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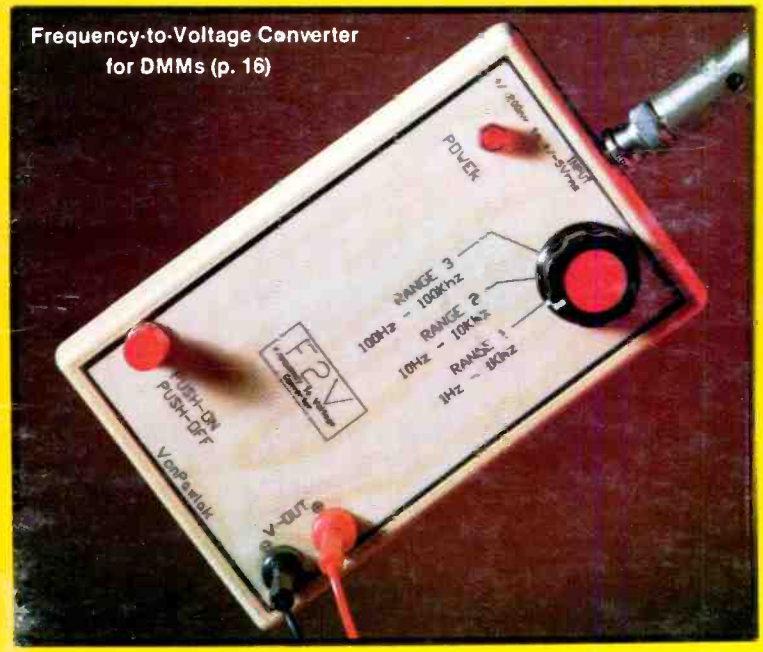

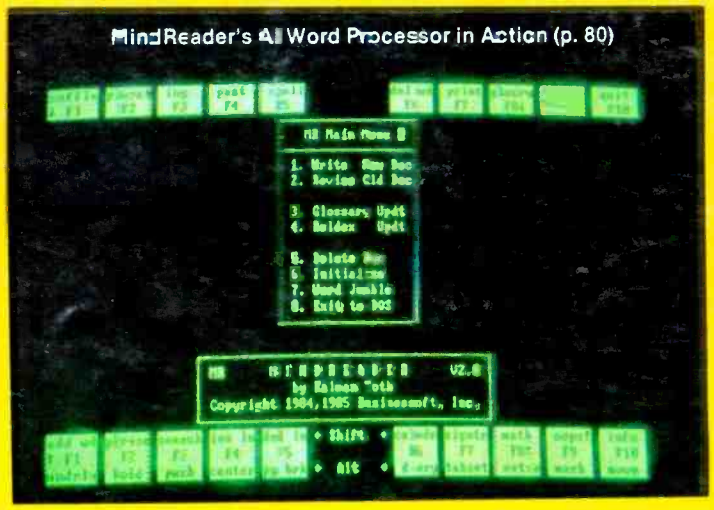

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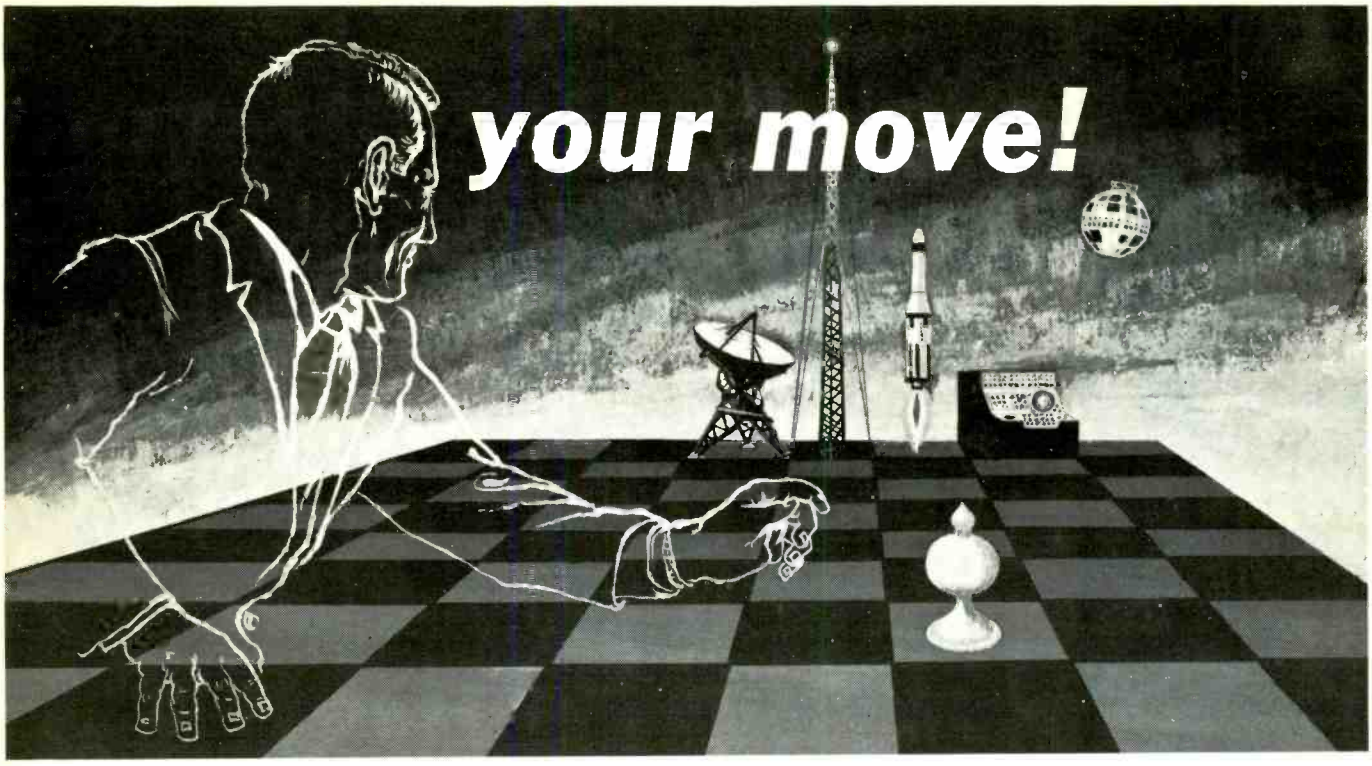

