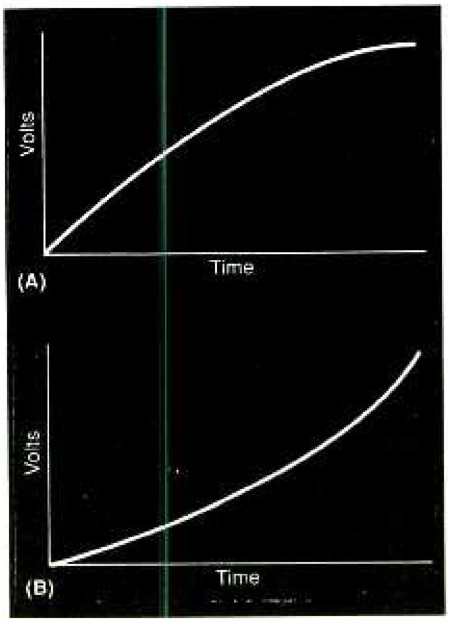


Fig. 2. Elementary sawtooth distortions include (A) convex and (B) concave distortion.

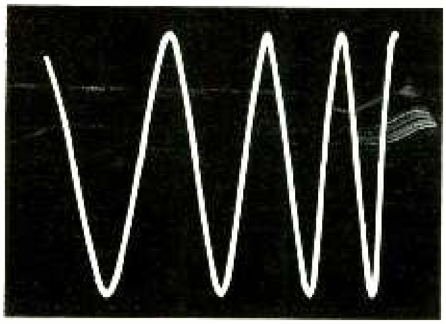


Fig. 3. This drawing illustrates cramping of the display at the right-hand end of the oscilloscope's screen by a convex sawtooth deflection waveform.

tion waveform. By the same token, circuit faults can cause nonlinear vertical deflection. Technically speaking, an ideal sawtooth waveform can be generated by charging a capacitor through a constant-current source, as is approximated by a very-high value of resistance for *R1* in Fig. 4.

A better approximation of a constant-current source is provided by a silicon transistor arrangement, such as shown in Fig. 5. The transistor presents a very-high effective value of charging resistance. Moreover, it does not require a high-voltage dc source, as would be required if an elementary RC integrating circuit were to be employed. Accordingly, V_{EE} may have the same value as V_{CC} in the associated electronic unit.

Observe in Fig. 5(A) that a silicon transistor has a nearly horizontal collector characteristic, or collector current is practically constant over a wide range of collector voltage at a given base-bias potential. This is simply another way of stating that the incremental collector resistance is very small and that the effective internal resistance of the constant-current source is very high. Of course, if a fault develops in the circuit configuration, such as collector-junction leakage, it will not operate as a constant-current source. Instead, it will operate as an ohmic current source.

Mathematical Integration Vs. "RC Integration"

It is helpful for you to recognize the distinction between mathematical integration and so-called "RC integration." Mathematical integration is performed in accordance with the laws of calculus, whereas RC integration is more or less an approximation of mathematical integration.

This distinction will become clearer as we consider a few practical examples. To begin with, if a capacitor is charged from a constant-current source, the sawtooth voltage developed at the capacitor's terminals is linear. This fact is in accordance with the basic law that states that the capacitor voltage is the integral of its charging current.

We have established that when a capacitor is charged through a resistor from a voltage (constant-voltage) source, the "sawtooth" voltage developed at its terminals is nonlinear. Instead, the "sawtooth" is an exponential waveform. It will approximate a linear sawtooth waveform only if the series resistor has a very-high value so that only a small portion of the rising exponential characteristic is utilized in waveform generation. As a side effect of employing a very-high value of series resistance, the source voltage must also be very high so that a useful output amplitude is obtained (charging current is made sufficiently large by using a very-high source voltage).

Integration of a Sawtooth Waveform

Some TV receiver circuits use integrated sawtooth waveforms in their

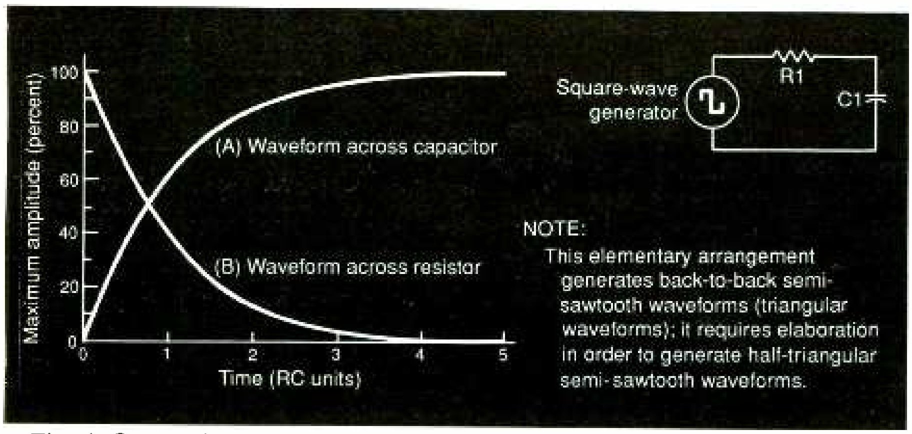


Fig. 4. Generating a semi-sawtooth waveform by integrating a square wave.

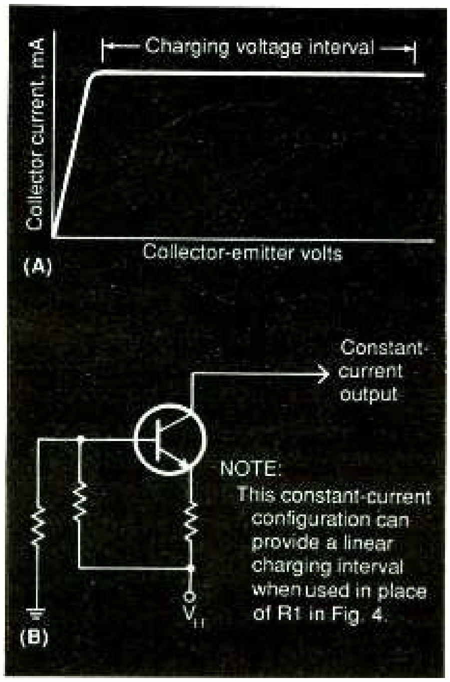


Fig. 5. Basic configuration of a constant-current source with a silicon transistor as the current controller. (A) illustrates the collector current characteristic at a given base bias, (B) the constant-current circuit configuration.

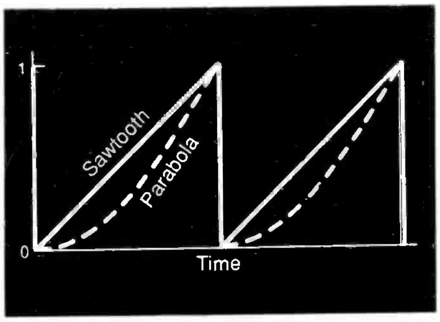


Fig. 6. Mathematical integration of a sawtooth waveform.

convergence sections. Under fault conditions, sawtooth processing circuits can develop faults that introduce objectionable integration into the waveform. Accordingly, it is helpful to consider the circuit action involved in RC integration of a sawtooth waveform.

Start by observing the mathematical integration of a sawtooth waveform, as illustrated in Fig. 6. The equation for this sawtooth is $y = x$, and the mathematical integral of x is x^2. Accordingly, $y = x^2$ plots as a parabola (actually, half of a parabola since we are not taking negative values of x into account).

Since an RC integrating circuit is only an approximation of the process of mathematical integration, you may suspect at this point that if a sawtooth waveform is passed through an RC integrating circuit that a true parabolic output will not be obtained. This is a well-founded suspicion, as demonstrated in the example in Fig. 7. Note that although the output waveform here resembles a parabola, it is skewed to the left. A check of x,y relationships will reveal that the output waveform in Fig. 7 is only a rough approximation of a true parabola.

A superficial analysis might anticipate that half-parabolas would be generated by the arrangement shown in Fig. 7, similar to the mathematical integral shown in Fig. 6. However, if this were so, the integrating circuit in Fig. 7 would necessarily output 0 volt immediately after the peak of the input sawtooth voltage is passed. This is an obviously impossible circuit action because the capacitor is left with a full charge immediately after the peak of the sawtooth input voltage is passed. This charge must decay exponentially via the series resistor.

The resulting circuit action comprises two processes following the peak of the sawtooth input voltage. Firstly, the charged capacitor is discharging at a rate determined by the RC time constant of the circuit. Secondly, the rising sawtooth input voltage is beginning once again to charge the capacitor. These are antagonistic processes, with the result that a valley point is reached. This valley point identifies the equality of charging and discharging currents at that instant. Thereafter, the exponential charging current dominates the output waveform up to the following peak of the sawtooth input voltage.

Since the circuit action consists of two currents in a linear system, it might be supposed that the charging current could be considered by itself and also that the discharging current could be considered by itself, followed by algebraic addition of the

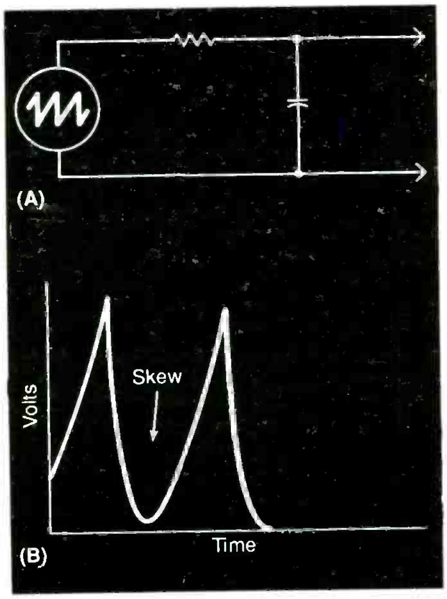


Fig. 7. Typical distorted parabolic waveform obtained by passing a sawtooth waveform through an RC integrating circuit. (A) illustrates the RC integrating circuit with a sawtooth voltage input, (B) the typical distorted parabolic output waveform.

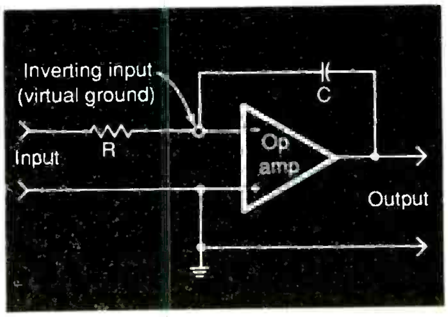


Fig. 8. A basic operational-amplifier circuit that provides nearly ideal integrating action.

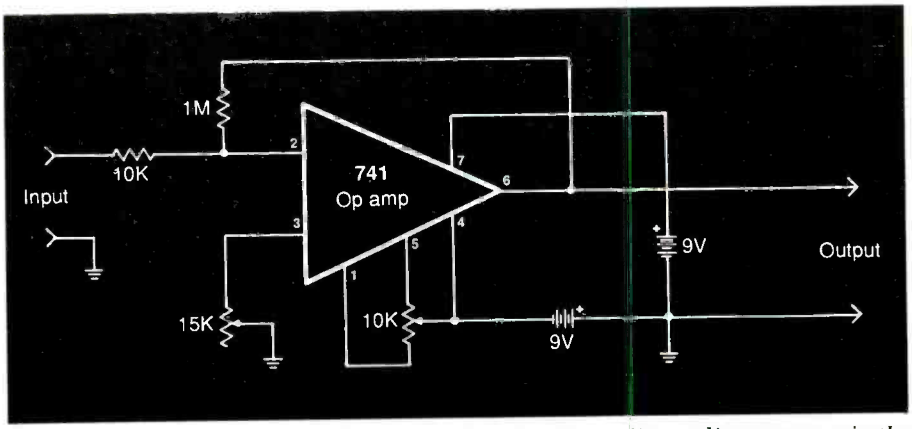


Fig. 9. A simple op-amp configuration showing the nulling adjustments, via the potentiometers, for cancellation of offset voltages.

two values at a given time to calculate the output voltage at that instant.

This supposition would be incorrect because the rate of charge is affected by the rate of discharge, and vice-versa. Consequently, you would not attempt any quantitative analysis. Instead, you would merely "read the waveform qualitatively" for clues concerning the circuit fault causing the waveform's distortion.

Integrating Circuits With Active Devices

We have seen that an RC integrating circuit is only a rough approximation of mathematical integration. However, if an active device, such as an operational amplifier, is included in the configuration, a much better approximation of mathematical integration can be obtained. A basic such arrangement is shown in Fig. 8. This configuration provides nearly ideal integrating action due to the high gain of the op amp and large amount of negative feedback from output to input of capacitor *C*.

The basic circuit shown in Fig. 8 is widely used for generation of horizontal sweep waveforms in modern oscilloscopes. It operates with a constant dc voltage input and develops a linear ramp output that is terminated at a desired point by means of an external discharge (short-circuiting) device.

Output waveform distortion can be caused by drift in the bias voltages, with the result that the waveform becomes clipped. Observe in Fig. 9 that 10K- and 15K-ohm potentiometers are in the bias circuitry. They are placed here to serve as means for adjusting offset current nulling. The settings of these pots are quite critical. A small error in null adjustment causes a large error in the operating point of the op amp. Moderate nulling results in waveform clipping, and serious nulling errors "kill" operational-amplifier action. **ME**

Experimenting With Photoresistors

By Forrest M. Mims III

The variety of light-sensitive electronic components available to today's designer and experimenter is truly astounding. Such components include photodiodes, phototransistors, photomultiplier tubes, light-sensitive SCRs, photoFETs, solar cells and various kinds of solid-state image sensors. Many kinds of thermal sensors designed primarily to detect infrared radiation can also detect visible light. Even light-emitting diodes (LEDs) and laser diodes can function as light detectors as well as generators.

With many detectors from which to choose, it is easy to overlook the lowly photoresistor. While photoresistors have notoriously low response times and suffer from the "light history" effect, they are among the most sensitive light sensors around. For this reason alone, they are well suited for use in many light-sensing applications. Photoresistors are also characterized by a narrower spectral response than are most other light sensors, which makes it possible for them to be used in a number of unique applications.

It is important for the well-rounded circuit designer and experimenter to be fully aware of the characteristics and operating requirements of the various kinds of light-sensitive components now available. Therefore, before we get into a description of the principles of photoresistors in detail, let's briefly review the various families of light-sensitive devices in general.

The Families

Besides photoresistors, the two most important classes of light-sensitive devices are classified as photoemissive detectors and junction photodiodes.

Photoemissive devices are electron tubes that incorporate a light-sensitive photocathode that emits electrons when struck by photons (light energy). The emitted electrons are collected by an anode electrode to form a photocurrent that is proportional to the intensity of the light that caused them to be emitted from the photocathode. Vidicons, image converters and image intensifiers are special types of photoemissive detectors.

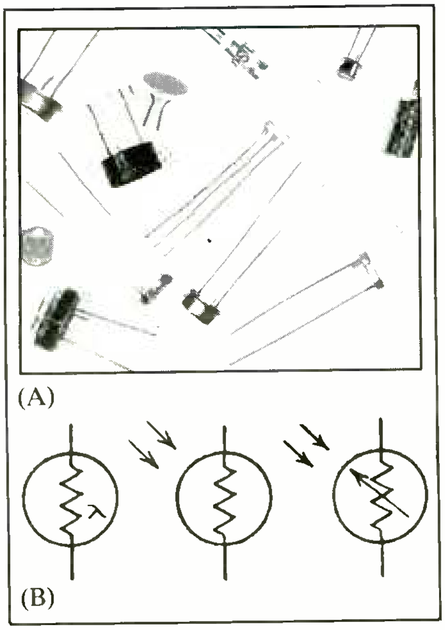


Fig. 1. Assorted photoresistors from author's shop (A) and common photoresistor schematic symbols (B).

The single biggest drawback of photoemissive detectors is their requirement for an evacuated envelope. When the envelope is glass, which is usually the case, the photoemissive device is quite fragile. Another drawback is that photoemissive detectors require a higher operating voltage than do most kinds of solid-state detectors. On the plus side, photoemissive devices known as photomultiplier tubes that incorporate a series of internal stages are among the most sensitive of all light detectors.

Semiconductor junction photodetectors make up a broad class of solid-state light sensors that include photovoltaic, photoconductive and avalanche photodiodes. Though most junction photodetectors are made from silicon, many other semiconductor materials are also used, including germanium, gallium-arsenide, indium-arsenide and others.

Photovoltaic photodiodes are pn junctions that generate a photocurrent when struck by photons. Many kinds of photodiodes can be used in the photovoltaic mode. Silicon solar cells are photovoltaic detectors. An important advantage of photovoltaic photodiodes is their exceptionally low dark current, which is the unwanted current that flows when a device is in total darkness.

Photoconductive operation of a photodiode is usually implemented by reverse biasing the device with an external current. When photons illuminate the photodiode's light-sensitive junction region, the diode permits a current to flow that is proportional to the flux of the incident photons. Photodiodes operated in the photoconductive mode are very sensitive and have very fast response time. However, they do have a higher dark current than do photovoltaic photodiodes.

Avalanche photodiodes have a high reverse breakdown voltage. They are designed to be reverse-biased at just below their breakdown potential.

Photons striking the photodiode stimulate a disproportionate flow of electrons, thus giving avalanche photodiodes a sensitivity that rivals that of photomultiplier tubes. The chief drawback of avalanche photodiodes is the requirement for the high reverse voltage. The requirement is made even more difficult by the temperature dependence of the diode's breakdown voltage. Therefore, for optimum performance over a wide range of temperatures, the power supply that provides the reverse bias must be temperature regulated.

Photoresistors

Also called photocells and light-dependent resistors, photoresistors are by far the simplest of light detectors. Though they are solid-state devices, they do not possess a pn junction. Instead, they are considered to be "bulk-effect" light sensors.

Shown in Fig. 1 are an assortment of photoresistors taken from my electronics shop and the most common photoresistor schematic symbols.

A typical photoresistor is fabricated by applying electrodes to a film of light-sensitive material. Often, the electrodes are applied in a zig-zag or spiral pattern to increase the exposure area of the material.

ELECTRONICS NOTEBOOK . . .