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NOVEMBER 1987 VOLUME 4, NUMBER 11

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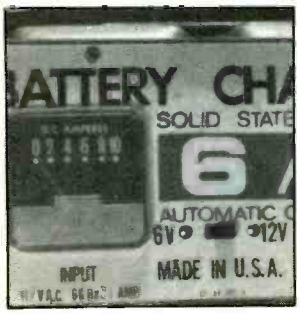

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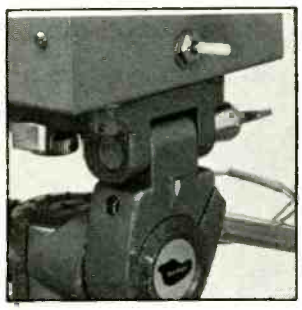

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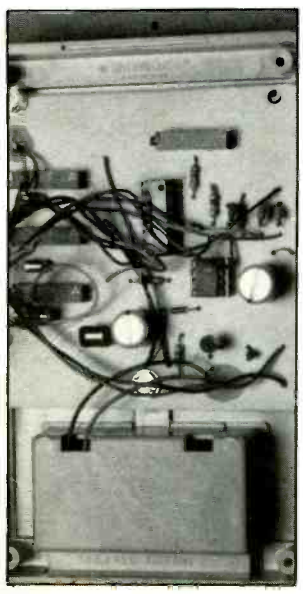

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COLUMNS

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Communications Electronics,™ the world's largest distributor of radio scanners, introduces new models of CB & marine radios and scanners.

NEW! Regency® TS2-RA

Allow 30-90 days for delivery after receipt of order due to the high demand for this product.

List price $499.95/**CE price $339.95**

12-Band, 75 Channel • Crystalless • AC/DC

Frequency range: 29-54, 118-175, 406-512, 806-950 MHz.

The *Regency* TS2 scanner lets you monitor Military, Space Satellites, Government, Railroad, Justice Department, State Department, Fish & Game, Immigration, Marine, Police and Fire Departments, Aeronautical AM band, Paramedics, Amateur Radio, plus thousands of other radio frequencies most scanners can't pick up. The *Regency* TS2 features new 40 channel per second *Turbo Scan*™ so you wont miss any of the action. Model **TS1-RA** is a 35 channel version of this radio without the 800 MHz. band and costs only $239.95.

Regency® Z60-RA

List price $299.95/**CE price $148.95/SPECIAL**

8-Band, 60 Channel • No-crystal scanner

Bands: 30-50, 88-108, 118-136, 144-174, 440-512 MHz.

The *Regency* Z60 covers all the public service bands plus aircraft and FM music for a total of eight bands. The Z60 also features an alarm clock and priority control as well as AC/DC operation. Order today.

Regency® Z45-RA

List price $259.95/**CE price $139.95/SPECIAL**

7-Band, 45 Channel • No-crystal scanner

Bands: 30-50, 118-136, 144-174, 440-512 MHz.

The *Regency* Z45 is very similar to the Z60 model listed above however it does not have the commercial FM broadcast band. The Z45, now at a special price from Communications Electronics.

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List price $799.95/**CE price $329.95/SPECIAL**

16 Channel • 25 Watt Transceiver • Priority

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Bearcat® 50XL-RA

List price $199.95/**CE price $114.95/SPECIAL**

10-Band, 10 Channel • Handheld scanner

Bands: 29.7-54, 136-174, 406-512 MHz.

The *Uniden Bearcat* 50XL is an economical, handheld scanner with 10 channels covering ten frequency bands. It features a keyboard lock switch to prevent accidental entry and more. Also order the new double-long life rechargeable battery pack part # **BP55** for $29.95, a plug-in wall charger, part # **AD100** for $14.95, a carrying case part # **VC001** for $14.95 and also order optional cigarette lighter cable part # **PS001** for $14.95.