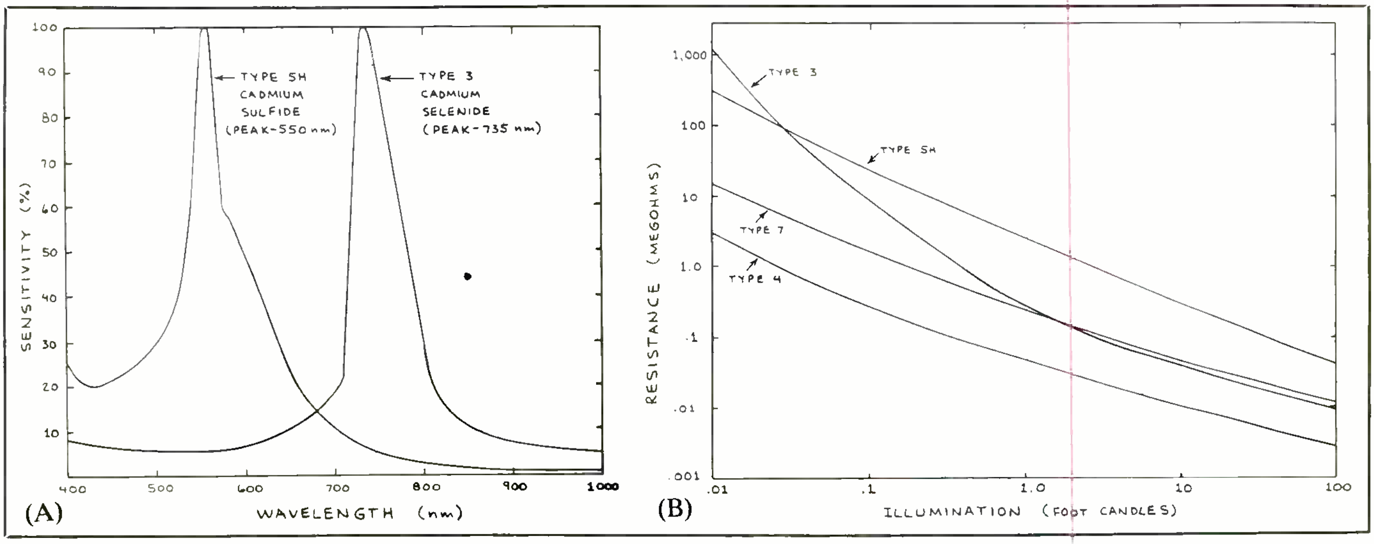


Fig. 2. Spectral sensitivity of representative cadmium-sulfide (CdS) and cadmium-selenide (CdSe) photoresistors (A) and resistance-versus-illumination plots of several photoresistor materials (B).

When a photoresistor is in total darkness, it has a very high electrical resistance. When light strikes it, though, its resistance decreases, often dramatically.

The *resistance ratio* is a figure of merit for the resistance change a photoresistor undergoes after an illuminating source is switched off. The resistance ratio can be specified in many ways, but the most common is the ratio of the resistance when the photoresistor is illuminated by 2 foot-candles (fc) to the resistance in total darkness within 5 seconds of switching off the light source. Therefore, a photoresistor that has a resistance of 2,000 ohms at 2 fc and a resistance of 800,000 ohms in total darkness has a resistance ratio of 2,000:800,000, or 1:400.

The level of light produced by a candle at a distance of 1 foot is known as 1 fc. A 25-watt tungsten lamp has an intensity of about 19 candle power, a 60-watt tungsten lamp about 60 candle power.

The response of photoresistors to a square pulse of light is much slower than that of photodiodes. While a silicon photodiode may have rise and fall times measured in nanoseconds, a photoresistor often has rise and fall (decay) times measured in milliseconds or even several *tenths* of a second.

Another drawback of photoresistors is the *light history effect*. The resistance a photoresistor assumes on being illuminated by light depends in part on the previous level of light received by the device. The magnitude and direction of the effect depends on many factors, including the duration of the previous light exposure and the current exposure.

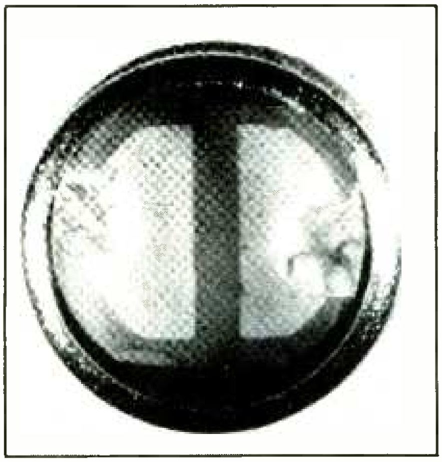


Fig. 3. Light-sensitive region of a CdS photoresistor in a TO-18 transistor can.

Photoresistors are specified to have a certain resistance when illuminated at a specified level of light. This resistance is sometimes called the *equilibrium resistance*. If a photoresistor that has been stored in a light-tight container is removed from its container and exposed to light, its resistance will at first be lower than the equilibrium value. Gradually, however, the resistance will reach the specified equilibrium value.

Now consider the case of a photoresistor that has been stored on a shelf illuminated by the morning sun. If this photoresistor is moved out of the sunlight and its resistance is measured at the much lower light level at which the equilibrium value is specified, its resistance will at first be higher than the equilibrium value. Gradually, its resistance will fall to the equilibrium value.

Photoresistor Materials

The two most common light-sensitive substances used to make photoresistors are cadmium-sulfide (CdS) and cadmium-selenide (CdSe). The spectral sensitivity of these two materials differs substantially.

Peak spectral response of the various formulations of CdS range from about 500 to 620 nanometers (nm). The peak response of Type 9 CdS is 550 nm, the same as that of the human eye. Some CdS formulations have an exceptionally narrow spectral width. For example, the spectral bandwidth of Type 2 CdS at the −3-dB points (50 percent) is about 50 nm. The spectral bandwidth of Type 5H CdS at the −3-dB points is about 40 nm.

The peak spectral response of the various formulations of CdSe range from about 720 to 780 nm. Therefore, CdSe affords reasonably good near-infrared sensitivity. For example, Type 3 CdSe has a peak sensitivity of 735 nm. At the 880-nm wavelength of high-power AlGaAs near-infrared emitting diodes, the sensitivity is 20 percent of the peak value. At the 940-nm wavelength of high-power GaAs:Si near-infrared emitters, the sensitivity is 10 percent of the peak value.

Spectral bandwidth of CdSe photoresistors is wider than that of most CdS devices. For example, the spectral bandwidth of Type 3 CdSe at the −3-dB points is about 95 nm. The spectral bandwidth of Type 4 CdSe at the −3-dB points is about 140 nm.

Though they will not be described here because they aren't designed to detect visible light, it's important to note that lead-sulfide (PbS) and lead-selenide (PbSe) are also used to make photoresistors. These materials provide infrared sensors that have peak spectral responses of a few micrometers.

Figure 2(A) graphically compares the spectral sensitivities of Type 5H CdS and Type 3 CdSe. The most striking aspect of this graphic representation is the substantial spacing between the peaks of the two response curves. This makes possible some interesting applications, some of which will be discussed later.

Figure 2(B) compares the resistances of several common photoresistive materials as a function of illumination. Types 5H and 7 are CdS and Types 3 and 4 are CdSe. The scales of both axes in Fig. 2(B) are logarithmic due to the exceptionally broad dynamic ranges and vast differences in sensitivity of both these photoresistive materials.

As noted above, the various formulations of both CdS and CdSe have different peak spectral responses and other characteristics. Clairex Electronics (560 S. Third Ave., Mt. Vernon, NY 10550), a major manufacturer of photoresistors, has published specifications and data about the most common formulations. The following information is extracted from Clairex's publications:

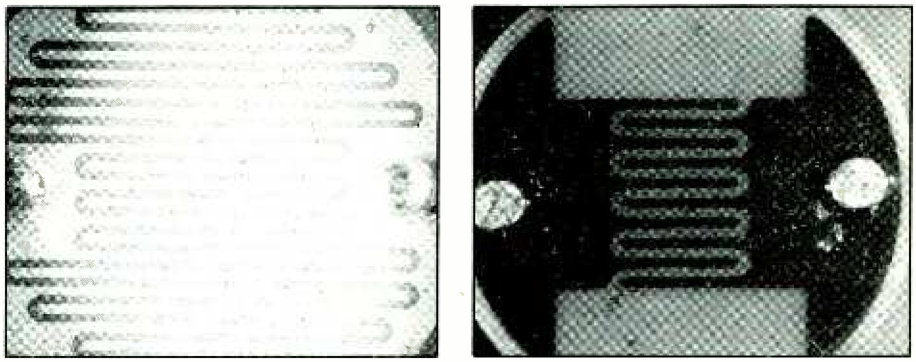


Fig. 4. Light-sensitive regions of CdSe (A) and CdS (B) photoresistors.

Cadmium-Sulfide Photoresistors

- *Type 5*—Peak spectral response of 550 nm closely matches that of the human eye. Minimum resistance ratio of 1:1,000. Very stable with less light-history effect than other formulations.
- *Type 5H*—Like Type 5, peak spectral response is 555 nm. Minimum resistance ratio of 1:1,000. Considerably faster rise time than most other materials, including Type 5.
- *Type 7*—Peak spectral response of 615 nm. Minimum resistance ratio of 1:300. Moderate rise time.
- *Type 7H*—Peak spectral response of 620 nm. Minimum resistance ratio of 1:1,000. Fast decay time.
- *Type 9*—Peak spectral response of 550 nm. Minimum resistance ratio of 1:1,000. According to Clairex, this is the most stable of photoresistive materials. It also has the lowest light-history effect.

Cadmium-Selenide Photoresistors

- *Type 3*—Peak spectral response of 735 nm. Minimum resistance ratio of 1:10,000 is much higher than that of any CdS material. Faster response time than most materials.
- *Type 4*—Peak spectral response of 690 nm. Minimum resistance ratio of 1:400. Lowest resistance of any photoresistor.

Photoresistor Fabrication

Photoresistors are much easier to make than junction photodiodes. Typically, a layer of CdS or CdSe is deposited on a ceramic substrate. A metal electrode pattern is then evaporated onto the light-sensitive region. Several different patterns are used, including simple bars and

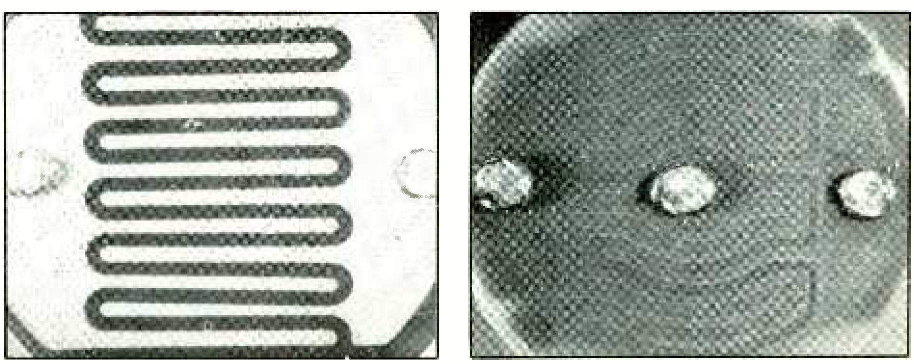


Fig. 5. Light-sensitive regions of a miniature CdS photocell (A) and miniature dual CdS photoresistor (B).

interleaved combs and spirals.

In some applications, the electrode pattern can be important. For example, a system in which a distant light source is imaged onto the light-sensitive surface by means of a lens might work best with a photoresistor that has a simple bar-shaped active region. On the other hand, non-critical applications that require maximum sensitivity without use of a lens work best with zig-zag or spiral electrodes that expose much more light-sensitive material than does a simple bar.

Maximum voltage rating of a photoresistor is in part determined by the spacing of its electrodes. The maximum voltage rating is specified when the photoresistor is dark because this is when the maximum voltage ordinarily appears across the device.

Figure 5 is a macrophotograph of the light-sensitive region of a photoresistor installed in a TO-18 transistor header. The light-sensitive region is the dark bar in the center of the header. The electrodes are the two semicircular shapes on either side of the bar. The two amorphous shapes on either electrode are conductive ink used to make electrical contact to the device's external wire terminals.

Shown in Fig. 4 are the active regions of two photoresistors with interleaved electrodes. In both cases, the light-sensitive material is the dark zig-zag pattern. The device shown in (A) is interesting because it makes maximum use of available space to expose more of the light-sensitive material. Less of the light-sensitive material in (B) is exposed because the spacing between the electrodes is slightly wider. This often indicates a higher maximum operating voltage for the particular device.

Figure 5 shows the light-sensitive regions of two miniature photoresistors. Note that the electrodes of the device shown in (A) are darker than the light-sensitive material.

The device shown in Fig. 5(B) is a dual photoresistor. The center terminal is connected to an electrode that snakes its way between the interleaved electrodes connected to the two outer terminals. Dual photoresistors have several specialized applications, including detection of motion.

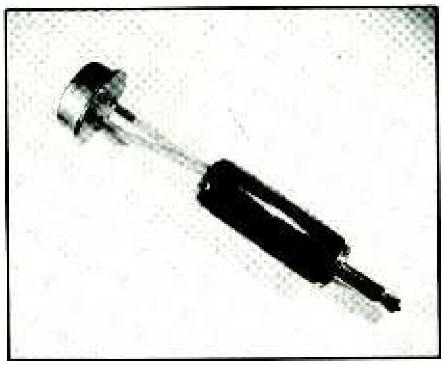


Fig. 6. Photoresistor soldered to miniature phone plug eases connections during experimenting.

Applications

Photoresistors have dozens of practical applications. Unlike photodiodes, they are not polarity-sensitive, so they can be powered by either ac or dc sources and their leads can be connected in either direction. Furthermore, many photoresistors can be operated at much higher voltages than most photodiodes and phototransistors.

For many years, photoresistors have been used in various kinds of light meters. While they have exceptional sensitivity and dynamic range, their lack of linearity over the entire range of their response is a major drawback.

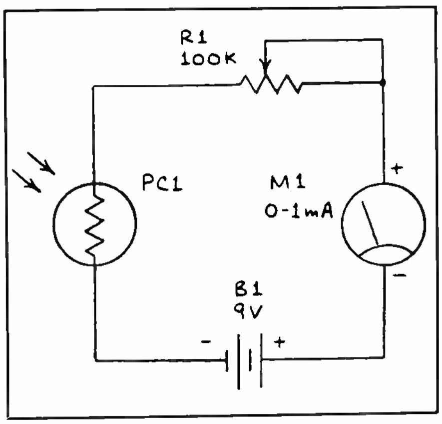


Fig. 7. A simple photoresistor light meter.

Many households are equipped with light-sensitive night lights that are controlled by photoresistors. Street lights and other kinds of indoor lighting are also switched on and off by simple photoresistor circuits.

Photoresistors can be used to make simple break-beam detection systems. Such systems are used to detect objects on a production line and to detect a person entering a store or approaching an electrically-activated door.

Various kinds of light and dark warning systems can be designed around photoresistors. A refrigerator door-open alarm, for instance, can be designed to sound a warning tone a predetermined time after the door has been opened.

Dual-element photoresistors can be used to make motion detectors. In a typical application, a single lens images a distant scene onto both halves of a dual-element photoresistor. The two halves of the photoresistor are connected to a differential circuit that ignores variations in the ambient light as long as the light level in each half of the photoresistor is equal. Should an object in the field of view of one photoresistor move or a new object enter the field of view of one half of the photoresistor, the resistance of that half will change. When this occurs, the circuit outputs a signal that ultimately causes an audible or/and visible alarm to actuate.

Photoresistors were once commonly used for electronic exposure control of cameras. The light-history effect, however, makes photoresistors much less satisfactory than photodiodes for this application. Therefore, most modern cameras use photodiodes for exposure control.

Many kinds of optical isolators (so-called "optoisolators") can be produced by pairing a photoresistor with a light source. Various kinds of light sources can be used, including LEDs and both tungsten and neon lamps. In a typical application, a very small current applied to a LED can produce sufficient light energy to lower the resistance of a photoresistor to the point where it can directly actuate a heavy-duty relay. This application

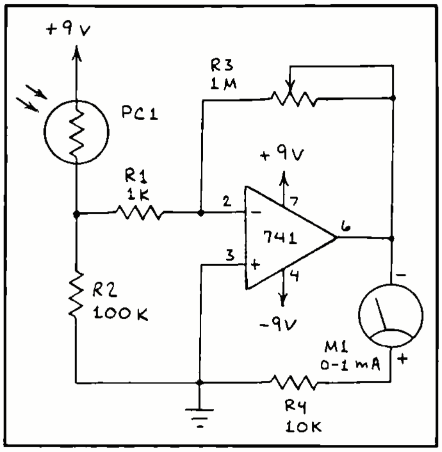


Fig. 8. A photoresistor light meter with a gain stage.

permits a tiny control current to switch a much larger current.

It's important to keep in mind that photoresistors can be exchanged for both fixed resistors and potentiometers to give light sensitivity to many kinds of circuits. For example, a photoresistor can be directly substituted for the frequency control potentiometer in a tone generator to form a light-sensitive generator. Similarly, a photoresistor can be substituted for the potentiometer that controls the gain of an amplifier to provide a light-sensitive volume control.

Some Circuits

In this section, we'll discuss several simple photoresistor circuits. In each of these circuits, the photoresistor is designated *PC1*, which identifies it as photocell 1. Many different CdS and CdSe photoresistors can be used in the circuits, some of which will function best with photoresistors selected for a particular resistance range or high light-to-dark resistance ratio.

If you plan to experiment with various kinds of photoresistors, you might want to solder several different devices to miniature phone plugs, as shown in Fig. 6. This will allow you to use a single photoresistor in different circuits. It will also permit you to use different kinds of photoresistors in the same circuit.

You can enhance operation of the circuits by installing the photoresistor in one end of a hollow tube that will then function as a collimator that gives the photoresistor a highly directional feature. You can also place various filters and apertures in front of the photoresistor or the tube in which it is installed. Finally, you can attach an optical fiber to a photoresistor to provide a remote-detection capability. The end of the fiber can be cemented directly to the photoresistor or be attached temporarily with clay, wax or any of the various compounds designed to hold pictures to walls.

• *Simple Light Meter.* Shown in Fig. 7 is the schematic diagram of an ultra-simple but surprisingly sensitive photoresistor light meter. Potentiometer *R1* controls the meter's sensitivity. If you wish greater sensitivity from this circuit, you can use a 0-to-50-microampere meter movement for *M1*.

Photoresistor *PC1* can be any CdS or CdSe device. For greatest sensitivity, select a device that has a high light-to-dark resistance ratio.

Since this circuit is very sensitive, you must use care to avoid forcefully "peg-

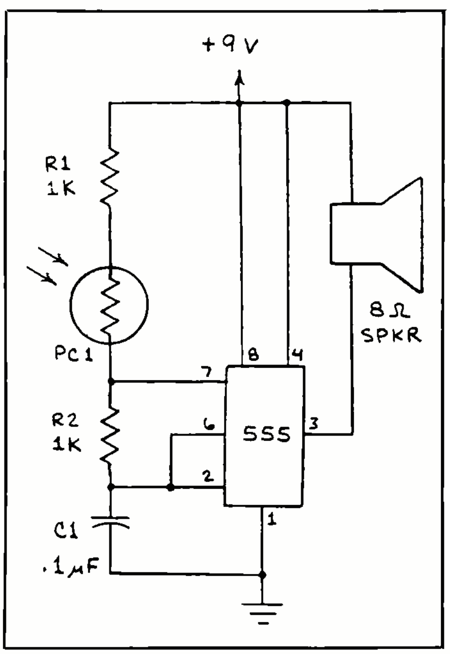


Fig. 9. A light-dependent oscillator built around a 555 timer IC.