PC 22

NEW! Scanner Frequency Listings

The new Fox scanner frequency directories will help you find all the action your scanner can listen to. These new listings include police, fire, ambulances & rescue squads, local government, private police agencies, hospitals, emergency medical channels, news media, forestry radio service, railroads, weather stations, radio common carriers, AT&T mobile telephone, utility companies, general mobile radio service, marine radio service, taxi cab companies, tow truck companies, trucking companies, business repeaters, business radio (simplex) federal government, funeral directors, veterinarians, buses, aircraft, space satellites, amateur radio, broadcasters and more. Fox frequency listings feature call letter cross reference as well as alphabetical listing by licensee name, police codes and signals. All Fox directories are $14.95 each plus $3.00 shipping. State of Alaska–**RL019-1**; Baltimore, MD/Washington, DC–**RL024-1**; Chicago, IL–**RL014-1**; Cleveland, OH–**RL017-1**; Columbus, OH–**RL003-2**; Dallas/Ft. Worth, TX–**RL013-1**; Denver/Colorado Springs, CO–**RL027-1**; Detroit, MI/ Windsor, ON–**RL008-2**; Fort Wayne, IN /Lima, OH– **RL001-1**; Houston, TX–**RL023-1**; Indianapolis, IN–**RL022-1**; Kansas City, MO/ KS–**RL011-2**; Los Angeles, CA–**RL016-1**; Louisville/Lexington, KY–**RL007-1**; Milwaukee, WI/Waukegan, IL–**RL021-1**; Minneapolis/St. Paul, MN–**RL010-2**; Nevada/E. Central CA–**RL028-1**; Oklahoma City/Lawton, OK–**RL005-2**; Pittsburgh, PA/Wheeling, WV–**RL029-1**; Rochester/ Syracuse, NY–**RL020-1**; Tampa/St. Petersburg, FL–**RL004-2**; Toledo, OH–**RL002-3**. A regional directory which covers police, fire ambulance & rescue squads, local government, forestry, marine radio, mobile phone, aircraft and NOAA weather is available for $19.95 each. **RD001-1** covers AL, AR, FL, GA, LA, MS, NC, PR, SC, TN & VI. For an area not shown above call Fox at 800-543-7892 or in Ohio 800-621-2513.

Regency® Informant™ Scanners

Frequency coverage: 35-54, 136-174 406-512 MHz.

The new *Regency* Informant scanners cover virtually all the standard police, fire, emergency and weather frequencies. These special scanners are preprogrammed by state in the units memory. Just pick a state and a category. The Informant does the rest. All Informant radios have a feature called *Turbo Scan*™ to scan up to 40 channels per second. The **INF1-RA** is ideal for truckers and is only $249.95. The new **INF2-RA** is a deluxe model and has ham radio, a weather alert and other exciting features built in for only $324.95. For base station use, the **INF5-RA** is only $199.95 and for those who can afford the best, the **INF3-RA** at $249.95, is a state-of-the-art, receiver that spells out what service you're listining to such as Military, Airphone, Paging, State Police, Coast Guard or Press.

Regency® HX1500-RA

List price $369.95/**CE price $218.95**

11-Band, 55 Channel • Handheld/Portable Search • Lockout • Priority • Bank Select Sidelit liquid crystal display • EAROM Memory Direct Channel Access Feature • Scan delay

Bands: 29-54, 118-136, 144-174, 406-420, 440-512 MHz

The new handheld *Regency* HX1500 scanner is fully keyboard programmable for the ultimate in versatility. You can scan up to 55 channels at the same time including the AM aircraft band. The LCD display is even sidelit for night use. Includes belt clip, flexible antenna and earphone. Operates on 8 1.2 Volt rechargeable Ni-cad batteries (not included). Be sure to order batteries and battery charger from the accessory list in this ad.

Bearcat® 100XL-RA

List price $349.95/**CE price $178.95/SPECIAL**

9-Band, 16 Channel • Priority • Scan Delay Search • Limit • Hold • Lockout • AC/DC

Frequency range: 30-50, 118-174, 406-512 MHz

Included in our low CE price is a sturdy carrying case, earphone, battery charger/AC adapter, six AA ni-cad batteries and flexible antenna. Order your scanner now.

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PRO540E-RA *Uniden* 40 channel CB Mobile . . . $119.95
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PC22-RA *Uniden* remote mount CB Mobile . . . $99.95
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Bearcat® 800XLT-RA

List price $499.95/**CE price $289.95/SPECIAL**

12-Band, 40 Channel • No-crystal scanner Priority control • Search/Scan • AC/DC

Bands: 29-54, 118-174, 406-512, 806-912 MHz.

The Uniden 800XLT receives 40 channels in two banks. Scans 15 channels per second. Size 9¼" x 4½" x 12½."

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BC 145XL-RA *Bearcat* 16 channel scanner . . . $98.95
BC 175XL-RA *Bearcat* 16 channel scanner . . . $156.95
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R1080-RA *Regency* 30 channel scanner . . . $118.95
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Add $12.00 shipping per shortwave receiver.
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EDITORIAL

Facts on Fax

Sales of facsimile machines are burgeoning. You might think of these fax machines as photocopiers located at great distances away that can replicate a paper document's information over phone lines from one to another. These digitally transmitted signals, from compact fax machines that cost as little as $2,500 for the better ones and less than $1,000 for "personal" models, are a boon for enhancing work efficiency.

Firstly, they're as simple to use as a photocopy machine, so no special training is required. Adding to this, resolution is good; transmission speed is fast; and prices have dropped to about half of what they were in 1980. There are a host of fax boards available for computers, too. Standalones, however, appear to be a better choice, it would seem, since computers require special operator know-how and most of us would rather have a separate fax machine left on 24 hours a day to serve a single unattended purpose than a computer doing the same.

Fax machines have been around a long, long time, of course. They were developed in Great Britain in the mid-1800s, in fact, though not used commercially until Marconi Wireless, among others, transmitted news photos with the system in the 1920s. It wasn't until Japanese manufacturers developed a high-speed digital transmission system that was approved as a standard by CCITT in 1981 that fax sales began to rise dramatically. Japan accounts for half the fax ownership in the world, with about one-million installed, so fax makers, virtually all Japanese, have a good base to build on for production-quantity numbers. The U.S. is catching up, with about 600,000 fax units installed to date.

The motivating force behind the Japan-developed fax machines was the difficulty of typing and transmitting Chinese ideograms, called "kanji," which the Japanese language is written in. Therefore, Telex machines are not as useful in their country as they are here. Moreover, Telex cannot handle graphics.

There are four groups of fax standards approved by CCITT, with Group III being the popular one used by most fax owners. So this is the one to get in order to communicate most widely. If you're planning to buy one (and they're already in department store catalogs), you'll likely want a separate phone line for it, so figure that into the cost. Also, you'll be faced with buying decisions between brands (Sharp, Canon, NEC, etc.) and various models in each line. Do you want plain paper or thermal paper capability? Higher speed? Greater resolution for transmitting halftone photos? Stack feeding? Legal-size paper capacity? LCD readouts? Automatic size reduction? And so on. Just as with any product line, you pay more for extras, naturally.

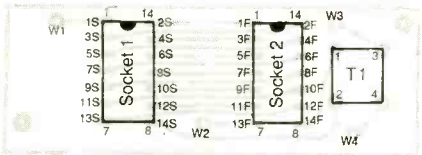
There are fax phone directories available, and even a directory assistance system with a 350,000 telephone entry data base. Since one pays for only standard phone time, and 20 seconds/page transmission time is not unusual, it can save a lot of money compared to air express . . .and a day's wait. We haven't got a fax machine yet, but we're giving it some thought. By next year, we think you will, too.

Art Salsberg

LETTERS

Communications Feedback

• In reading over my "AM Broadcast-Band Loop Antenna" (September 1987) article, I noted a couple of errors. The first is in the fifth line of the third column on page 56, which should read "maximize" instead of "minimize"; on page 60, the second sentence should read "the ungrounded side," instead of "the grounded side." The other is in the Fig. 9



nS = Conductor number Start
nF = Conductor number Finish

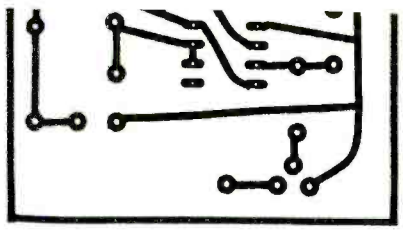
wiring guide, the corrected version shown here. Note also that the etching-and-drilling guide is shown from the *component* side and must be flopped before using it to make a pc board. Also, it should be understood that under "Checkout and Use," the antenna circuit (points W3 and W4) must be directly connected (temporarily) to the receiver's external antenna and ground terminals.

Brad Thompson

A Visual Difference

• I am interested in building the "Audible Target" (September 1987), but am confused by the differences between the schematic diagram and wiring guide. In one or the other, C1 appears to be in the wrong place. Can you please tell me which is incorrect and what must be done to correct it?

Robert E. Merrick
Thornton, PA



The schematic is correct. In the wiring guide, C1 should be installed in the two holes shown to the left of R1 and there should be a jumper wire installed in the holes that are now labeled C1. Also, there is a slight error in the etching-and-drilling guide. The affected lower portion of the guide is shown corrected here.—Ed.

Two to Tango

• I am very interested in your article by Walter Schopp on EPROMs. The issue I have is part 2. Do I need the previous issue to make the programmer? A lot of questions need to be answered. This was my first time reading ME. I think the magazine is great and very helpful! The articles are informative and very friendly. I have already ordered my subscription. Keep up the good work. If I need the back issue to complete the programmer, do I order it directly from you?

Brian Reid
Fort Washington, MD

Yes, you must have Part 1 (Feb. 1987), which describes construction of the basic EPROM programmer upon which Part 2 is based. Back issues are available at this office for $2.50 each.—Ed.

MODERN ELECTRONICS NEWS

NEW INSTRUMENT BUS PROPOSED. The IEEE-488 bus has been around for some ten years now, and has been the standard for interfacing electronic instruments to computers for almost as long. Now, however, with the support of a handful of companies, including the developer of the old bus, Hewlett-Packard, a proposed VXIbus (VMEbus Extensions for Instruments) has been made. It's said that the new proposed standard offers an open architecture design and is generally more capable than the existing instrument interface standard.

A FACSMILE SCRAMBLER. Facsimile machines are the hot electronic products now, with "personal" ones for under $1,000 coming on to the market. Sharp, in fact, has a memo-size one (up to 5½" x 4½") that lists for $899, and transmits documents via phone (built-in) in a reported 20 seconds. There are even a host of facsimile boards that plug into personal computers. Now we've also got a facsmile scrambler being marketed. The Model FSR 1000 from CCS Communication Control (Port Chester, NY) uses a data encryption algorithm to secure documents, correspondence or schematics before they're transmitted over the phone networks. It installs between fax machine and phone line. The compact interface has a clear/private mode switch.