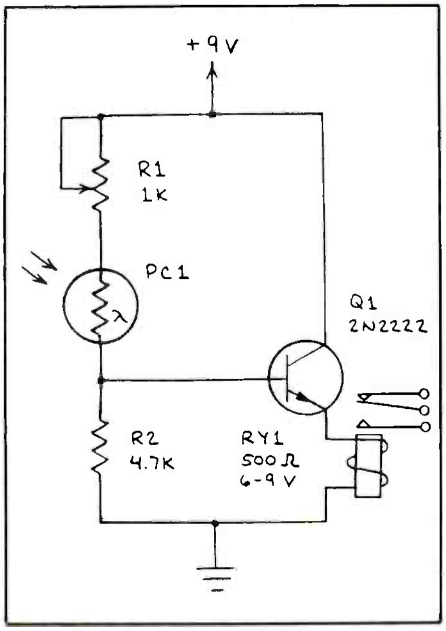


Fig. 10. A light-activated relay.

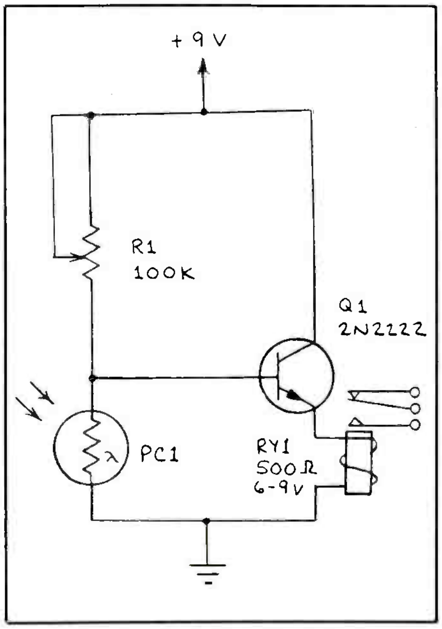


Fig. 11. A dark-activated relay.

ging" the meter's pointer. Therefore, always make certain that *R1* is set for minimum sensitivity (maximum resistance) before applying power to the circuit.

• *Advanced Light Meter.* Considerably more sensitivity to light can be obtained with the circuit shown in Fig. 8. Indeed, at its most-sensitive setting, the circuit is difficult to use because the light level required to read the meter may itself be bright enough to forcefully peg the meter's pointer!

As with the Fig. 7 circuit, many different photoresistors can be used in the Fig. 8 circuit. A high light-to-dark resistance ratio will provide best results.

Since this circuit is so sensitive, always make sure the *R3* is set to its lowest value before applying power. Also, always increase *R3*'s resistance gradually to avoid pegging the meter's pointer.

• *Light-Dependent Oscillator.* The frequency of virtually any oscillator can be changed in response to light by including a photoresistor in the RC portion of the circuit. How this can be accomplished with a simple audio-frequency oscillator made from a 555 timer chip is illustrated in Fig. 9. Many different photoresistors can be used for *PC1*. Increase the capacitance of *C1* to reduce the tone frequency, or decrease the capacitor's value to increase the frequency.

If the sound from the speaker is too loud, insert a resistor between the speaker and pin 3 of the 555 timer. Try a few hundred ohms, or use a 1,000-ohm potentiometer that can be adjusted to give a comfortable sound level.

• *Light-Activated Relay.* Many kinds of light-activated relays can be made using photoresistors. Some relays can be driven by nothing more than a photoresistor and a power supply. However, a gain stage provides greater sensitivity. For example, Fig. 10 shows a straightforward light-activated relay that uses a single transistor to increase sensitivity. Relay *RY1* is a Radio Shack Cat. No. 275-004 device. Potentiometer *R1* controls sensitivity.

• Light-activated relays are used to sound a warning when a door has been left ajar and to detect objects and people passing by.

• *Dark-Activated Relay.* The Fig. 11 circuit is the opposite of the previous circuit. When *PC1* is illuminated in this circuit, the relay is *not* actuated. Only when the light level on *PC1* falls below a certain point, determined by the setting of *R1*, does the relay energize. This circuit can be used to activate a light at dusk and to switch it off at dawn.

• *Light/Dark-Activated Buzzer.* The circuit shown in Fig. 12 controls a piezoelectric buzzer. A dpdt switch is used for *S1*. When *S1* is in position "L" (light), the buzzer sounds when *PC1* is exposed to light. Setting *S1* to "D" (dark) causes the buzzer to sound in darkness.

This circuit has many of the same applications as the previous two circuits. Its advantage is that it is self-contained and requires no external warning device. It can also be used to control a relay.

• *Dark-Activated LED Flasher.* A simple way to actuate a flasher LED with a photoresistor is shown in Fig. 13. This simple circuit makes a handy warning light for a darkroom. The flasher LED installs near the outside of the darkroom's door. The remainder of the circuit installs anywhere else inside the darkroom. With this setup, the flashing LED warns outsiders that the lights in the darkroom have been extinguished. For this application to be practical, it is necessary to install an on/off switch inside

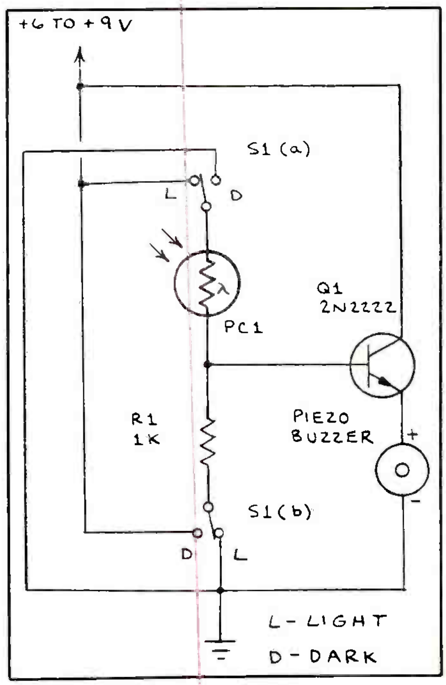


Fig. 12. A light/dark-activated relay.

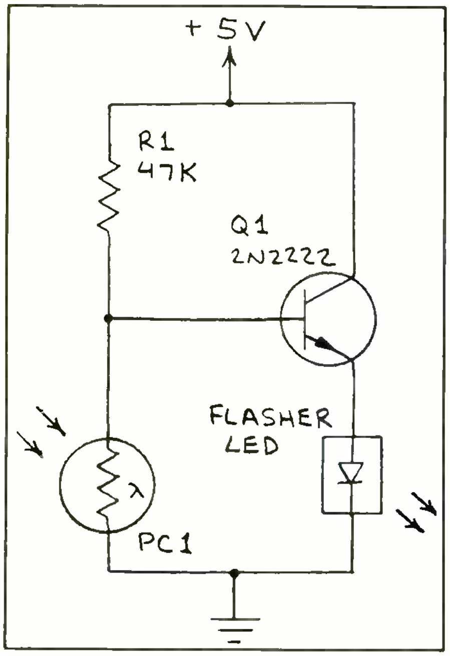


Fig. 13. A dark-activated LED flasher for darkroom warning use.

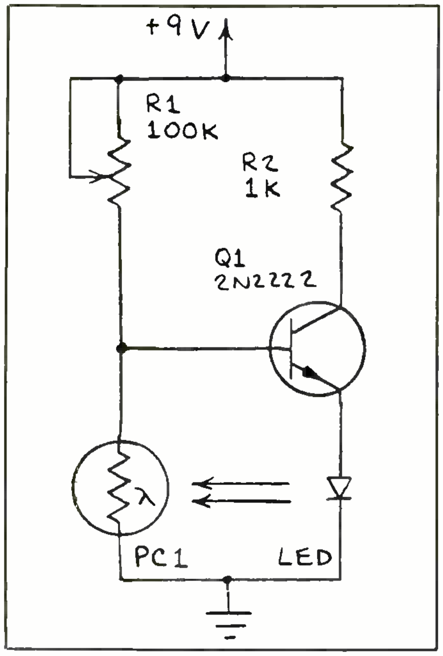


Fig. 14. A photoresistor optical feedback circuit.

the darkroom to disable the circuit when the darkroom is not in use.

• *Photoresistor Optical Feedback.* If your home is equipped with a photoresistor-controlled night light, you have probably noticed that the light will flicker when an object is placed near it at night. This occurs when some of the unit's light is reflected back to the photoresistor, thereby switching the device off. When the light switches off, the resistance of the photoresistor increases and causes the light to switch on again, and the cycle repeats.

This phenomenon, which is a form of optical feedback, can be used to regulate the brightness of a light source, such as a LED or miniature incandescent light. Shown in Fig. 14 is a simple circuit that does just this.

Assume the circuit is in darkness. The resistance of *PC1* will be high and *Q1* will be conducting. This allows current to flow through the LED. If the LED is positioned so that some of its light strikes *PC1*, the photoresistor's resistance will be lowered. In turn, this reduces the current flowing through *Q1*, thereby reducing the brightness of the LED. Therefore, the circuit functions as a current regulator.

Potentiometer *R1* is adjusted for optimum circuit operation. The LED's brightness is determined by the placement of the LED relative to the sensitive surface of *PC1*. When the two are closely spaced, the LED will be dim; when father apart, the LED will be brighter. Reflective objects placed near the LED will increase the light falling on *PC1*, thus reducing the light from the LED.

Since the light from the LED responds almost instantaneously to changes in the LED's forward current, the LED does not flicker. Instead, its brightness changes just as if it were connected to a potentiometer that controlled its forward current.

Going Further

The circuits described here are merely representative of what can be accomplished with the help of a common photoresistor. For additional ideas, see my *Engineer's Mini-Notebook: Optoelectronics Circuits* (Siliconcepts, 1986), a Radio Shack book. I have also included a number of photoresistor circuits or circuits suitable for use with photoresistors in *The Forrest Mims Circuit Scrapbook* (McGraw-Hill, 1983) and *Forrest Mims' Circuit Scrapbook II* (Howard W. Sams, 1987).

Many other possibilities exist. For example, you might wish to design a circuit that uses photoresistors that have different spectral responses to detect objects that have different coloring.

In any event, be sure to experiment with all kinds of photoresistors. Most published circuits specify CdS photoresistors that have high light-to-dark resistance ratios. You may discover that other kinds of photoresistors will function as well or better in a particular circuit you have in mind. **ME**

New Developments in Op Amps and New Offerings from GE/RCA

By Harry L. Helms

Operational-amplifier devices have been around for so long that it's easy to take them for granted. Indeed, some op amps, such as the 741 and 1458 devices, have become *de facto* standards and familiar to generations of people. Although specialized op amps have been created for certain purposes, one might easily assume that general-purpose op amps reached their highest level of development several years ago and haven't improved since. But op amps have been subjected to steady and continuous improvement.

Two prime examples of improved op amps are the *LT1013 dual precision op amp* and the *LT1014 quad precision op amp*, both from Linear Technology. The LT1013 is a pin-for-pin equivalent of popular dual op amps such as the 1458, LM158 and OP-221, while the LT1014 is a pin-for-pin equivalent of the 4156, LM324, LM328 and OP-11 op-amp ICs. While the pins and functions of the LT1013 and LT1014 are the same as other widely-used op amps, their performance is not; both offer substantially better performance than the other devices.

The LT1013 and LT1014 are known as "precision" op amps because they meet certain critical specifications better than conventional devices. For example, their drift is less than 2 microvolts per degree centigrade and the offset voltage is less than 150 microvolts. Common-mode rejection is 117 dB and gain is in excess of 8 *million*!. Supply current is only 350 microamperes per amplifier section, and the output stage of each section can source and sink in excess of 20 milliamperes of load current. These characteristics make the LT1013 and LT1014 especially useful in such applications as instrumentation amplifiers, multiple-limit threshold detection, multiple-gain blocks, and other situations where op amps must closely adhere to crucial performance targets.

Both the LT1013 and LT1014 can be operated from a single 5-volt dc power supply or a dual-polarity supply of up to

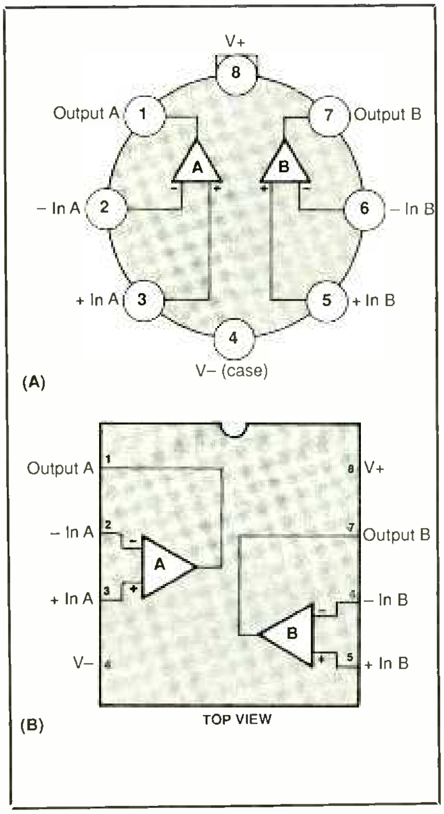


Fig. 1. Pinouts for LT1013 op amp in metal "can" (upper) and more familiar DIP package (lower).

±22 volts. In the "single-supply" mode, input voltage range extends to ground and the output swings to ground while sinking current. Both devices can operate with a supply potential down to 3.4 volts.

Figure 1 shows pin connections for the LT1013 in both the "metal-can" (H) package and the familiar dual-inline (DIP) package. Figure 2 shows the pin connections for the LT1014. The accompanying table gives specifications for both devices measured at dual polarities (±15 volts).

The theory and applications of the LT1013 and LT1014 are essentially the same as those of the devices they are functionally equivalent to. They can be used in any circuit where their functional equivalents can be used. However, the

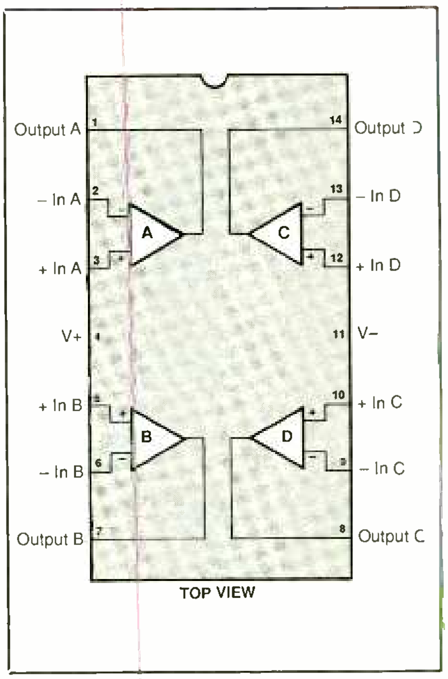


Fig. 2. Pinouts for LT1014 op amp in standard 14-pin DIP package.

LT1013 and LT1014 really shine in circuits where their precision characteristics are required. One example is shown in Fig. 3, which uses an LT1014 in a *single-supply precision instrumentation amplifier*. The resistors marked with an asterisk must be 1-percent film types, while the diodes marked with a dagger indicate 2N2222 transistors used as diodes. The gain of this particular circuit is found by the formula:

$$\text{Gain} = (400{,}000/RG) + 1$$

in which resistor *RG* typically has a value of 2K ohms. The values of the 10K-ohm 1-percent film resistors should be matched within 0.05 percent for highest precision operation. (This illustrates an important point regarding precision devices such as the LT1013 and LT1014—"precision" operation of the circuits using them requires that other component tolerances must be higher as well.) Note that pin 8 of the LT1014 (an output of one of the amplifier sections) goes to

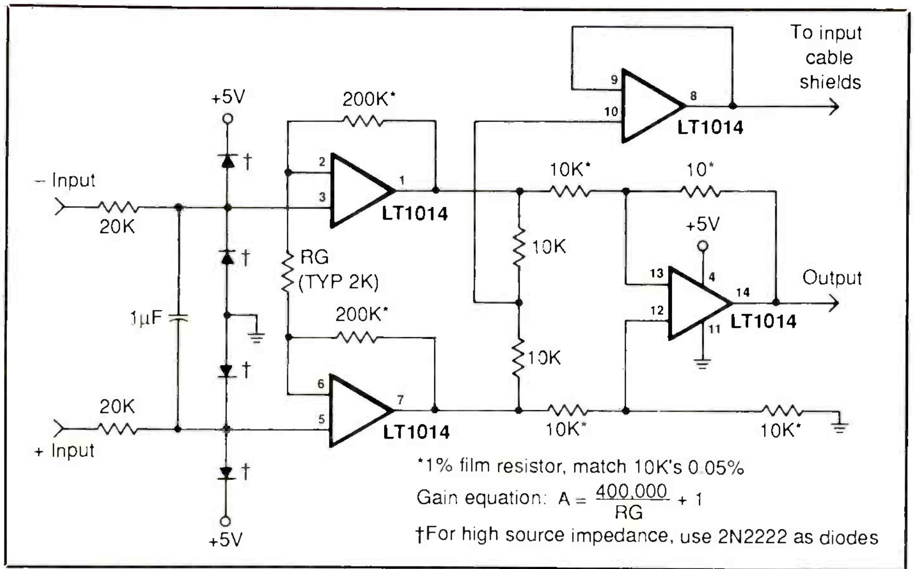


Fig. 3. Single-supply precision instrumentation amplifier built around single LT1014.

shielding braid of the input cables for the amplifier.

Figure 4 shows how the LT1014 can be used in a *thermocouple thermometer* application. The thermocouple is a YSI44007, a K type whose resistance is 5K ohms at 25 degrees centigrade. Outputs at pins 1 and 7 will show a change of 10 millivolts for every degree centigrade change detected by the thermocouple. For greatest accuracy, all resistors used in this circuit should be 1-percent tolerance film types.

Precision characteristics of the

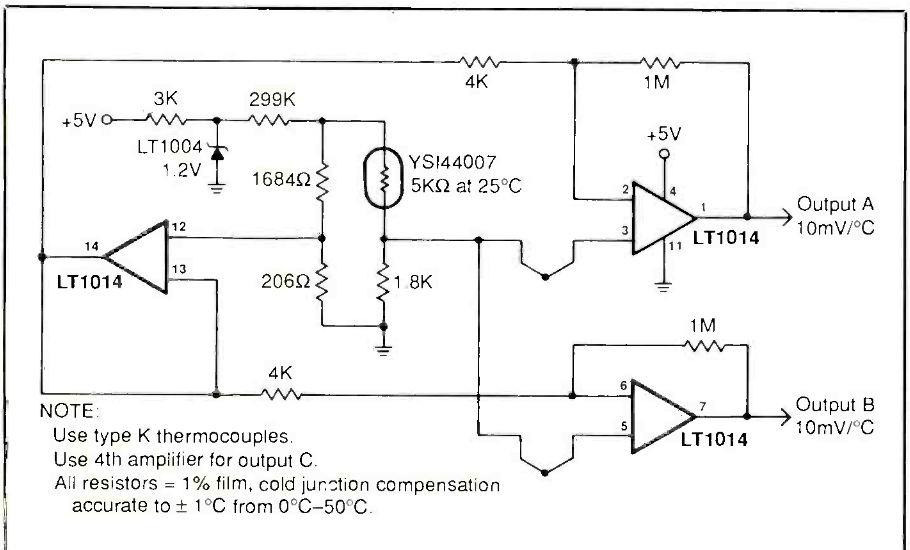


Fig. 4. A thermocouple thermometer application for the LT1014.