HEATH/ZENITH SPREADS RETAIL WINGS. You normally buy Heath/Zenith products through its mail-order catalogs or at Heath/Zenith Computers & Electronic Centers. Now you'll be seeing the brand--at least for its home security product line--at hardware, home center and electronics stores around the country, as the Heath Company broadens distribution.

COMPACT DISC VIDEO. CD-V is moving along, with Spinnaker Software releasing its first compact Disc Video product: Agatha Christie: The Scoop. A VHS tape version is also being readied. Playing the Scoop on a CD-V player, viewers can switch tracks at specified points to uncover clues. There are more than 200 different paths through the game to keep owners' crime-detection play going for a long time.

APPLE COMPUTER HAPPENINGS. Support for Macintosh computers continues strongly. Apple Computer introduced new software to enhance its Macs, including the HyperCard personal toolkit that lets users customize and create information in new ways, including authoring and using English-language commands and extending Mac power to music, voice and animation. Also, a multitasking operating system called MultiFinder gives users new performance flexibility, allowing document printing to be done while continuing work on other tasks and integrating information between different operating systems (such as MS-DOS)....Letraset unveiled its newest Ready Set Go!, Version 4.0, page layout program for Macs. It adds more than 80 new features, such as arbitrary runarounds, high-resolution graphic support, interactive facing pages and custom page sizes up to 99" x 99", as well as an enhanced spelling dictionary, specification sheets, and more....A new version of LogicWorks, Ver. 1.3, a popular circuit-design package, adds logic-analyzer timing diagram output, an unlimited number of circuit windows that can be opened, and a host of other features. The $200 package includes basic 7400 libraries, analog and LSI symbol libraries. Capilano Computing (Bellevue, WA) also released a low-cost Programmable Logic Device compiler for designing logic chips in a Pascal-like language and verifying circuit operation on screen. Once the circuit logic is known to be correct, it can be programmed into a real chip.

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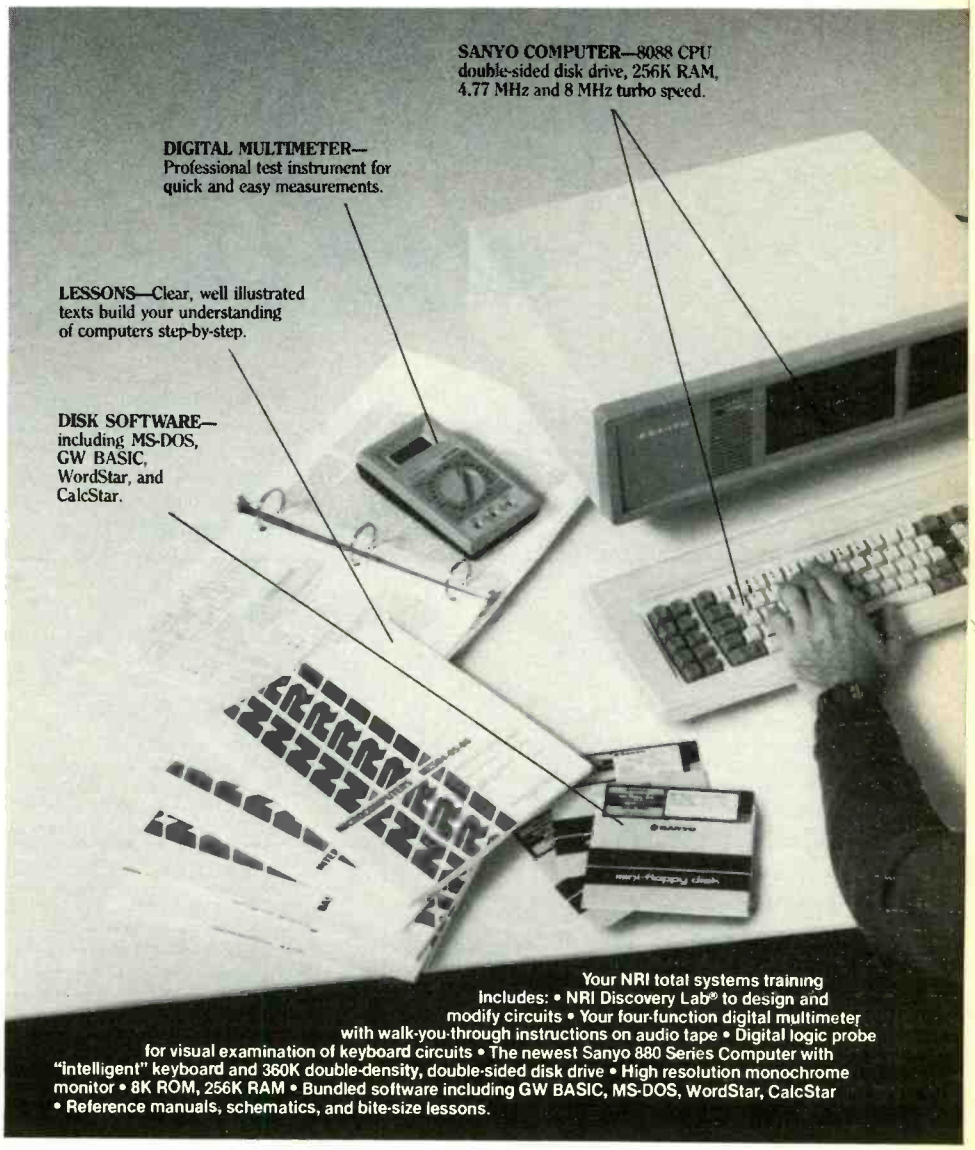