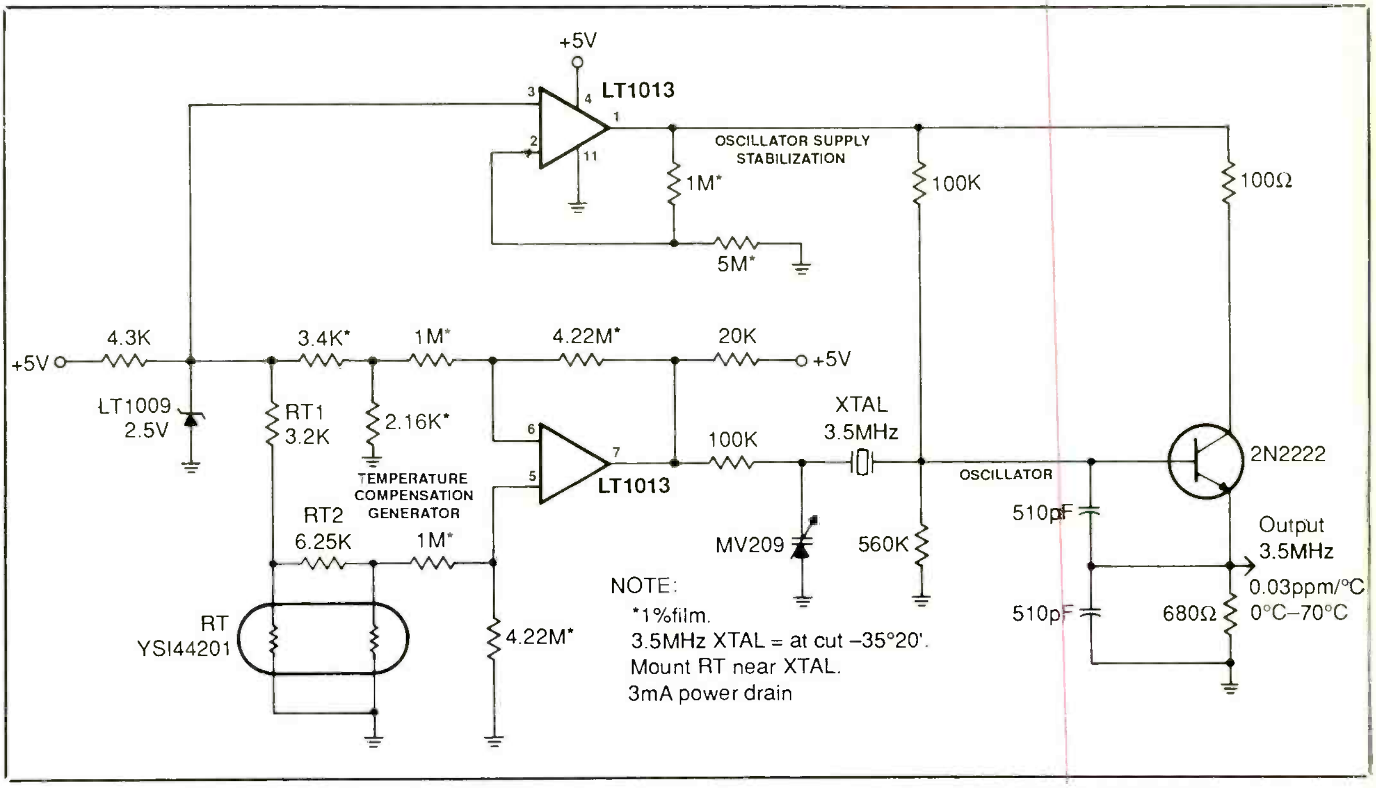


Fig. 5. Both halves of an LT1013 used in a temperature-compensated crystal-oscillator application.

LT1013 and LT1014 make these op amps useful in other circuits where you want output or performance restricted to a narrowly-specified range. Figure 5 shows both halves of an LT1013 used in a *temperature-compensated crystal oscillator (TXCO)*. The YSI44201 thermistor is used in an amplifier/varactor network to produce a compensating voltage to correct any drift in the oscillator's frequency caused by the temperature coefficient of the 3.5-MHz crystal. All asterisked resistors should be 1-percent film types. The resulting output of the circuit holds at 3.5 MHz within 0.03 parts per million (ppm) over the range of 0 to 70 degrees centigrade, making it ideal as a precision frequency reference for digital counters and similar circuits.

Not every application of the LT1013 and LT1014 is quite as complex as the ones we've discussed so far. One example is shown in Fig. 6, which is a 9-volt-to-5-volt *converter* that uses both halves of an LT1013 for an efficiency of 75 percent. Inductor *L* is a Dale No TE-3/Q3/TA used in a switching "preregulator" to control the voltage drop across the 2N5434 FET to 200 millivolts. The output from this circuit is a well-regulated 5 volts at 20 milliamperes.

More information on the LT1013 and LT1014 and applications for them can be found in the "LT1013/LT1014 Quad Precision Op Amp (LT1014) Dual Precision Op Amp (LT1013)" data sheet available from Linear Technology. A design for a 1-Hz to 100-MHz voltage-to-frequency converter using the LT1013

LT1013/LT1014 Specifications

Offset voltage (max.)	150 μV
Drift (max.)	2 μV/°C
Offset current (max.)	0.8 nA
Minimum gain (5 mA load current)	1,500,000
Slew rate	0.4 μs
Input voltage	Equal to positive supply voltage or 5 V below negative supply voltage
Supply current	500 μA
Supply voltage	±22 V or +5V (single supply)

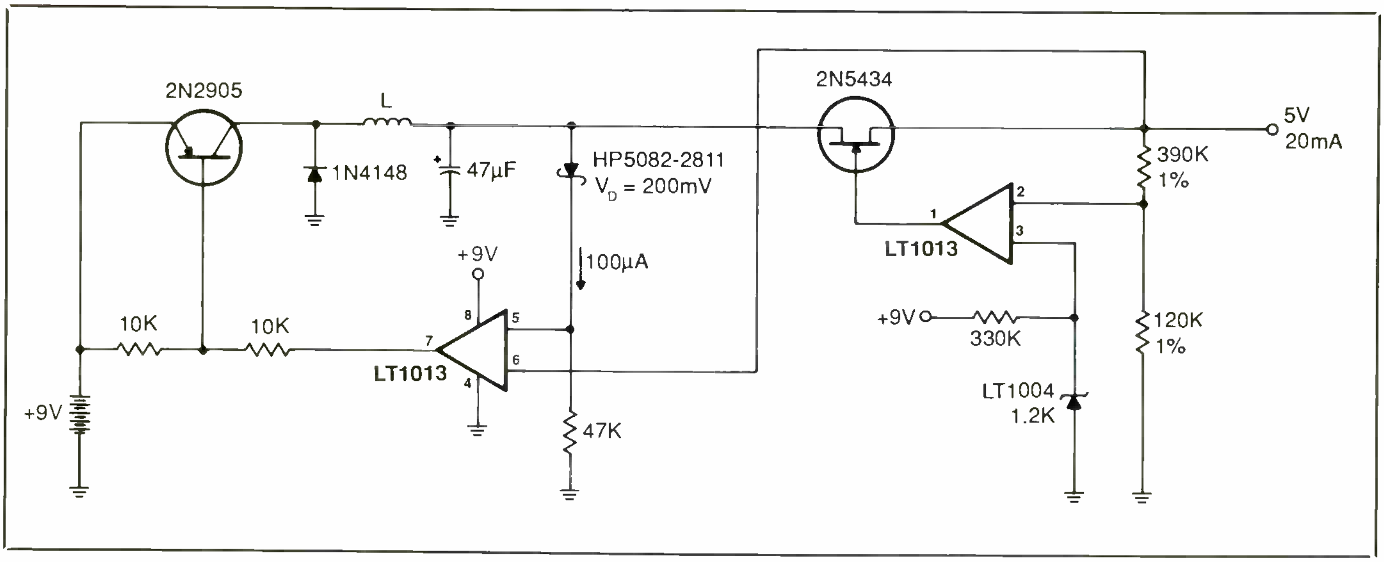


Fig. 6. A 9-volt to 5-volt converter using both halves of an LT1013.

can be found in Linear Technology's Application Note No. 14, "Design for High Performance Voltage to Frequency Converters." Both are available from your nearest Linear Technology sales representative or from Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7487. Your requests should be made on your business or professional letterhead.

New from GE/RCA

The former GE/RCA Solid State is now known strictly as GE Solid State, but new products identified by the "RCA" logo continue to be introduced by them. Two are the LM1822 and LM1823 video i-f signal-processing devices. Both devices contain PLL detector and i-f amplifier stages and can operate at frequencies up to 70 MHz. They are identical except that the LM1822 has a "white spot" noise inverter for luma amplifiers. The chips are suitable for use in television receivers and cable converter applications.

More information on the LM1822 and LM1823, along with applications circuits, can be found in the data sheets for both available from GE Solid State, Box 3200, Somerville, NJ 08876 . . . Hints on using the GE Solid State CDP68HC05C4 microcontroller data-acquisition sampling system device can be found in "Low-Cost Data-Acquisition System Features SPI A/D Converter," an applications note available from GE Solid State. This note describes a system for monitoring analog parameters (humidity, rate of flow, etc.) using a system that has a serial peripheral interface (SPI) for use with personal computers. It's available from the address given above. ME

Free Product Information

Readers can obtain free information on products advertised by certain companies, as well as for some editorially mentioned products. Simply circle the appropriate number printed below an advertisement onto the Modern Electronics "Free Information Service" card bound into this issue. After filling in your name and address, just mail the postpaid card. Your request will be forwarded directly to the advertiser with a mailing label prepared by our reader-service department to ensure speedy response.

Packet Radio

By Curt Phillips

In the July column, I discussed "Computer Communications," using modems and your telephone to connect your computer to the world. Well, as any ham-radio operator knows, what telephones can do well, radios can do better—which leads us to the latest rage in computer-radio communication: packet radio.

Microcomputers + Ham Radio = Packet

Actually, the equation isn't quite that simple, but the advent of amateur packet radio did come hot on the heels of the microcomputer revolution. In 1978, the Canadian Department of Communication authorized packet transmission on the amateur radio bands. The idea of a switched packet data network dates back to a RAND study in 1964, and the name came from D.W. Davies of the British National Physical Laboratory in 1965. However, it took the widespread availability of moderate-cost computing power to bring it to ham radio.

The encouragement of the DOC caused a group of Montreal-area hams to organize the Montreal Packet Network (MP-NET), which was the world's first amateur packet radio system. Soon thereafter, in early 1979, the Vancouver Amateur Digital Communication Group (VADCG) was formed. The VADCG did pioneering work in amateur packet protocols and hardware development.

About 18 months (March 1980) after Canadian amateur packet radio was permitted, the FCC allowed U.S. hams to transmit in ASCII and operate radio packet switched networks. In late 1981, the Tucson (Arizona) Amateur Packet Radio Corporation (TAPR) was formed with the goal of lowering the cost of packet radio hardware. By the end of 1982, TAPR (pronounced "taper") was testing a second-generation hardware design using the newly created AX.25 standard.

November 1983 saw the first shipment of TAPR packet hardware kits. The years since then have seen the introduction of packet hardware by numerous electronics manufacturers, many of them licensing the TAPR designs. Finding packet hardware now is easy, and the prices for it are similar to other hobby radio equipment ($200 to $300).

How It's Done

Although packet radio has some aspects in common with telephone modem communications, there are significant differences. With a telephone modem, as shown in Fig. 1(A), you have a line of communications all to itself. If there is any time-sharing (and there usually is when you call the commercial services), all the equipment needed to accomplish this is owned and maintained by the service companies. You don't need to know anything about it to use it.

With amateur radio, you can't be sure of having a frequency all to yourself. Besides, to better make use of the limited number of frequencies available to hams, promoting simultaneous use of frequencies is a worthy goal. Computerized data transmission is fast enough, however, that most of the time the frequency or line is not being used. By enabling other stations to communicate during these pauses, the frequencies are more fully utilized. This is precisely what packet radio does; it assembles a "bundle" or packet of outgoing information, sends it quickly, then waits for the next packet to be assembled.

The procedures needed to make all this work are more complicated than connecting a computer and modem to a phone line. Using a telephone connection, most of the data is exchanged "blind"; that is, the sending computer has no idea whether the receiving computer accurately reproduced the data or not. Since the telephone line is usually not shared and is relatively quiet, most of the data is transferred correctly. For the most important data transfers, an error-checking protocol like XMODEM is used.

On a radio frequency with multiple users, error checking is needed for *all* the data transmitted. On multiplexed frequencies, a means of reducing signal collisions (simultaneous transmissions) is also required. Finally, each packet of data needs to be addressed, so that if station "A" is communicating with station "B" on a given frequency, stations "C" and "D" also using that frequency will ignore the transmissions of stations "A" and "B."

Many of these problems have been dealt with in creating the public telephone-based packet-switching networks, so after some experimentation, the CCITT (the International Telegraph and Telephone Consultative Committee) Recommendation X.25 protocol was modified for amateur radio use and named AX.25. Presently in its second revision, the AX.25 protocol allows for the unique aspects of ham radio, such as using callsigns in the packet address, allow-

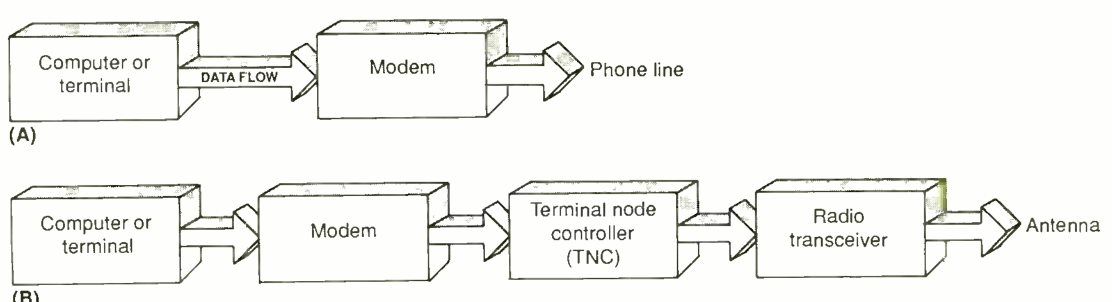


Fig. 1. Equipment used for computer-telephone communication (A) and computer-packet radio communication (B).

Field name	Flag	Address	Control	PID	Information	FCS	Flag
Length (in bits)	8	112–560	8	8	≤2048	16	8

(A)

Field name	Flag	Address	Control	FCS	Flag
Length (in bits)	8	112–560	8	16	8

(B)

Fig. 2. The Information frame (A) and Unnumbered and Supervisory frames (B).

ing for unacknowledged packet transmission for beacons, calling CQ, and the ability to re-transmit packets through several other stations (repeaters).

Telephone modem communications are *asynchronous*, which means that data must be sent in groups of a specified length with start and stop bits defining each character. Packet radio's AX.25 High-level Data Link Control (HDLC) provides for *synchronous* signals that use a flag field, as in Fig. 2(A), of eight bits (called not a byte, but an octet!) to "synchronize" the sending and receiving stations' clocks. This permits a long packet or "frame" of data to be transferred without the overhead of start and stop bits for each character and allows for fields of varying lengths.

The flag field is 01111110 (7E hex). In order to prevent any other octet in the frame from having this unique combination, the originating station inserts a zero bit after any group of five consecutive one bits; this is called *bit stuffing* or, perhaps more accurately, *zero bit insertion*.

The receiving station compensates for bit stuffing by discarding any zero bit after a sequence of five one bits. If it sees a one bit after a sequence of five one bits, it recognizes that as the flag field.

Next is the address field, which contains call letters of the originating station, the destination station and up to eight stations through which the packet is to be repeated (re-transmitted). After the address field is the control field, an octet that defines the HDLC frame as either Information, Supervisory or Unnumbered. The field that follows the control field is the PID (Protocol IDentifier) field, which indicates the type of network layer protocol (if any) is being used.

Now the data to be transmitted is inserted in the information field. Up to 256 octets (before bit stuffing) are allowed in the information field. The Frame Check Sequence (FCS) field is where the error checking is accomplished. The originating station calculates a 16-bit number using the frame data and the procedures detailed in ISO standard 3309 (a "corollary" of X.25). The destination station performs the same calculation on the frame field data and, if its answer is equal to the number in the FCS field, the frame is considered to be errorless.

The foregoing is an Information frame. The Unnumbered and Supervisory frames, as shown in Fig. 2(B), control the link and data flow, and don't carry informational data. For instance, Supervisory frames are used by the destination station to signal that the data was received OK (ACKnowledge) or to request re-transmission.

Dodge Ball

So far, the protocol for error checking and addressing has been described, but what about collision avoidance? This is controlled by Carrier-Sense Multiple Access with Collision Detection (CSMA/CD) circuitry.

First, the packet station waits until the frequency is clear to transmit. If its transmission collides with another, perhaps due to two stations simultaneously determining that the frequency was clear, it waits a random interval of time and re-transmits (after again checking to see if the frequency is clear). Usually this and the high speed of transmission allows several stations to coexist on each frequency. However, many stations on a given frequency will increase the incidence of collisions and the resulting delayed re-transmission, as well as increase the number of errors and resulting requests for repeats. Thus, the information throughput on a crowded frequency can suffer, though communication remains intact.

Packet Hardware

All the aforementioned manipulation and packetizing of data is performed by the Terminal Node Controller (TNC), a name coined by Doug Lockhart VE7APU of VADCG. The TNC is a computer in itself, most often using Z80 or 6809 CPUs. Internal RAM is used to buffer the incoming data, ROM holds the programming and, usually, a dedicated chip (like the Zilog 8530) handles HDLC.

Although the modem is technically a separate piece of equipment, as in Fig. 1(B), most recent TNCs have a modem built-in and included in their cost. Since the TNC is a computer itself, and the computer is usually configured as a dumb terminal, why not use the computer's power as a TNC?

Software-based TNCs do exist, but they have been hampered by several drawbacks. Different programs must be written for each type of computer. Because of the precise and fast timing required, the programs must usually be written in non-portable assembly language that requires significant development time. Also, with a software TNC, the user is stuck with the provided terminal interface, whereas with a hardware TNC, there are many choices of terminal interface software.

Software-based TNCs have not become very popular, but if you can find one for your type of computer, they can provide an inexpensive way of getting started in packet communication.

In coming months, I'll discuss specific types of packet hardware and communication procedures. ME

Your comments and suggestions are welcome. You can contact me at P.O. Box 678, Garner, NC 27529 or by computer on Delphi (CURTPHIL), Compuserve (733167,2050) or The Source (BDK887).

BOCA Research's "TophAT II" Memory Board and a Different Kind of Printer Switch

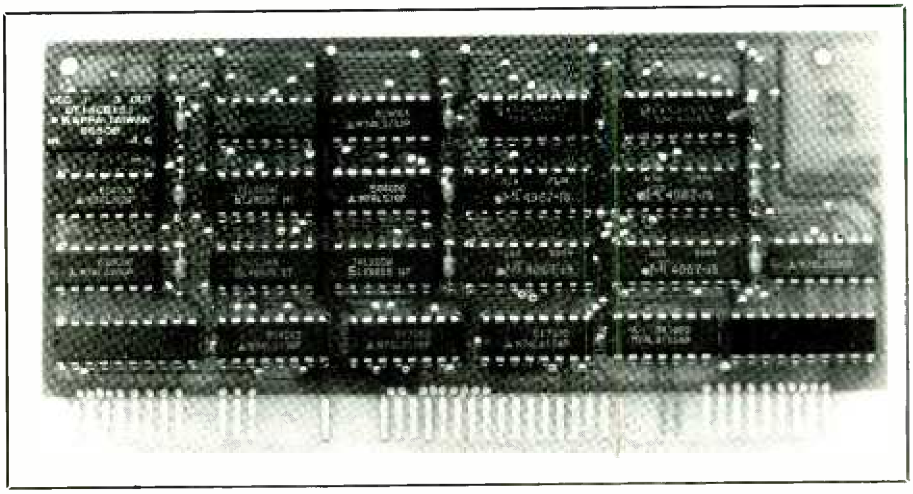
By Ted Needleman

This month, I'd like to play "catch-up" and expand upon several subjects touched on in past columns. Several months ago, I discussed some advantages and disadvantages of buying a clone. One very definite advantage of a clone, which I didn't mention, was that almost every AT compatible has the capability of handling *at least* 640K of RAM memory on the motherboard.

Genuine "Big Blue"-brand ATs come equipped with 512K, and while you can add memory above this, you can't do it on the motherboard. Why IBM did things this way is beyond me. Perhaps at the time the AT was designed, "Big Blue's" engineers figured that 512K was more than enough memory. After all, the original PC (5150) came with only 16K on board. But MS-DOS has always had the ability to directly address 640K (called conventional memory), and with all the TSR (Terminate and Stay Resident) utilities, such as SideKick, which have proliferated in the past few years, the additional 128K RAM to bring an AT up to 640K not only makes sense, but its absence is often annoyingly felt.

There are several ways around this problem. One way is to add a large-capacity memory card. These use a variety of memory-addressing schemes to provide expanded and extended memory up to 4 or more megabytes. For programs that can take advantage of this extra memory, such as some spreadsheets, graphics packages, and scanner software, the extra memory makes sense. With a "true" AT, most of these cards allow you to use the first 128K to backfill the system's conventional memory, bringing it up to the 640K MS-DOS maximum.

If, on the other hand, your applications don't really need more than the 640K that most clones offer, using one of these boards in an AT is not only overkill, but expensive overkill at that. The bare boards run anywhere from $150 on up. And with 256K RAM chips now averaging about $14 each, bringing the bare board up to 256K adds an additional $126 to the tab. For a few dollars more than the cost of nine 256K chips, you can buy a TophAT II board from BOCA Research. This slightly less than half-size card comes populated with 128K of parity-checked RAM soldered onto the circuit board. The TophAT isn't meant to add additional memory to machines which already contain 640K of system RAM—only to bring an AT (or AT compatible) up to this amount of total memory. If you later add additional memory boards, the TophAT can remain in the computer, allowing all of the memory on expansion cards to be used as expanded/extended memory.



BOCA Research's "TophAT" II fills an AT or compatible computer's memory to 640K.

Installing the board is easy—it takes almost as long to write about as to do it. Pop the cover on your system, remove the cover plate from an unused expansion slot, and insert the board. It *must* go into a 16-bit expansion slot. Close up the cover and run the SETUP program included as part of the diagnostics disk. Change the memory setting from 512K to 640K, then follow the screen instructions to reset the computer. When you reboot the system, the power-on self-test should now indicate 640K. That's the whole deal. There are no switches to set, and outside of resetting your system to know that 640K is installed, no software to run.

This is the kind of product I like to review. It's easy to install, and does the job it's supposed to without any frustration. There's no flashing lights, and no DIP switches to set. Just plug it in and use it. The only possible problem might be with one of the original 6-MHz ATs that have been souped-up with a new crystal to 10-MHz. The 150-ns chips used in the TophAT will easily handle the standard 6- or 8-MHz clock speeds of an unaltered AT. The TophAT II costs only $145, and is covered by a two-year warranty. BOCA Research is well-known for its graphics boards, and they also have other memory products and I/O boards for IBM's new PS/2s.

A Different Kind of Printer Switch

Many of you will be familiar with the standard RS-232 serial printer switch. This device lets you plug two or more serial printers into the box, along with the serial I/O from a computer. Turning a knob determines which of the printers will receive the computer's output. This is a handy gadget to have if you have a low speed letter quality and high speed dot matrix printer that you use back and forth. Or, perhaps, you need to switch frequently from regular computer paper to labels or other special forms.

Unfortunately, at least for many potential users, the computer world has in the last few years wholehardedly embraced the parallel printer interface. Parallel switchboxes exist, but they tend to be fairly expensive devices. The major reason for this is that the serial printer interface usually uses only three or four conductors of a printer cable, whereas a parallel interface requires many more conductors to transfer information. With a switch box, this translates into the difference between switching four lines and twenty or so. Whether the switching is done mechanically (as many inexpensive units do) or electronically, more components, or more expensive components, translate into a more expensive product.

Recently, however, I received a SmartPrint from Dresselhaus Computer Products. Dresselhaus is the producer of an Epson printer upgrade called DotsPerfect, which provides most inexpensive Epson printers with Near Letter Quality print capabilities. Years ago, when it was called FingerPrint, I had one on an MX-80 printer and was quite impressed with its quality, performance and value. The SmartPrint strikes me the same way.

For $149, you receive a small (8 × 3.25 × 1.5-inch) metal box with six male DB-25 connectors for output to parallel printers, a centronics type connector for input, a small plug for the wall-plug-style ac power supply (included), and a software disk. The six output ports are labeled "Parallel Port 1" through "Parallel Port 6" and each port has a small LED indicator that lights up when you select that particular port. SmartPrint also contains signal-boosting circuitry that allows you to use a 15-foot cable run on both sides of the box. Printers, therefore, can be placed up to 30 feet from the computer with which they are used.

Installing the box takes less than a minute. Plug a standard parallel printer cable between the SmartPrint and your PC. If you are using a hardware print buffer, it must be installed between the printer and the SmartPrint, *not* between the SmartPrint and the PC (you don't want to buffer the instructions which command the box to switch printers). Next run standard printer cables between the SmartPrint and the printers you are using.

The small instruction booklet that comes with SmartPrint states that you can also use SmartPrint to switch between serial printers. You accomplish this by choosing "Printer 7" or "Printer 8" from the selection menu. This toggles the output between COMM1 and COMM2. I haven't tried it, but you should also be able to use SmartPrint as a standard RS-232 switchbox. After all, if it will switch enough lines to handle parallel output, the few lines that handle serial throughput shouldn't pose a problem. First, you should *still* use a standard parallel printer cable between the PC and SmartPrint, but it *must* be plugged into the PC's serial I/O port (COMM1 or COMM2). The cables between the SmartPrint and the printers are standard *serial* cables.

Secondly, for the switching software to work correctly, your application must be printing to LPT1. Redirecting the output through the COMM port is done using the MODE command found in DOS. Since the software (both the application and the pop-up printer selection utility) still think they are printing to LPT1, the SmartPrint should be more than happy to switch along from one printer to another.

The software disk that accompanies SmartPrint contains several utilities. These include SPMENU.COM, a 5K memory resident utility that pops up a printer selection menu when you press the "Hot Key" (ALT and the Left Shift). SPCONFIG.EXE lets you customize this menu, adding descriptive phrases (such as laser printer, mailing labels, etc.) in place of "Printer 1," "Printer 2," and the like. This utility also lets you choose another set of keys for your "Hot Key" should you wish. SPSELECT.EXE is the same menu as SPMENU, but is not memory resident. It can be called from DOS, or from within a batch file or program. The disk also contains SPOOL.COM, a 64K RAM print spool, and a batch file to install the software on a floppy or hard disk.

Once the software has been installed, you can switch printers by one of three methods. The pop-up utility can be invoked with ALT/Left Shift key combination. This will present you with a moving-bar menu for you to make your choice. If the utility SPSELECT.EXE is in the current directory, or in one which is accessible through the PATH command, typing "spselect P#," where P# is the number of the printer you want, will also switch to the selected printer. This command is most useful if it is used from within a batch file to select a particular application. The third method is to use a command string from within a program or dBASE. The format of this command is PRNTR# (where # is the number of the printer). The pop-up menu utility, SPMENU, must be loaded for this command to work.

Except for one petty annoyance, I'd wholehardedly recommend SmartPrint to anyone who needs a parallel switch box. This complaint concerns the installation routine. As part of the installation process, the SmartPrint software creates an AUTOEXEC.BAT file to run SPMENU every time the computer is booted.

Most other software that creates these AUTOEXEC files check to see if one already exists, and if it does the package modifies the existing file. SmartPrint's install routine, on the other hand, chose to simply rename my existing file (as AUTOEXEC.TMP) and install its own without mentioning mine had been replaced and renamed. When I rebooted, I had a few anxious moments until I went looking through the directory. This is not a major problem, but at the very least, the documentation should have made mention of this possibility. Other than this, SmartPrint looks like another winner for Dresselhaus. ME

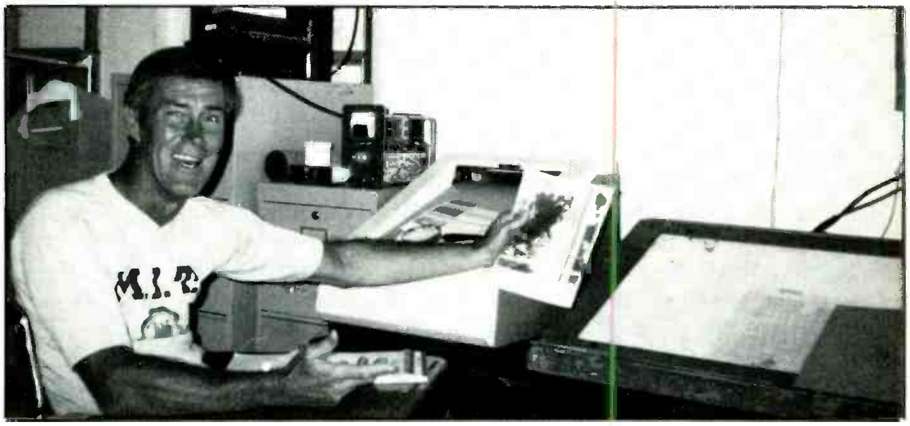
Products Mentioned:

TophAT II
BOCA Research, Inc.
6401 Congress Ave.
Boca Raton, FL 33487
(305) 997-6227

SmartPrint
Dresselhaus Computer Products
8560 Vineyard Ave.
Rancho Cucamonga, CA 91730
(800) 368-7737
(714) 945-5600

Receiving Satellite Weather Photos

By Hank Brandli



Author, who has multiple sclerosis, at his home receiving station holding Soviet Meteor photo. Shown in background are borrowed Harris Laserfax and receiver.

I've always been a believer in the old adage that "a picture is worth a thousand words," but I was never more convinced of it as when I first saw a weather satellite photo. If you've seen such photos on TV weather reports, you probably think it takes a small fortune for sophisticated equipment to receive and reproduce their 22,000-mile-high geostationary weather photos. You would be correct—at least for the TV stations. But the reality is that this need not be the case if you want to *personally* receive such photos from lower-orbiting 500-mile-high meteorological satellites. Cost can be moderate, maybe only a few hundred dollars if you're already equipped with a computer system.

In this column, I'll be discussing my experiences in getting started in personal reception of weather satellite photos to help you get started. Along the way, I'll be discussing the satellites themselves and give you some technical details on the fine art of receiving photos and interpreting what they mean.

The "Birds"

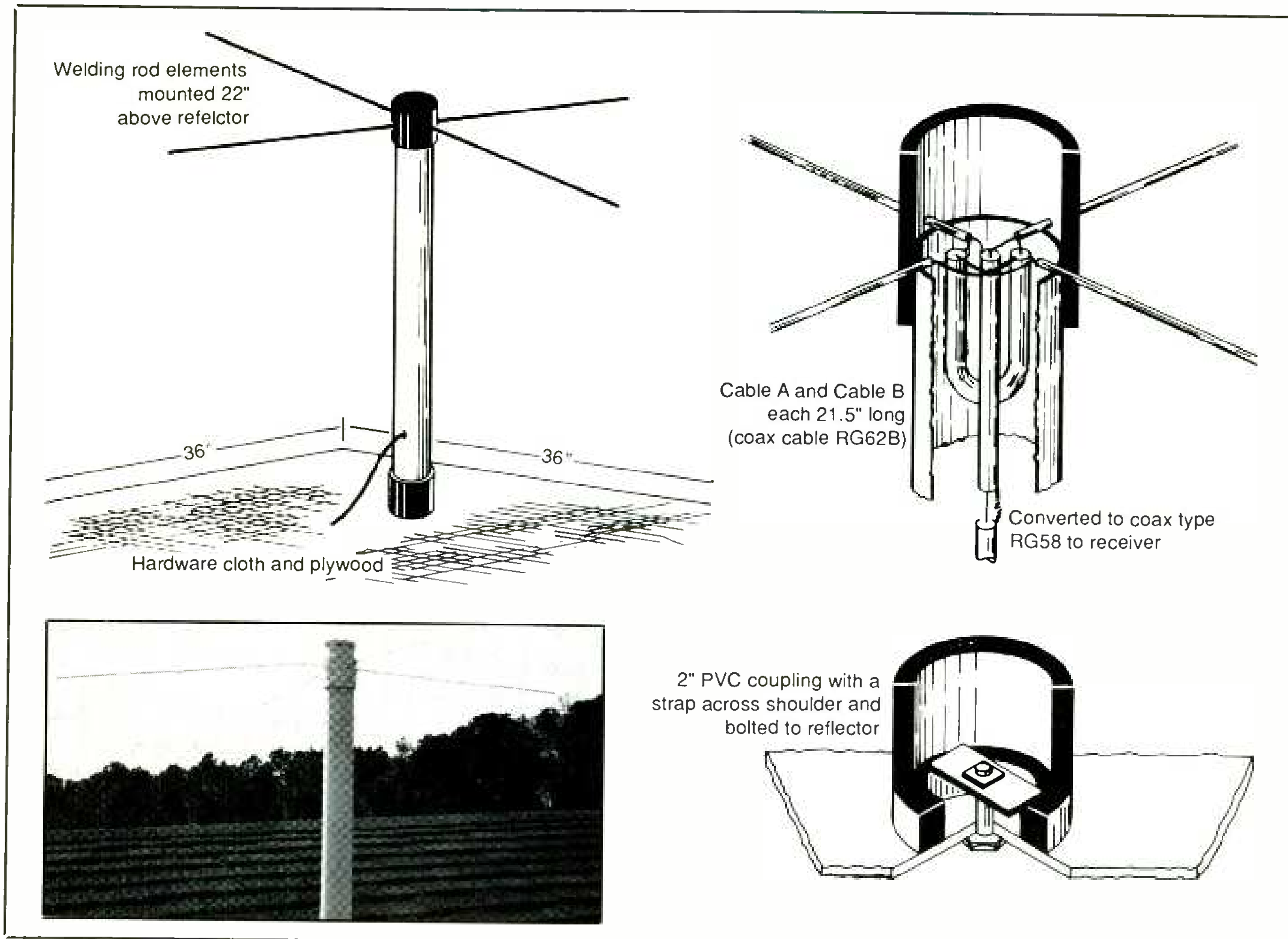
Day and night, polar-orbiting meteorological satellites launched by the U.S. and U.S.S.R. take visual and/or infrared images of every area on Earth from satellite platforms out in space. Next year, the Peoples Republic of China will join the weather-satellite community with a "bird" of their own, giving you more to tune in on and expanding your viewing horizons. These satellites circle the globe at altitudes ranging from 400 to 600 miles up, passing over the Earth every 100 minutes or so, ceaselessly taking pictures and transmitting them back to ground stations.

Two U.S. NOAA (National Oceanic and Atmospheric Administration) weather satellites in solar-synchronous orbits take, record and transmit to Earth photos of the same location at approximately 9:00 a.m. and 9:00 p.m. and at 3:00 a.m. and 3:00 p.m.. Simultaneous visual and infrared (thermal) imagery 1,600 miles wide are processed during the day, while nighttime pictures, in the absence of visible light, are infrared-only. This summer, a third NOAA weather satellite was to be launched to provide photos at 1:00 a.m. and 1:00 p.m.

Russia's Meteor III and IV spacecraft transmit mostly visual-only pictures that are 1,200 miles wide from orbital platforms. The near-polar paths of these two satellites permit photo-taking at increasing or the opposite times during the day. Whereas the 1,600-mile-wide NOAA images can spot areas of cloud as small as 2 miles on a side, constant across the image scan, the Meteor "shots" record locales as small as 1 mile square. Previous U.S. and U.S.S.R. meteorological spacecraft had poorer resolutions and distorted images on the edges.

The NOAA birds make a single pass every 101.58 minutes, which works out to 14.2 orbits per day. The Meteor birds, on the other hand, make a pass every 105 minutes, which works out to about 13.7

Blow-up of a Florida weather photo on the screen of a Radio Shack computer.



Construction details for simple antenna needed for receiving weather-satellite photos and photo of finished antenna (lower-left).

orbits per day. Equator crossing times for NOAA-9 and NOAA-10 are 1530 local ascending and 0730 local descending, respectively. Equator crossing times for the Meteor spacecraft are variable.

Orbits for the weather satellites aren't perfectly circular. For the NOAA birds, the average altitude is 850 km, while the Meteor birds average 950 km.

Transmission frequencies of the U.S. birds are 137.50 and 137.62 MHz, while those for the Soviet birds are 137.30 MHz and 137.40 MHz. Transmit antenna polarization in all cases is right-hand vertical. Subcarrier frequency is 2.4 kHz, while carrier deviation is ±17 kHz. The ground station should have a 1.4-kHz seventh-order linear filter for clear reception. Synchronization is seven pulses at 1,040 pulses per second, 50-percent duty cycle for channel A or seven pulses at 832 pps, 60-percent duty cycle for channel B.

For the technically minded, some of the more important transmission parameters of the NOAA birds are detailed in the accompanying Table.

The Antenna

Though the U.S. government and commercial weather services may use very expensive equipment for receiving and imaging satellite weather photos, yours need not be quite as elaborate to get similar results. Most of the equipment you need can be obtained from mail-order houses (and other outlets) for reasonable prices. However, one piece of equipment you will not so readily find is the antenna. This you will have to fabricate yourself. Fortunately, the task isn't very complicated and the cost for materials is very low. What you need to make the antenna is some PVC plastic pipe, four welding rods, some hardware cloth, plywood, coaxial cable and hardware. For most of this, your sources of supply will be a hardware store and lumber yard.

Assembly details are given in the drawing. Note in the upper-right detail that the welding-rod elements that make up the antenna proper must be mounted in a PVC plastic collar that snugly fits around the PVC pipe "mast." The elements mount at 90-degree angles to each other and must be held rigidly in place.