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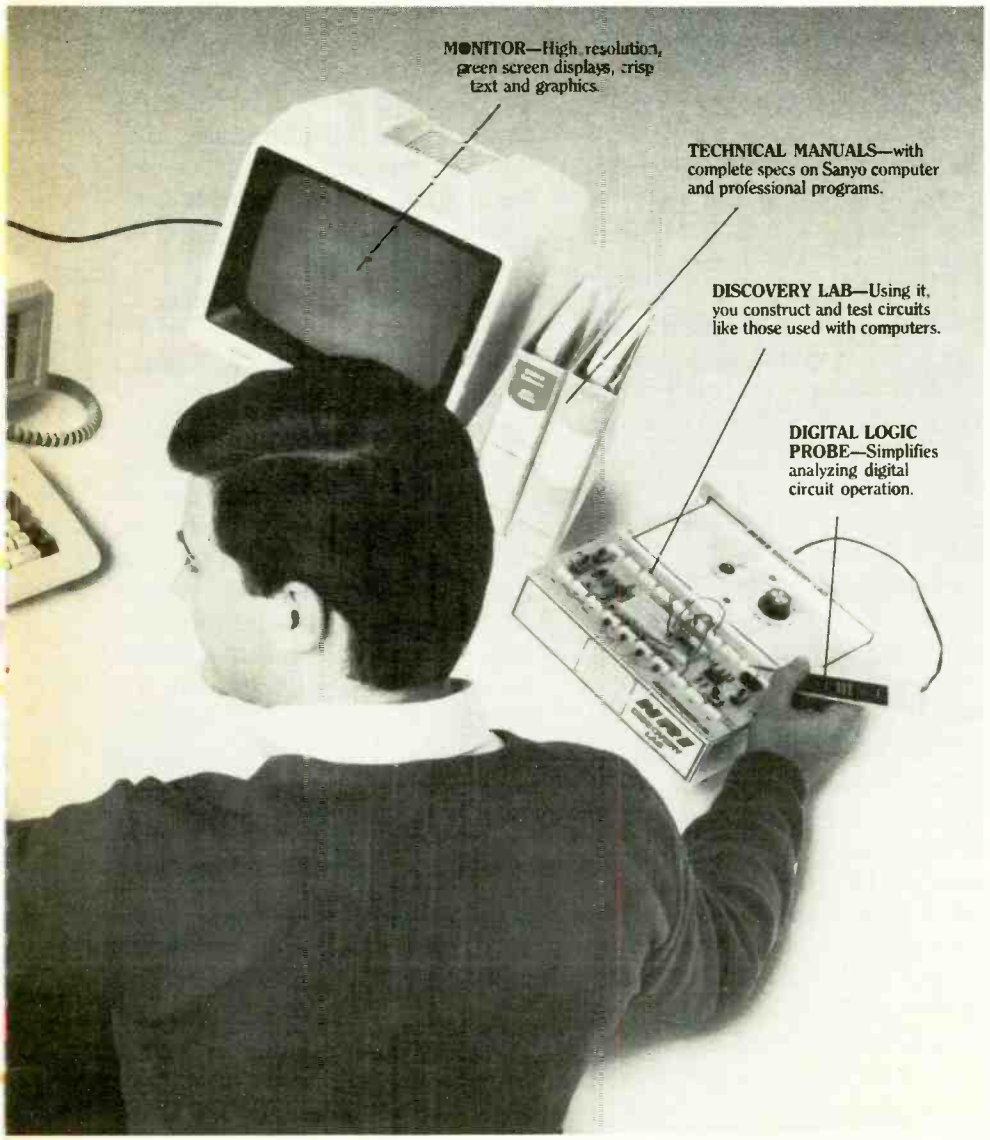

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EPROM Programmer

Logical Devices (Ft. Lauderdale, FL) "Shooter" is a low-cost stand-alone EPROM programmer with memory upgrade. The new Shooter operates with a 256K-bit (32K × 8) internal RAM buffer or an optional 512K-bit (64K × 8) buffer and programs EPROMs from 2716 through 27512, including CMOS and "A" version EPROMs. Among the programmer's features are a number

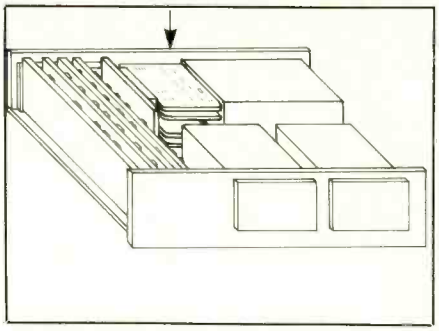
that are typically found only in higher-priced programmers. The programmer interfaces with any computer, dumb terminal or modem via a standard RS-323 serial port. It uploads/downloads Intel/Motorola/Straight/ASCII/binary file formats, uses fast, intelligent algorithms, and has built-in debug firmware that permits RAM editing and display on a terminal. As a stand-alone programmer, the Shooter directly copies and verifies EPROMs.

The programmer is powered by an external wall-mount transformer. It is packaged in a low-profile steel enclosure. $395 with 256K RAM; $199 for 512K RAM option.