Drill the four element holes in the plastic collar, sizing them so that the welding rods make a fairly tight fit when inserted into them. The welding rods should each be 43 inches ling and should not be trimmed shorter. Once the rods are in place, prepare both ends of two 21.5-inch lengths of RG62B coaxial cable and wire them to the elements as shown. If the elements appear to be a bit loose when you are done, use a fast-setting epoxy cement to anchor them in place.

Cut the hardware cloth and plywood to 36 inches square. Since this will be an outdoor antenna, weather seal and paint the plywood to stand up to the elements. Then drill a ¼-inch hole in the exact center of it. Staple or tack the hardware cloth to the plywood. This assembly will serve as the mounting medium and ground plane for the antenna. If you wish, you can also paint the hardware cloth for protection from the elements.

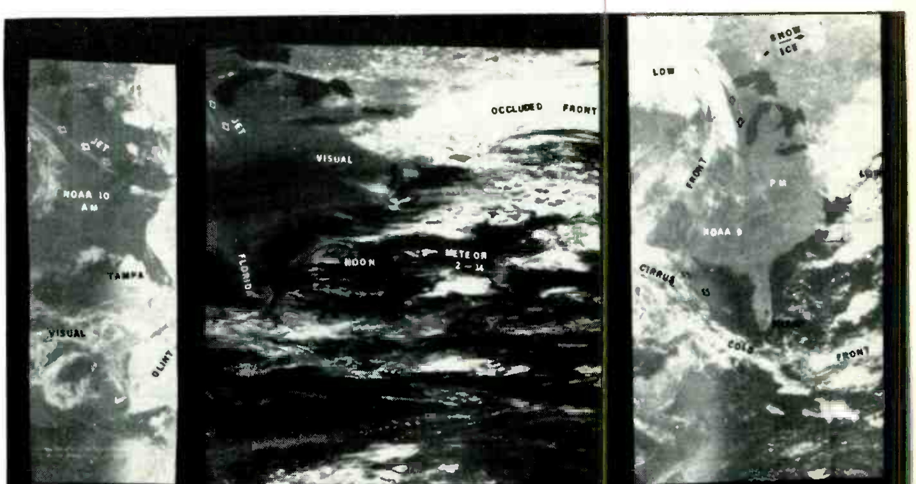
Fit the element/cap assembly onto one end of the 2-inch-diameter PVC pipe that serves as the mast and measure 22 inches from the elements down the length of the pipe. Mark this point on the pipe. Remove and set aside the element/cap assembly. Cut the pipe to length at the marked location.

About 6 inches from the bottom end, drill a ¼-inch hole in the pipe. Then mount the pipe mast to the ground plane as shown in the lower-right detail in the drawing. Use a steel strap and a ¼-inch bolt and nut to secure it in place. Then mount this assembly where it will be permanently located. Choose a location that gives the antenna an unobstructed view of the sky, such as on a flat section of your roof.

Run a length of RG58 coaxial cable from the location where you will be setting up your receiving and imaging equipment to the antenna. Route the end of the cable through the hole in the antenna mast and out through the top. Connect and solder the end of this cable to the free end of the RG62B cable connected to the antenna elements. Tape the connections and then apply a coating of silicone adhesive over the entire joint to seal it from the elements.

APT Transmission Parameters

Type of signal	vhf, AM/FM 2.4 kHz DSB-AM 1.44 Hz video
System output	
Frequency/polarization	137.50 MHz/right-hand circular 137.62 MHz/right-hand circular
EIRP at 63°/nadir	33.5 dbm worst case 37.2 dbm nominal
Antenna	
Gain at 63°/nadir	0.5 dbi/right-hand circular
Ellipticity circuit loss	2.4 to 4.0 dB maximum
Transmitter power	5 watts minimum
Carrier modulation index	±17 ±0.85 kHz
Premodulation bandwidth	0.1 to 4.8 kHz
Subcarrier modulator	
Frequency	2.4 kHz +0.3 kHz
Modulation index	87% ±5%
Post modulator filter	3-pole Butterworth
Post modulator 3-dB bandwidth	6 kHz minimum
Premodulator filter	3-pole Butterworth-Thompson
Premodulator 3-dB bandwidth	(2.4 kHz minimum)



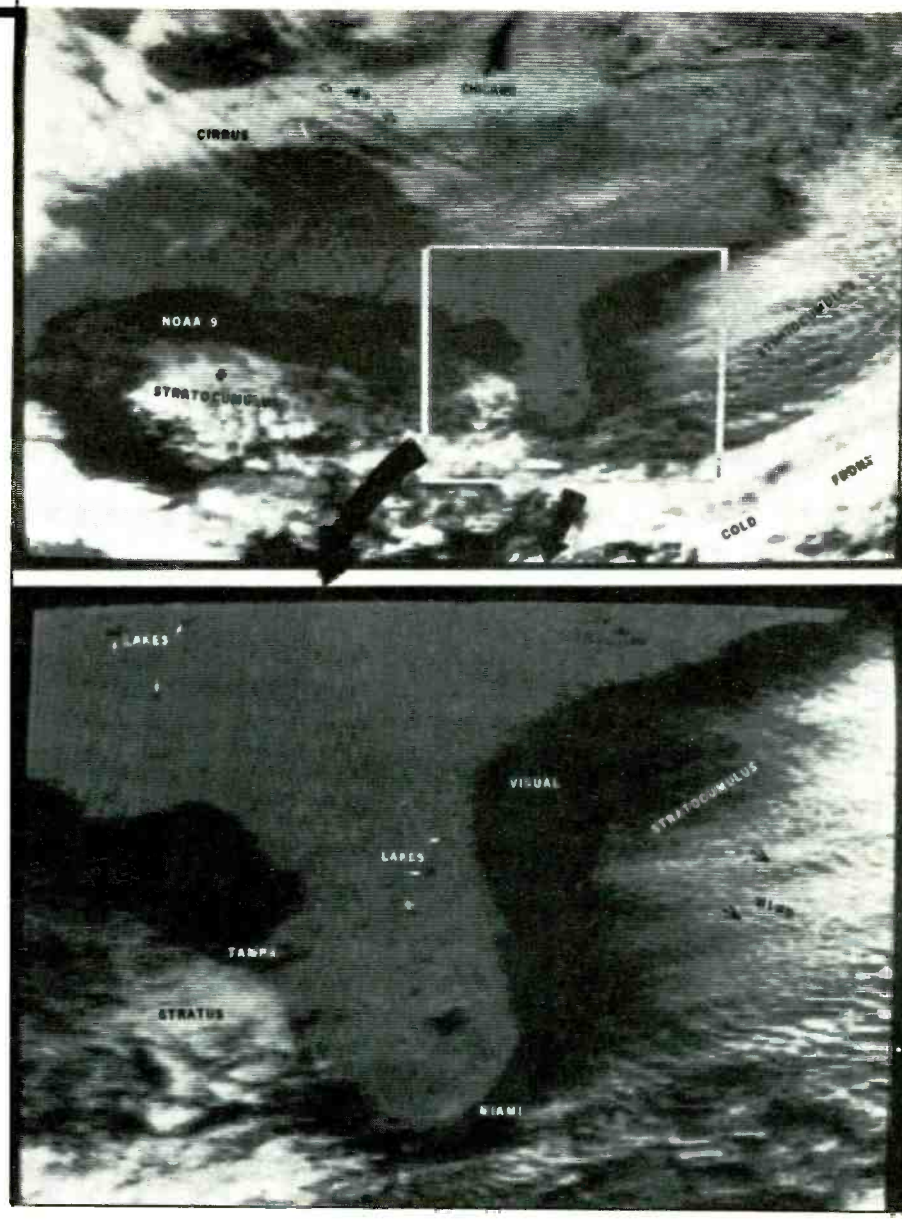
Three photos show, left to right Meteor 2-14, NOAA-9 and NOAA-10 views of the eastern U.S. on the first day of spring 1987. With basically clear skies, the coastline is easy to separate from the Atlantic Ocean.

On the Cover: Conversion from black and white to color is not restricted to the 22,000-mile-high geostationary satellite that views Florida every 30 minutes. Converting images taken by polar-orbiting National Weather Service meteorological satellites to color can provide far better resolutions to allow smaller areas to be viewed in greater detail by these low-level orbiting birds.

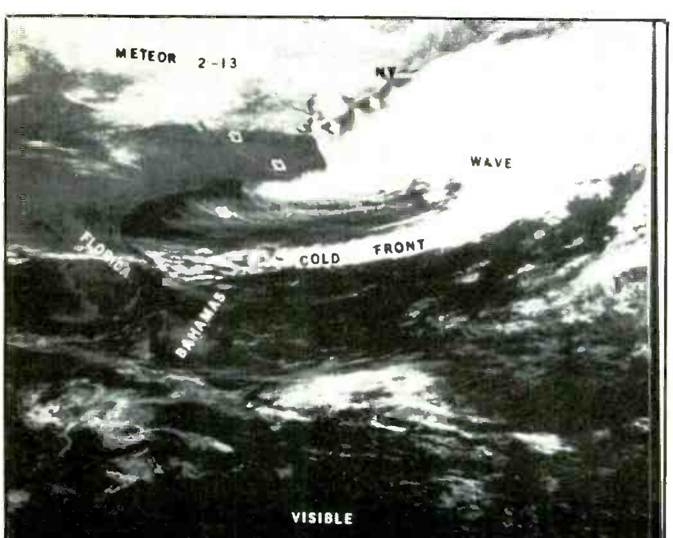
Gently pull the RG58 cable back through the hole until the connection is halfway or so down the length of the mast and lower the element/collar assembly into place. Use the recommended bonding agent for the pipe to fuse the mast to the element/collar assembly. When fusing is complete, cut a circle of heavy-duty plastic to the same diameter as the collar and cement this over the open end of the assembly with silicone adhesive to seal it against the elements. Also, seal the cable entry hole in the pipe with silicone adhesive.

Receiving/Imaging Gear

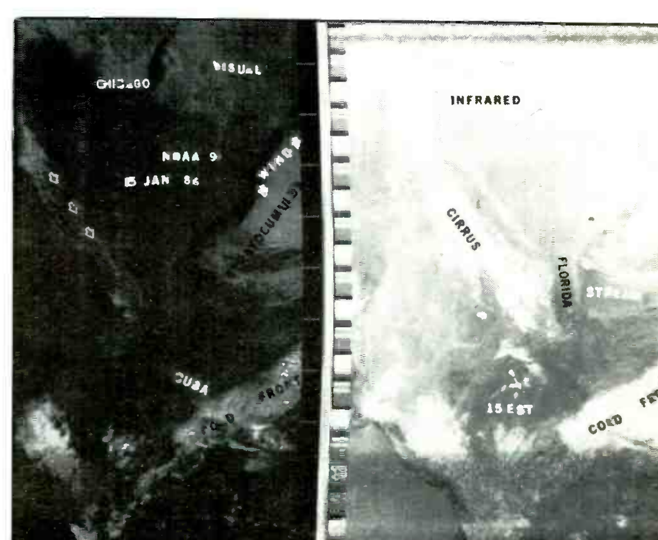
After a stint as a weather-satellite specialist with the U.S. Air Force, my ambition was to get current photos from low-level orbiting American and Russian satellites, using equipment installed in my home. Needless to say, whatever equipment I decided to use had to be priced within my budget.



A "wide-angle" visual shot taken by NOAA-9 and snapped from the CRT display of an Apple computer (upper) with a "blow-up" of Florida (bottom).



U.S.S.R.'s Meteor satellite analyzed this winter scene showing a cold front moving through Florida.



Visual (left) and infrared (right) photos transmitted by NOAA-9 show snow near the Great Lakes and a cold front over Cuba.

Though I had been a professional weather-satellite specialist, I needed help in determining what I needed and, just as important, where I could obtain what I needed. Thanks to an amateur-radio friend, I got a lead on an inexpensive receiver from Vanguard Labs (196-23 Jamaica Ave., Hollis, NY 11412; telephone 718-468-2720). About the size of a hard-bound book, its cost of less than $200 is surprisingly low. For receiving the signals from the NOAA and Meteor spacecraft, the receiver had to be equipped with five crystals.

The remainder of the gear required for receiving satellite weather photos can all be obtained from various mail-order suppliers. These items include the receiver, a preamplifier and some type of imaging device. With regard to the latter, a facsimile machine is a good start. Another better choice might be a computer, especially if it's equipped for color processing and display, which can be used to display beamed-back weather pictures and photograph them from the screen.

My weather-satellite photo receiving station consists of the Vanguard Model FMR-260-PL receiver, but other receivers, such as the Yaesu Model 9600 and the Uniden Bearcat 175XL scanner, both available from a number of sources that handle shortwave, ham-radio and scanning communications gear, can serve just as well. For the preamplifier, I chose the Vanguard Model 102-W low-noise r-f model. Again another preamp, such as the Hamtronics, Inc. (650 Moule Rd., Hilton, NY 14468; telephone 716-392-9438) Model LNA-144, can be substituted. I also use a facsimile machine, purchased on the "surplus" market, which I use as a hard-copy imaging device. Keep in mind that personal computers—specifically those from Apple and IBM—make great processing and imaging devices. Plug-in cards and software are available for weather-satellite image processing from Jim MacLean (2112 S. Parsons Ave., Melbourne, FL 32901; telephone 305-727-3646).

Seikosha Co.'s (Cupertino, CA; telephone 408-446-5820) Model VP-115 printer can capture images directly from a CRT screen. It carries a price tag of $900 and is well worth looking at if you're serious about reproducing weather-satellite photos as a hobby.

Computer processing requires digital data signals. Therefore, the audio output from the receiver must be converted into a format usable by the computer. This is accomplished with an interface card and some software, which may cost you a few hundred dollars, but a lot less than if you were to start from scratch with no equipment at all. With a computer setup, high-quality hard-copy prints can be obtained at a fraction of the cost of what they used to be. Too, the computer can be used to program satellite acquisition times and locations exactly.

Much of the equipment you need for receiving and imaging weather-satellite photos can be purchased at bargain prices from dealers who do business on the so-called "surplus" market. For example, for receivers, try Fair Radio Sales Co., P.O. Box 1105, 1016 E. Eureka St., Lima, OH 45802, tel.: 419-223-2196; for FAX equipment, try Atlantic Surplus Sales, 3738 Nautilus Ave., Brooklyn, NY 11224, tel.: 718-372-0349.

Up and Running

Having set up your equipment, you check the time. A weather satellite is due for a fly-by. You turn on the equipment and listen. Soon you hear the *thump . . . thump . . . thump . . .* of its arrival. You watch your computer screen and, there before your eyes, a picture appears. It's at that moment that you know for a certainty that a picture can, indeed, be worth *more* than a thousand words.

Once you're up and running, you'll most likely want to leave your receiver on at all times so that you won't miss a fly-by. However, to determine exactly when a satellite is to pass overhead, you should get the daily APT prediction message transmitted over worldwide communication circuits under the heading TBUS-1 for north-to-south orbits during daylight hours or TBUS-2 for south-to-north swings. These tell you the exact locations and times of successive passes each day. A good source for any satellite status and electronic bulletin board service is the APT Coordinator, Direct Readout Services, U.S. Dept. of Commerce, NOAA/NESS, Washington, DC 20233.

Visual satellite photos are very easy to interpret. Clouds are in white and land masses are simple to trace. Infrared photos, on the other hand, are somewhat more difficult to interpret. Infrared film records *thermal* properties. Hot temperatures appear as black images and cold temperatures appear as white images. Since high clouds, for example, are colder than lower ones, the former are much whiter in the pictures. Infrared cameras are used exclusively at nighttime to detect clouds and thermal properties. With no cloud covers, land and water temperatures can easily be distinguished in infrared images.

The ability to differentiate between clouds is important because cold fronts are very easy to detect on photos and can be tracked to determine velocity of movement. By using such information, an exact time for arrival of a weather front can be predicted.

You may at first have some difficulty in interpreting the photo images you receive, as illustrated by the photos shown here. Without the explanatory legends on them, many people not versed in "reading" weather-satellite photos might be hard pressed to understand what they are seeing. As time goes by, you'll likely become as adept as many a professional meteorologist is at interpreting these photos.

Due to advances in color digitizing photography, observers now have a choice of colors that can be spread across any temperature range. Using computer techniques, any color can be assigned any temperature value for a specific photo to enhance detail and understanding.

Twenty years ago, as a professional weather-satellite specialist with the Air Force, I used equipment costing more than ten times what my home station cost me. Oddly, I got less reception then than I do now with my "amateur" setup. This says a lot for technical maturity on my part and that of the equipment being used. Beyond this, I get a tremendous amount of pleasure from my hobby, and so will you.

SOFTWARE FOCUS

"Special Days" Software

By Art Salsberg

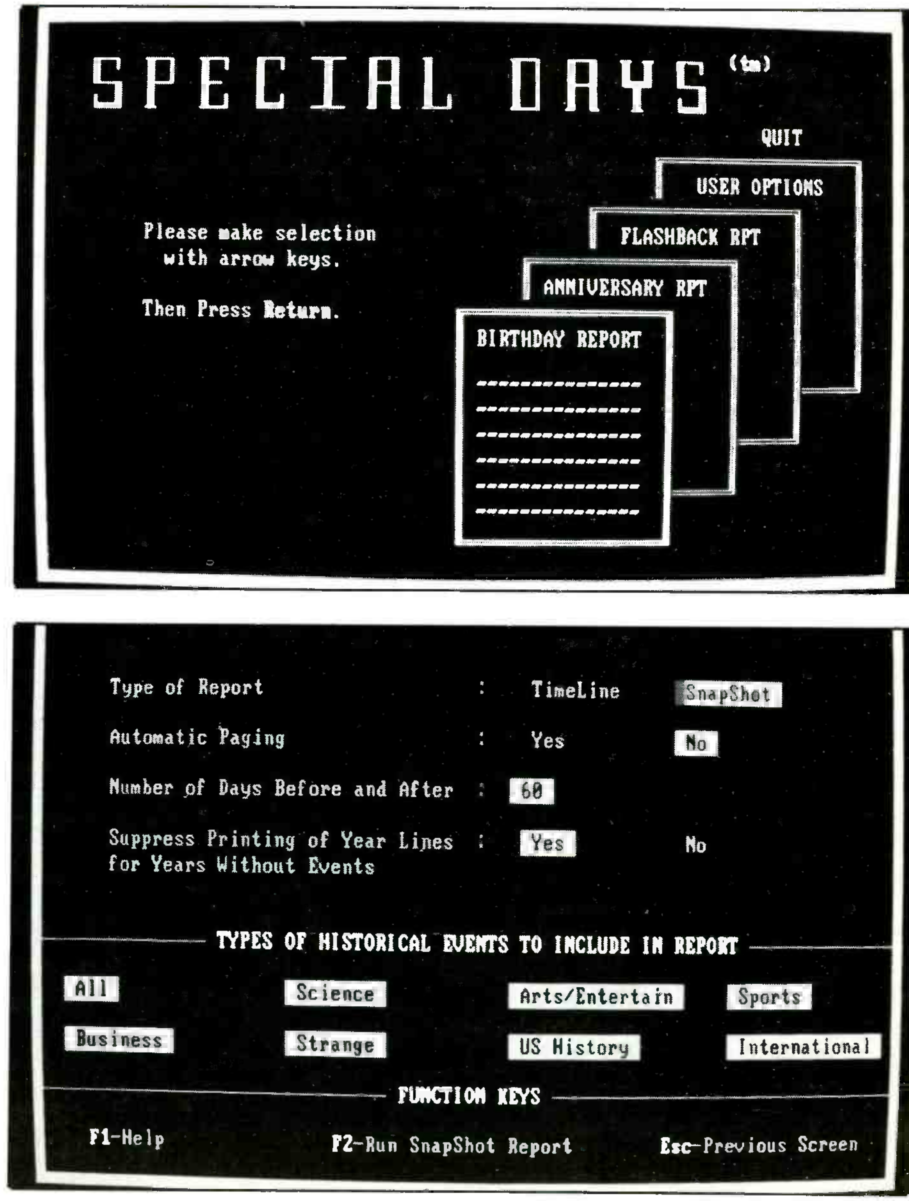
Two low-cost software packages from Salinon Corp. (Dallas, TX; 800-722-0054) —"Special Days" and "Footprints in History"—let you produce personalized, nostalgic documents that will doubtlessly be appreciated as a gift by any recipient. Each lists for only $39.95 and runs on IBM PCs and compatibles. Just 256K RAM with DOS 2.1 is required, though "Footprints" needs 320K with DOS 3.0+, an easily met requirement. In keeping with today's trend in software, the programs are not copy protected.

Special Days (Version 1.1) spotlights a person's memorable day (birthday, anniversary or any other chosen day) with a headline greeting, followed by a bevy of interesting happenings on that day and in that year. A built-in historical library contains a vast amount of information to accompany the date chosen, such as names of famous people born in the same year, best entertainment (movie, actor, etc.), prices of commodities such as butter, popular songs, celebrities from the state a person is from, and so on.

The program is menu driven, has help screens (Function Key F1), and operates in color or monochrome. At the user's option, reports can be generated with different contents for the same date chosen, too. An ASCII file of the last document made is automatically created, and there's support for multiple printers, including Hewlett-Packard's LaserJet, including a font file for the latter.

To enhance the personal document, you can use parchment paper on your printer. Two sources are noted in the accompanying user's guide. For a truly complete gift, the document can then be packaged in a picture frame. The program worked flawlessly and its parallel-running history was very interesting.

The second program, "Footprints in History," lists multiple milestones in a person's life, surrounded by historical happenings in the same period. It operates in the same manner as the company's "Special Days," so that if you've used one the other is strikingly familiar. Its output is different, though.



Some user options shown on screen for "Special Days" and "Footprints" programs.

Footprints has seven libraries that the user can tap: International, U.S. History, Business, Science & Technology, Sports, Arts & Entertainment, and Strange & Weird. Each year is followed by a series of dates and historical occurrences, with the individual's name together with his or her personal event printed in capital letters and boldfaced. With such a resource, a document can be quickly created that provides one with a snapshot of events that happened when a special moment in one's life occurred.

The Footprints program enables you to edit occurrences, adding other interesting aspects of times past. It makes use of ten function keys to simplify actions.

I found both programs to be delightful people-to-people programs, priced right, and easy to use. The results can make great gifts for friends, relatives, and business associates.

CIRCLE 55 ON FREE INFORMATION CARD

thing is okay, power down the circuit and install the ICs in their respective sockets. Make sure the ICs are properly oriented and that no pins overhang the sockets or fold under between ICs and sockets as you push the chips home.

You must now perform an operational check. To do this, you need about a 10-foot length of speaker zip cord. Separate the conductors at both ends of the cord a distance of 4 to 6 inches. Strip ¼ inch of insulation from the conductors at both ends, tightly twist together the fine wires and sparingly tin with solder. Attach medium-duty spade lugs at one end of the cable, soldering them into place to assure mechanically and electrically sound connections

Secure the spade lugs to the SPKR + and SPKR − contacts of the terminal strip or barrier block. Connect the conductor whose insulation is ribbed or otherwise identified to the SPKR + contact, the other conductor to the SPKR − contact. Solder the identified conductor at the other end of the cable to the speaker's "hot" lug and the other conductor to the speaker's other lug.

Power up the project. The audio tone should be heard from the speaker at this time, pulsing on and off as described above for as long as power is applied. If you do not hear the tone or it is very low in volume, adjust the setting of *R6* as necessary, assuming you are using the optional power-amplifier circuit to drive the speaker. Note also that the LED (if used) lights in step with and for as long as the tone is heard.

Once the project is working as it should, power it down and disconnect from it all cables. You are now ready to install it in your vehicle. Keep in mind that mud, snow, rain and mechanical vibrations present a hostile environment for this project.

If you plan on installing the project box in the engine well of your vehicle, use silicone adhesive to seal it from contaminants. Apply the adhesive to all openings: mounting hardware holes for the circuit-board assembly, rear of the LED and its holder and entire perimeter of the terminal strip or barrier block. If the enclosure is metal, seal all its joints. Whatever the type of enclosure being used, seal around its lid or chassis half. If the project box will be mounted inside the passenger compartment, where the only consideration will be mechanical vibration, you do not have to seal it.

To provide insulation from mechanical vibrations, place self-adhering (one side only) foam rubber strips on the outside of the enclosure and secure it in place in some convenient location where the LED will be readily visible inside your vehicle with a pair of sheet-metal screws. Place a flat washer and a small rubber grommet on each screw before placing the screws in the mounting holes drilled for them. Tighten the screws until the rubber grommets and foam-rubber strips are only slightly compressed.

The speaker used for this project should be an outdoor type that can bear up to the elements. Desolder the cable from the speaker and reconnect it to the terminal strip or barrier block, observing polarity. Mount the speaker in any convenient location that will readily permit the beep to be heard. A good location is inside the engine well, where it will be somewhat protected from the elements. It can be mounted on the firewall or on a fender, whichever is more convenient and will not cause interference with engine operation or other elements inside the engine well.

Route the free end of the speaker cable from the project box through the firewall. Determine how long the cable should be with about 8 inches of slack and cut it to that length. Separate the conductors a distance of about 3 inches. Then strip ¼ inch of insulation from both remaining conductors, tightly twist together the fine wires and sparingly tin with solder. Connect and solder the identified "hot" conductor to the "hot" lug and the other conductor to the other lug on the speaker. Secure the cable in place with cable ties to other cables in the engine well.

Now enlist the aid of a relative or friend to trace your vehicle's wiring to the back-up lights. Use a dc voltmeter or multimeter set to dc volts to determine where to make the connection to the back-up light circuit. Remember, the correct connection point should give a + 12-volt meter reading only when the vehicle's transmission is placed in reverse gear and the back-up lights are on. You should have no meter indication with the transmission set to any other gear.

Once you know which wire to make the connection to, trace it as far forward as possible to make the actual connection. Using the spade lugs, secure your twisted-pair power cable to the project's terminal strip or barrier block, observing polarity.

Route the free end of the cable through the firewall into the engine well to the point where you will be making the + 12-volt connection to the back-up light circuit. If you are making this connection to an existing conductor run in the vehicle's electrical system, split the conductor. Trim the red-insulated conductor of the power cable as needed, leaving about 6 inches of slack. Strip from both ends of the split electrical-system back-up light conductor and the red-insulated power conductor ¼ inch of insulation.

Slip over the free ends of the red-insulated conductor and one of the other conductors a 4-inch length of small-diameter heat-shrinkable tubing. Then tightly twist together all three conductors and solidly solder the connection. Bend the soldered conductors flat against the conductor that does not have the tubing over it and slide the tubing over the connection. Center the tubing over the connection and solidly shrink into place. When this is done and the tubing has cooled, seal the ends of it with silicone sealant.

Trim the black-insulated conductor to suitable length and fasten to the remaining end a medium-duty ring-type lug. Locate a chassis-grounded screw on your vehicle to which to fasten this cable. Remove the screw and, if necessary, sand it with fine emery cloth until the surface around the hole is bright and shiny. Place a toothed lockwasher on the screw, followed by the conductor's ring lug and another toothed lockwasher. Drive the screw solidly back into the hole from which it was removed.

A final note on safety: Always exercise extreme caution whenever you back up your vehicle, even when using a "beeper" like the one described here. Little children may not understand the meaning of the beeping sound, and hearing-impaired people may not hear the alert. **ME**

Wireless Data Link *(from page 27)*

ends, including baud rate, number of data and stop bits, and parity. The Wireless Data Link will operate at 300 baud or slower if desired.

Turn on the system, including both Wireless Data Link units. When the system is set up properly, data sent by the transmitting end will appear at the receiving end just as it would if you were using a hard-wired cable link. If you have set up a computer-to-printer link, the printer should operate just as if it were simply cable-connected to the computer. Since the Link communicates in only one direction, the printer must be able to keep up at 300 baud, or it should have a buffer that is large enough to hold the entire transmission. Most dot-matrix printers can easily keep up at this rate (300 baud translates to about 30 characters per second).

If you are receiving data that is garbled or otherwise not intelligible, double-check the communications protocol. If possible, cable-link the two devices, without using the Wireless Data Link to first make certain that the system is properly set up and operating as it should. This will confirm that the two ends can communicate and eliminates the end devices as sources of error. When you have the cable-link arrangement working, replace it with the wireless link and you are ready to transmit. **ME**

1-MHz to 2-GHz Amplifier *(from page 38)*

all four pins of both ICs are soldered into place.

Keep in mind that the MAR-6 ICs are delicate devices that can easily be damaged by excessive heat. Therefore, apply the tip of your soldering iron to the junction between IC pin and solder-coated land only long enough to assure a good electrical connection. It helps, too, to wait a few seconds before applying heat to each pin/land junction to allow the IC to cool off. Alternating between the ICs as above, you will allow the ICs to cool off between soldering operations.

The type of BNC connectors used for *J1* and *J2* in the prototype of the project is designed for perpendicular pc mounting, though in this case they were edge mounted directly to the board. When mounting these connectors in place as shown, make sure the center-conductor pins solder directly to the indicated micro-strip land conductors on the board. Ground connections are critical; so be sure you make good solid connections here. During installation, take care not to torque the center-conductor center pins or you may peel up the micro-strip copper trace to which they connect. If this occurs, the board will be ruined as far as full-bandwidth operation is concerned.

If you are using the 9-volt transistor battery to provide power for the circuit, tack solder the unfinished conductor ends of the battery snap connector to the indicated points on the circuit-board assembly. Make certain that the red-insulated conductor goes to the "+" land and the black-insulated conductor goes to the ground that surrounds the board. Alternatively, connect the ac-operated power supply to the circuit board in the correct polarity. Then connect the amplifier into the system with which you wish to use it, snap into the connector a 9-volt transistor battery or turn on the ac supply, and the project is ready to operate.

Parting Remarks

I measured the gain of this r-f amplifier prototype using several signal generators (I had access to no single generator that could cover the entire 1-MHz-to-2-GHz band!), a frequency counter and an r-f power meter. The results are shown in Fig. 3. Even with the economy approach used for designing this amplifier, the results are quite impressive. R-f chokes could have been added in series with bias resistors *R1* and *R2* to increase the circuit's gain, but this would probably not be worth the additional cost and circuit complexity for most applications.

you connect the free ends of the wires coming from the LED assembly that they go to the proper points in the circuit before soldering them into place.

Operational Checks

Set toggle switch *S3* to OUT. Plug a three-conductor extension cord into *SO1* and its plug into a three-conductor ac outlet—*not* the GFCI. Press and hold pushbutton switch *S4* (located just below the line of LEDs). At this point, green *LED2* should be on, indicating voltage between the hot and neutral lines. Also, red *LED1* should be off, indicating no voltage between neutral and ground, and green *LED3* should be on, indicating normal voltage between hot and ground. If the project fails this test, check its wiring and that of the ac outlet into which it is plugged.

Once the project has passed the LED test, plug it into the GFCI unit and press the pushbutton switch below the LEDs. Now green *LED3* should flash and the GFCI should trip because the current in the diode is a ground-fault current condition that exceeds 5 mA.

Plug a three-contact to two-contact adapter onto the end of the project's line cord. Plug the adapter into the ac outlet in reverse. Red *LED1* should light, indicating reversed polarity.

Zener diodes *D7* and *D8* should be reasonably well matched to minimize the dc component of the clipped sine wave they generate. Connect a dc voltmeter or multimeter set to measure dc volts from GROUND jack *J1* to the upper end of *R17*. Set *S3* to IN and apply ac power to the project. If the measured potential is greater than 1 volt, replace *D7* or *D8* for a closer match with the remaining zener diode.

ZERO ADJUST potentiometer *R18* must now be set to cause the GFCI to trip when TRIP control *R17* is set to approximately 500 ohms. With no power applied to the project and *S3* set to OUT, set *R17* to about 500 ohms, as indicated on an ohmmeter. Set *R18* for maximum resistance and close *S3* by setting it to IN. Plug the project into the GFCI. If the GFCI trips, the value of *R16* is too small and must be increased. If the GFCI does not trip, slowly decrease the setting of *R18* until the GFCI trips. If it does not trip, the value of *R16* is too large and must be decreased.

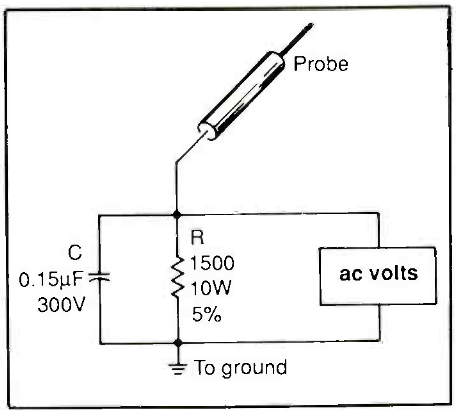


Fig. 5. Test circuit for checking leakage currents of TV receivers, VCRs and other consumer products.

When you are finished setting *R17*, you have set it for the zero index trip point. Rotate the knob on *R17* so that its pointer is at the 7 o'clock position on the panel and make a pencil mark at this first trip-point location. Set *R17* fully counterclockwise and place a mark at the dial location to which its knob points.

It is not necessary to calibrate *R17*'s dial because you can set the control against fault currents selected with rotary switch *S1*. If you do calibrate *R17*'s dial, though, the calibration applies to only the GFCI used during calibration, the one on your workbench. With a calibrated dial, the project can be used to check leakage currents.

As an example of calibrating the dial at the 1-mA trip setting, set *R17* fully clockwise, set *S1* to the 1-mA position and press and hold *S2*. Slowly adjust *R17* counterclockwise until the GFCI trips and mark the location to which the pot's knob is pointing at that time. Do the same for all 11 positions of *S1* under the same conditions and mark the panel at each position *R17*'s knob points. When you are finished, remove the control knob from *R17* and label its dial plate accordingly. Mask off the rest of the panel and spray on two or more light coats of clear acrylic to protect the new legends from scratching.

Applications

A GFCI cannot protect itself from excessive load current. If the branch circuit has a 25- or 30-ampere circuit breaker, plug into the project's receptacle an ac power strip that has a 15-ampere circuit breaker built into it. If the power strip also has an emi filter, plug the GFCI into the strip.

The GFCI Calibrator/Tester checks a GFCI by applying known fault currents. To do this, set the toggle switch to OUT to remove pre-load fault current. Unplug any load connected to the GFCI and any other receptacle that is protected by the GFCI. Set the rotary switch on the project successively to each position between 2 and 8 mA and press the pushbutton switch below the rotary switch for each position selected until the GFCI trips. A good GFCI may trip at 4 mA but more likely at 6 mA. A trip-point at higher or lower current settings indicates that the GFCI is not within normal specifications.

You can check the "hot" leakage current of electrical and electronic equipment if you have calibrated *R17*'s dial. However, first perform the "cold" leakage current test with no ac power applied. To perform this test, connect a jumper wire across the prongs of the equipment's ac line cord plug and set the power switch to on. Using an ohmmeter, check the resistance from the prongs of the line cord to external exposed metal parts on the equipment. The meter should indicate at least 50 megohms. Products that have three-conductor line cords should yield a resistance reading from the grounding (half-round) prong to external metal parts of zero ohm (a complete short) but at least 50 megohms between the other two prongs and the exposed metal parts.

A leakage-current "hot" test is performed with ac power applied and the equipment turned on. In Fig. 5 is shown the circuit to use for checking leakages on TV receivers, VCRs and similar consumer products. The bottom end of the resistor connects to an earth ground, such as a cold-water pipe. To perform this test, use an ac voltmeter that has an input impedance of at least 5,000 ohms per volt.

With all cabinet parts and insulation in place, touch the meter's probe to all exposed metal screw heads and metal parts. The maximum specified voltage limit varies from 0.3 volts (0.2-mA leakage current) up to 0.75 volt (0.5-mA), with 0.45 volt (0.3-mA) being typical. Reverse the equipment's line cord in the ac receptacle and repeat the test.

When using the GFCI Calibrator/Tester, verify proper operation before proceeding with any tests. Unplug the load from the project and set the toggle switch to IN. Slowly rotate the potentiometer control's knob clockwise to the zero index and verify that the GFCI trips. At the zero index, you may notice a negligible discrepancy of roughly 0.05 mA, depending on actual line voltage.

To check leakage of a soldering iron that has a two-prong line-cord plug, perform the above zero-index test with the iron unplugged from and plugged into an the receptacle on the project with no ground wire. The results should agree with each other.

Ground the tip or barrel of the iron to earth through a 1,500-ohm resistor. Slowly adjust the setting of the project's potentiometer control counterclockwise until the GFCI trips and make a note of the leakage current indicated.

Next, adjust the setting of the control fully clockwise and reset the GFCI. Reverse the iron's line cord in the receptacle and slowly adjust the control's knob counterclockwise until the GFCI trips and again note the current.

When using this project, limit the "hot" leakage current test to products that draw no more than 400 watts of power from the ac line. This limits a zero-index offset error to about 0.05 mA for power on and off conditions with no ground wire attached (zero fault current). A 1,500-watt load with no ground wire attached produced a 0.2-mA zero-index error on switching from power on to power off.

The table shown in Fig. 6 lists various on/off combinations for the three test LEDs and associated wiring faults. As with commercial pocket testers, all LEDs light (red bright and green dim) if the "hot" terminal (brass-colored) is open and the remaining terminals carry the hot conductor in addition to neutral or ground in any combination. You should cut this table out (or a photocopy of it) and cement it to one of the walls of the project for ready reference whenever making tests.

A products that has a three-conductor ac line cord may include a built-in emi filter that includes capacitors connected from both lines to ground. A test on an emi filter revealed a 0.3-mA capacitive current to ground that pre-loads the GFCI and adapter trip-point settings. When protecting a power strip that has a number of instruments plugged into it, measure the combined leakage current and set the project's potentiometer control to a suitably higher trip-point current. **ME**

	LED1	LED2	LED3
	RED	GREEN	GREEN
Correct	■	□	□
Open GND	■	□	■
Open hot	■	■	■
Open neutral	■	■	□
Hot/GND reversed	□	■	□
Hot/Neutral reversed	□	□	■
See text	□	□	□

LEGEND:
□ = LED on ■ = LED off

Fig. 6. Table lists indications for various combinations of LED operation. Cut this out or photocopy it and cement it to the project for ready reference.