CIRCLE 61 ON FREE INFORMATION CARD

IBM PC Bus Slot Extender

Addcard from Merak Industries (Warren, NJ) offers a cleverly de-



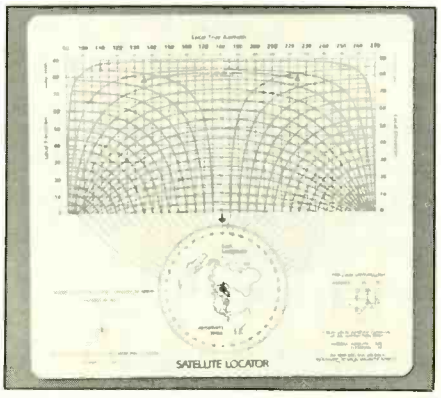
signed, low-cost way of adding expansion slots to the standard five in true IBM PCs. When installed in the computer, it makes available eight total slots within the system unit. Plugged into the slot nearest the power supply, it uses a normally wasted area in which to mount four standard half-cards. (These cards reside in the same space that was used in the XT for its short slots.)

Expansion cards plugged into the Addcard operate as direct extensions of the PC bus, ensuring full compatibility. No external cabinet is required, and no alterations have to be made to the system. A variety of cable adapters are available for cards that require D-shell connectors to connect to external devices. $79.

CIRCLE 62 ON FREE INFORMATION CARD

Satellite-Locator Slide Rule

A slide rule that gives azimuth/elevation angles for geosynchronous satellites in space from almost anywhere on Earth is available from WTS Products (Tulsa, OK). The all-in-one slide rule includes: visual representation of the full satellite arc, horizon to horizon, around the world, even from the southern hemi-



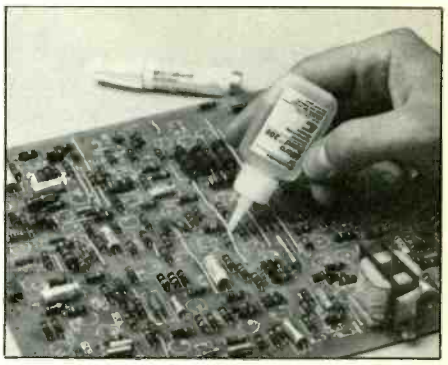
sphere, with local azimuth and elevation angles; U.S. satellite longitude positions; magnetic declination map of the U.S.; true-to-magnetic azimuth conversion; and AZ/EL formulas for greater precision.

With this slide rule, a user can quickly determine azimuth/ elevation angles from anywhere on Earth from which the satellite arc is visible. A magnetic declination map and a true/magnetic slide rule on the back permits true azimuth to be converted to local magnetic azimuth. The AZ/EL formulas printed on the back of the slide rule provide more precise angle computation with an electronic calculator. $10.

CIRCLE 63 ON FREE INFORMATION CARD

PC Board Tack Kit

Chemtronics' (Hauppauge, NY) new Micro Bond Tack Kit is designed for printed-circuit board repair work. The Kit consists of a 5-ounce no-spill squeeze bottle of Micro Bond No. 200 cyanoacrylate adhesive, a Teflon applicator needle and a Micro Bond activator pen. It provides fast, reliable wire tacking and component bonding to pc boards to produce a

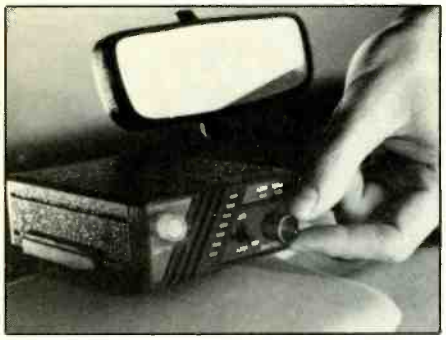


low PCB profile that prevents damage due to sagging wires or loose components. Each Micro Bond Kit contains enough adhesive for 800 to 1,000 drops or "tacks."

CIRCLE 64 ON FREE INFORMATION CARD

Compact Radar Detector

Regency Electronics' new Informer RD-2 compact dual-superheterodyne X/K-band radar detector measures only 4 13/16"D × 3 3/16"W ×



1½"H but offers a full range of features and performance. It provides drivers with three distinct warning signals when a radar signal is detected: an indicator that lights, an attention-getting audio tone and a LED field-strength meter that shows the relative strength of the detected radar signal. The detector is designed for accurate, reliable long-range reception on X-band signals on 10.525 GHz and K-band signals on 24.150 GHz. Discrete logic circuitry is said to eliminate false triggering from interfering signals from nearby microwave relay stations, radar garage door openers, aircraft radar, etc. A single power switch/volume control turns on the detector and adjusts the volume of the warning tone.

A highway/city switch lets the driver select unfiltered sensitivity for highway travel or filtered sensitivity for urban travel. In the "highway" position, a "highway" indicator lights to alert the driver.