SUBSCRIBER SERVICE
CHANGE OF ADDRESS

Planning to move? Please let us know six weeks in advance so you won't miss a single issue of MODERN ELECTRONICS

Attach old label and print new address in space provided. Also include your mailing label whenever you write concerning your subscription to insure prompt service on your inquiry.

Modern Electronics
76 N. Broadway,
Hicksville, NY 11801

ATTACH LABEL HERE

NEW ADDRESS HERE — PLEASE PRINT

NAME ____

ADDRESS ____

CITY ____ STATE ____

DATE ____ ZIP ____

MODERN ELECTRONICS MART

Classified Commercial Rates: $1 per word, 15-word minimum ($15.00) prepaid. (Word count includes name and address; ZIP code and abbreviation each count as one word; P.O. Box number and telephone number count as two words each.) Indicate free category heading (**Computers, Communications, Electronics, Video** or **Miscellaneous**). A special heading is available for a $6 surcharge. First word only is set boldface caps at no charge. Add 20% for additional boldface words.

Non-Commercial Rates: FREE to subscribers, as space permits; maximum 15 words. A recent **MODERN ELECTRONICS** mailing label must accompany ad.

(All advertisers with P.O. Box addresses must supply permanent address and telephone number. Copy is subject to publisher approval.)

Mailing Information: Copy must be received by the publisher by the 25th of the third month preceding the cover date. Send Advertising material with check or money order or credit card information (Visa or MasterCard only) with number and expiration date to: **MODERN ELECTRONICS**, Classified Department, 76 N. Broadway, Hicksville, NY 11801.

VIDEO

PROJECTION TV . . . Convert your TV to project 7 foot picture . . . Easy! . . . Results comparable to $2,500 projectors . . . **PLANS AND 8" LENS** $24.95 . . . Professional Systems available . . . Illustrated Catalog FREE . . . **MACROCOMA** 15MA Main Street, Washington Crossing, Pennsylvania 18977. Creditcard Orders 24 HRS. (215) 736-3979.

COPYGUARD CORRECTOR RESTORES RENTAL MOVIES. Connects between VCRs. Satisfaction Guaranteed. $59.95 plus $4 handling. 1-800-338-8751.

VHS-VCR repair solutions volumes I, II, III. Each contains 150 symptoms and cures, cross reference chart, free assistance. Each $11.95, any two $19.95, all $29.95. Eagle Electronics Dept. A, 52053 Locks Lane, Granger, IN 46530.

CABLE TV CONVERTER/DESCRAMBLERS - Original Factory Zenith, Tocom, Scientific Atlanta, Oak, Jerrold, Panasonic - Remotes, Video Accessories, Kits. Best Buys/ Warranties - **FREE CATALOG. ARIZONA VIDEO**, 7739 E. Broadway, #108, Tucson, Arizona 85710. (602) 323-3330.

INFRARED-BEAM CHECKER tests VCR, TV and other invisible-IR remote controls. Self-contained, business-card size, guaranteed. Only $6 plus $1 P&H. Soltek Enterprises, P.O. Box 185, Merrick, NY 11566.

VCR REPAIR COURSE home study details $2, VCR maintenance guide $8.50, VCR/TV adjustment tape VHS $18.50. Western Hemisphere Enterprises, Box 673, Commack, NY 11725.

VIDEO Sender no wires watch TV in any room even on the patio; 69.95 plus $5.95 shipping; Money Order, Check, COD to Video Sender, 481 West Willow, Suite 103, Long Beach, CA 90806.

ELECTRONICS

LASERS and OPTICAL COMPONENTS. Write for free catalogue. M.J. Neal Co., 6672 Mallard Court, Orient, OH 43146. 614-877-3719.

VOICE Disguisers! FM Bugs! Telephone Transmitters! Phone Snoops! More! Catalog $1.00: XANDI ELECTRONICS, Box 25647, "AA", Tempe, AZ 85282.

$$$$$ SUPER SAVINGS $$$$$ on electronic parts, components, supplies and computer accessories. Free 40-page catalog for self-addressed and stamped envelope. Get on our mailing list. BCD ELECTRO, P.O. Box 830119, Richardson, TX 75083 or call (214) 343-1770.

TUBES, Name Brands, New, 80% Off List, Kerby, 298 West Carmel Drive, Carmel, IN 46032.

EXOTIC Electronics Devices like James Bonds. Catalog, $2.00. F&P Enterprises, Box 51272, Palo Alto, CA 94303-H.

TUBES 59¢. Year Guarantee. Free Catalog. Tube Tester $8.95. CORNELL 4219 University, San Diego, CA 92105.

PHOTOGRAPHIC positives/negatives from magazines or your original artwork. Up to 4" × 5" $3.95, up to 8" × 10" $6.95 plus S&H. Fabrication and assembly also available. Skyline Electronics Inc., 1 Putnam Street, Milford, NH 03055 (603) 673-2935.

SOUND CHASER unusual complete plans $5.00. R.D.J. Enterprise, P.O. Box 378, Orleans, Ont., Canada K1C 1S8.

FACTORY DIRECT CMOS **TIMERS** (555) (same as **TEXAS INSTRUMENTS** TLC series) 2volt **$0.75**, 1volt $0.99, dual 2volt **$1.40**, quad 1volt $3.25 plus CMOS operational **AMPLIFIERS** single **$1.30**, dual $1.95, quad $3.65 each, with spec, Shipping US $2.55, Canada $3.55 **AE/MC/VS** no minimum **H.T.S.** (suite 209) 2512 Chambers, Tustin, CA 92680 (714)-259-7733.

COMMUNICATIONS

TELEPHONE TAP or Room Monitor. Range Unlimited. Catalog, $3.00. **LISTEN** 603 Elgin, Muskogee, OK 74401 1-800-633-TAPS.

DESIGNERS HANDBOOK contains over 60 useful circuit modules. Audio, digital and microprocessor. $3.95. Design, P.O. Box 47, Raymond, ME 04071.

CABLE TV EQUIPMENT

CABLE DESCRAMBLER LIQUIDATION. Major makes and models available. Industry pricing! (Example: Hamlin Combo's, $44 each . . . minimum 10 orders). **DEALERS ONLY!** Call West Coast Electronics, (818) 989-0890.

THEFT DETERRENT

SCARE car thieves away before break-in. Electronic theft deterring device installs in seconds! Send $14.00. HARTLEY'S CHOICE, 13110 N.E. 177th PLACE, SUITE 314, WOODINVILLE, WA 98072.

WEATHER INSTRUMENTS

ADVANCE WARNING OF THUNDERSTORMS AND LIGHTNING! SASE GETS FREE COMPLETE INFORMATION ON OUR LIGHTNING/STORM DETECTORS. Or send check or money order: Model LD-7000 is $38.65. Light and Alarm for Cloud-to-Ground discharges. Over 35 miles range. LD-8000 is $62.25 and has L/S-Intensity Meter. Write to: McCallie Enterprises, Inc., P.O. Box 946, Land O' Lakes, FL 34639.

SATELLITE TV

SAVE $$$$$ - SYSTEMS UPGRADES Uniden, Houston, Etc. **FREE** Catalog 218-739-5231. **SKYVISION,** 2014 Collegeway, Fergus Falls, MN 56537.

EMPLOYMENT INFORMATION

SEND your job Resume to over 1700 New Mexico employers of electronic engineers/technicians. List of 40 categories $2.00. Refundable. DK Co., POB 53445, Albuq., NM 87123.

CABLE

CABLE TV Secrets - the outlaw publication the Cable Companies tried to Ban. HBO, Movie Channel, Showtime, Descramblers, Converters, etc. Suppliers List Included. $8.95. Cable Facts, Box 711-ME, Pataskala, Ohio 43062.

INVENTORS

INVENTORS! Have idea for product or invention, don't know what to do? Call AIM we present ideas to manufacturers - Toll Free US and Canada 1-800-225-5800.

INVENTORS

INVENTORS! Can you profit from your idea? Call AMERICAN INVENTORS CORPORATION for free information. Over a decade of service, 1-800-338-5656. In Massachusetts or Canada call (413) 568-3753.

MISCELLANEOUS

STAMP it out! Three line address rubber stamp $6.00. Francis, Box 70-1085E, Flushing, NY 11370-9998.

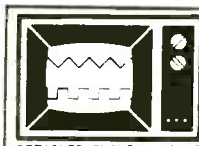
ASIAN LADIES want correspondence for friendship, marriage, SUNSHINE INTERNATIONAL, Dept. TW, Box 5500, Kailua-Kona, HI 96745.

ADVERTISERS' INDEX

CABLE T.V. CONVERTERS WHY PAY A HIGH MONTHLY FEE?

All Jerrold, Oak, Hamlin, Zenith, Scientific Atlanta, Magnavox and all specialized cable equipment available for shipment within 24 hours. For fast service MC/VISA or C.O.D. telephone orders accepted (312) 638-5320 60 Day Warranty (Quantity Discounts) 8 A.M. to 5 P.M. Monday through Friday Central Time. Stamp Envelope (60¢ postage) for FREE Catalog.

Midwest Electronics Inc.
5143 W. Diversey • Chicago, IL 60639
No Illinois Orders Accepted



DETAILED PLANS: $4.95
TV-SCOPE
PENN RESEARCH, Box 3543 Williamsport, PA 17701

FINALLY!
An interesting and worthwhile project. This EASY-TO-BUILD circuit lets you use any regular TV set as a simple OSCILLOSCOPE. Build for less than $10. **NO MODIFICATIONS TO TV!** Single or dual trace. Send for **FREE CATALOG** of other plans and kits.

USE YOUR FREE INFORMATION CARD

CIRCLE NO. 116 ON FREE INFORMATION CARD

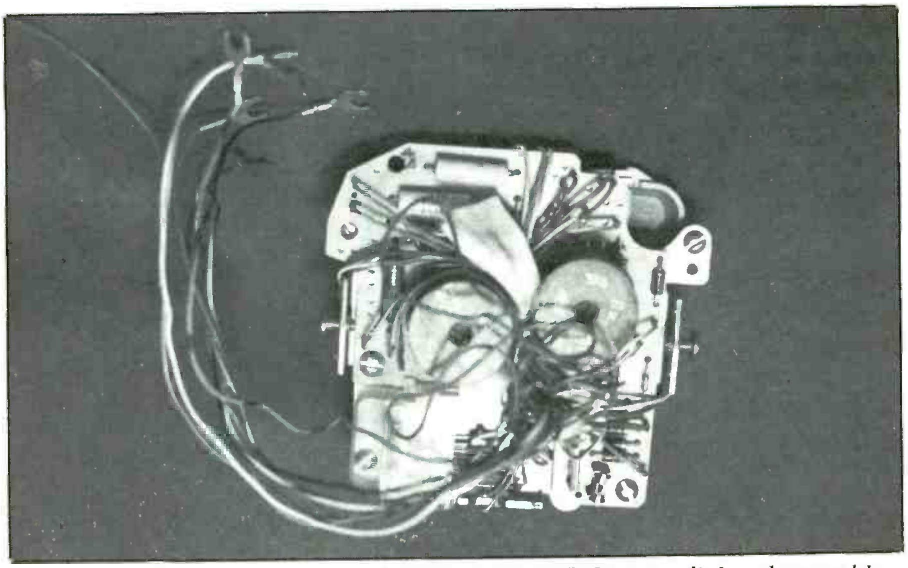


Fig. 19. Component side of 3300 OPG DTMF-type dial pad assembly that uses transistor oscillator circuit and two coils for generating tone-pair frequencies.

• **Low Volume or Distortion.** The handset assembly is virtually always responsible for low volume and distortion in the transmitter or receiver. The transmitter is usually a carbon microphone in the conventional telephone instrument. It uses a delicate but rigid diaphragm that is tightly stretched over a capsule packed with carbon granules. The resistance of the capsule changes in step with the frequency and amplitude of the sound pressure it intercepts. It is this change in resistance that varies voice current sent over the phone line.

Over time, the vapor in human breath as well as foreign matter will start to corrode and wrinkle the microphone's diaphragm, loosening its tension. When this occurs, the varying speech current will drop in amplitude and will no longer be a faithful reproducer of the sound entering the microphone. The result is low transmitting volume and/or distortion.

The receiver element works exactly the opposite of the carbon microphone. Varying speech current entering it varies the magnetic field of a small coil wrapped around a permanent magnet that rests behind a delicate metal diaphragm. The varying electromagnetic field vibrates the rigid diaphragm to produce sound energy that is a reproduction of the talker's voice.

Over a period of time, environmental effects and everyday usage will loosen the diaphragm. The result is a loss of volume and intelligibility of the received voice signal.

The solution to a weak transmitter or receiver is to either replace the offending transmitting or receiving element or replace the entire handset assembly.

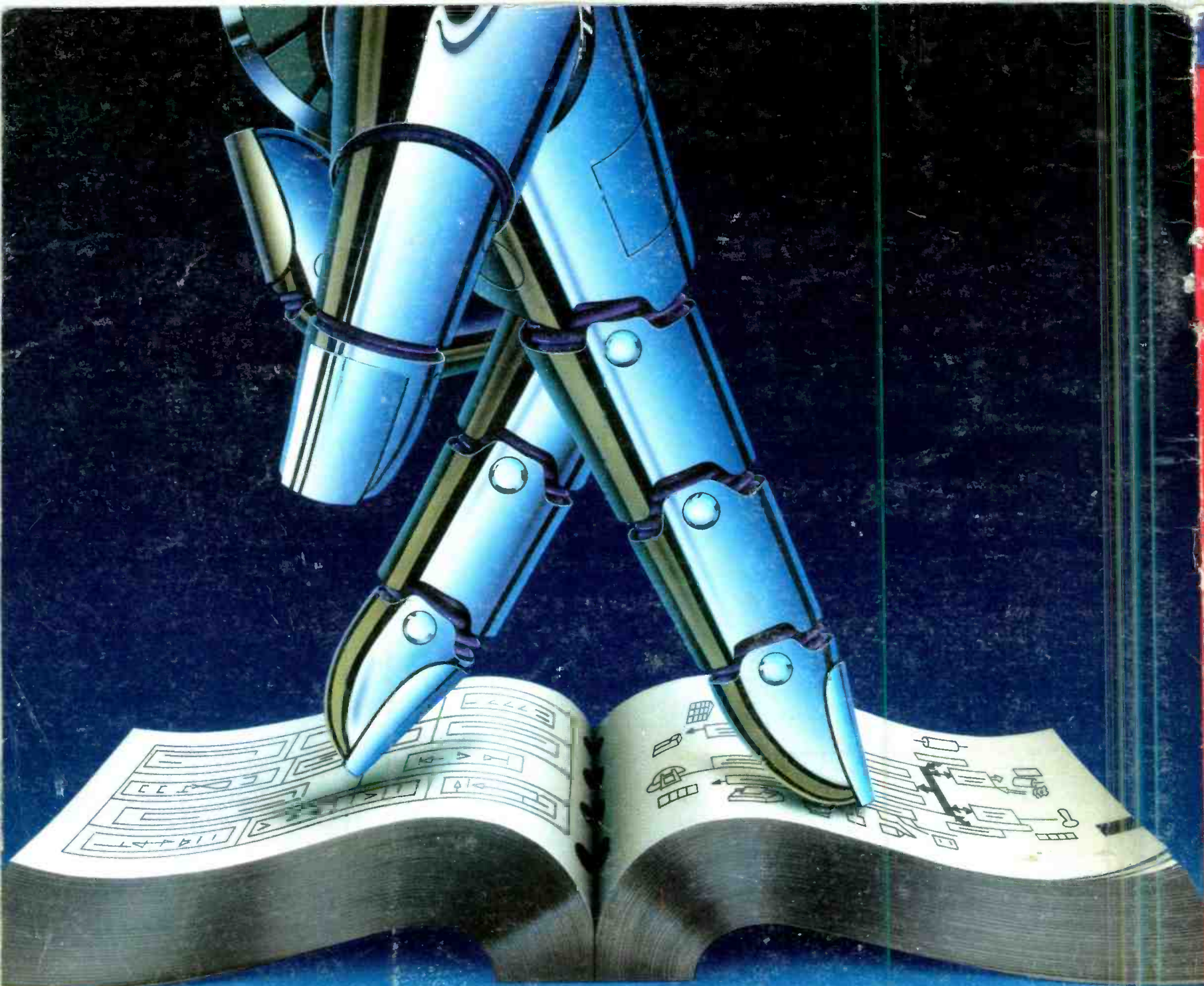
Telephone Instrument Troubleshooting Chart

Symptoms	Handset Cord	Line Cord	Hook-switch	Dial Unit	Ringer Assembly	Handset Assembly	Network Assembly
Appears Dead (does not activate)	N.A.	X	X	N.A.	N.A.	N.A.	X
Appears Dead (will activate)	X	N.A.	N.A.	N.A.	N.A.	X	X
Low Ring	N.A.	N.A.	N.A.	N.A.	X	N.A.	N.A.
No Ring	N.A.	N.A.	N.A.	N.A.	X	N.A.	X
Noise/Intermittent	X	N.A.	X	N.A.	N.A.	X	X
Single Tone Output	N.A.	N.A.	N.A.	X	N.A.	N.A.	N.A.
No Output Tone	N.A.	N.A.	N.A.	X	N.A.	N.A.	X
Keypad Row Or Column Not Operating	N.A.	N.A.	N.A.	X	N.A.	N.A.	N.A.
Will Not Break Dialtone	N.A.	N.A.	N.A.	X	N.A.	N.A.	N.A.
Low or Garbled Transmit	N.A.	N.A.	N.A.	N.A.	N.A.	X	N.A.
Low or Garbled Receive	N.A.	N.A.	N.A.	N.A.	N.A.	X	N.A.

N.A. = Not applicable; X indicates possible cause.

In Closing

As promised, the Table included here is a quick reference troubleshooting chart that covers the typical problems one can encounter with the telephone discussed here. Modern electronic telephone instruments are slightly more sophisticated than their predecessors, but they still use the same five basic assemblies to perform the same functions. With a little patience and some careful observation, troubleshooting and repair of telephone instruments should become a straightforward task. **ME**



Now you can put your fingers on 214,000 replacement semiconductors.

Finding the precise solid state replacement part is as easy as opening one book: the RCA SK Guide.

Inside you'll find listings for making over 214,000 solid state replacements, using some 2900 quality-built RCA SK and KH types. From transistors and thyristors to integrated circuits and microprocessors. All cross-referenced so you can replace original parts of all makes, quickly and easily.

Whatever your responsibility — power generation, chemical processing, telephone systems, hospital/medical equipment, or process control — this is one book your fingers will turn to automatically.

To get your SK Guide (SKG202E), see your local RCA SK Distributor. Or write: Sales Promotion Services, GE/RCA Distributor and Special Products, 2000 Clements Bridge Road, Deptford, NJ 08096-2088.

CIRCLE 59 ON FREE INFORMATION CARD

RCA SK Replacement Solid State