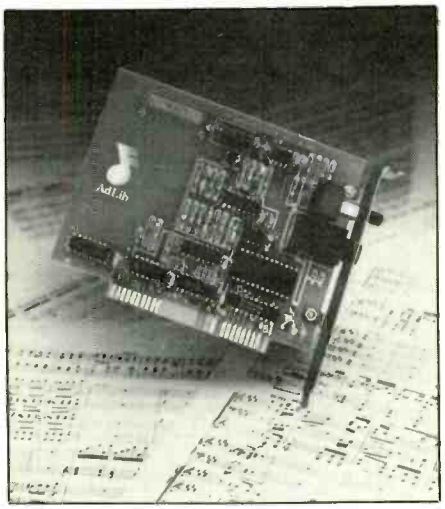
The radar detector comes with a power cord that plugs into a dashboard cigarette lighter receptacle and a universal mounting bracket. The easily installed detector can be mounted on a sun visor or on a dashboard. $159.95.

CIRCLE 65 ON FREE INFORMATION CARD

PC Music System

New from Ad Lib Inc. (Boston, MA) is the Ad Lib Personal Computer System™ for the IBM PC/XT/AT and compatibles that provides instrument-like sound for music training, composition and playback. It consists of the Ad Lib Music Synthesizer Card, the Ad Lib Visual Composer, a software package for musical composition and a Juke Box song selection program. The half-size Music Synthesizer Card allows the user to create and play back up to six melodic and five percussive instruments simultaneously, allowing a computer to perform as a single musical instrument or a complete orchestra. A headphone jack, an amplifier capable of driving a small bookshelf speaker and a built-in volume control are provided.

Visual Composer enables users with no prior musical knowledge to



create, play back and modify their own musical compositions. Music is composed by selecting an instrument and drawing a line across the screen. Volume, tempo, pitch and instrument features on each track or for any note within a track can be changed. Visual Composer comes with a variety of preprogrammed instrument sounds (drums, flutes, pianos and horns) and accepts monophonic MIDI input for voice-by-voice editing.

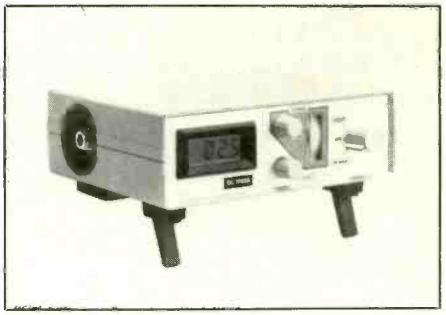
Juke Box enables the user to hear preprogrammed compositions or compositions created with Visual Composer. It features a juke box graphic interface with a turntable that spins while music is being played.

Included in the package is *Composition Projects* #1, a basic guide to composing music. $245.

CIRCLE 66 ON FREE INFORMATION CARD

Digital Power/VSWR Meter

The new Model DC1500A Coline TPI digital power/VSWR meter from Test Probes, Inc. (La Jolla, CA) displays true rms power and VSWR on a 0.5-inch digital numeric LCD display. Frequency coverage is



continuous from dc to 1,500 MHz (1.5 GHz) without the need for plug-in elements. Power measurements are possible up to 100 watts CW or 200 watts with 50-percent duty cycle, with a resolution of 100 milliwatts. VSWR differences of 0.1 are detectable and are displayed over a range of 1:00 to 99:1. An internal 9-volt battery powers the 2.5-pound meter for up to a year. $785.

CIRCLE 67 ON FREE INFORMATION CARD

Digital Sound Converter

Covox's "Speech Thing" is a full-featured digital sound converter that attaches to the parallel printer port of an IBM PC or compatible computer, where it is said to generate

high-quality speech, sound effects and music. The computer's system unit need not be opened to install the Speech Thing, and normal printer operation is not affected. Supplied with the product is an audio amplifier with built-in speaker and headphone jack, software and manual.

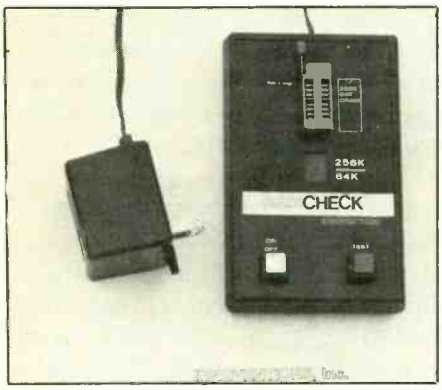
Software consists of a resident

talking appointment calendar, English/Spanish talking calculator, talking game demonstration, music sampler keyboard, graphics-based sound editor, special-effects control panel, and several prerecorded vocabularies suitable for inclusion in user-written programs. Also included is "Smooth Talker," a text-to-speech synthesizer licensed from First Byte. $69.95.

CIRCLE 68 ON FREE INFORMATION CARD

Portable 256K/64K DRAM Tester

Ramcheck from Innoventions, Inc. (Houston, TX) is said to be the first low-cost device that tests and identifies standard 256K and 64K dynamic RAM memory chips. This portable instrument uses a powerful processor to provide fast testing of an entire 256K DRAM within 2.35 seconds.



Chips to be tested plug into a ZIF (zero-insertion-force) socket to eliminate plug/unplug damage to the chip. Only two switches are provided. One turns on and off power to the instrument, while the other initiates the testing sequence. A seven-segment numeric LED display gives fast go/no-go indications, as well as automatic identification of the chip under test. Automatic current limiters prevent damage to a chip that is accidentally plugged into the ZIF socket the wrong way.

Ramcheck measures just 5.75″ × 3.5″ × 1.12″ and weighs less than 1 pound, including its plug-in ac power supply. $199.

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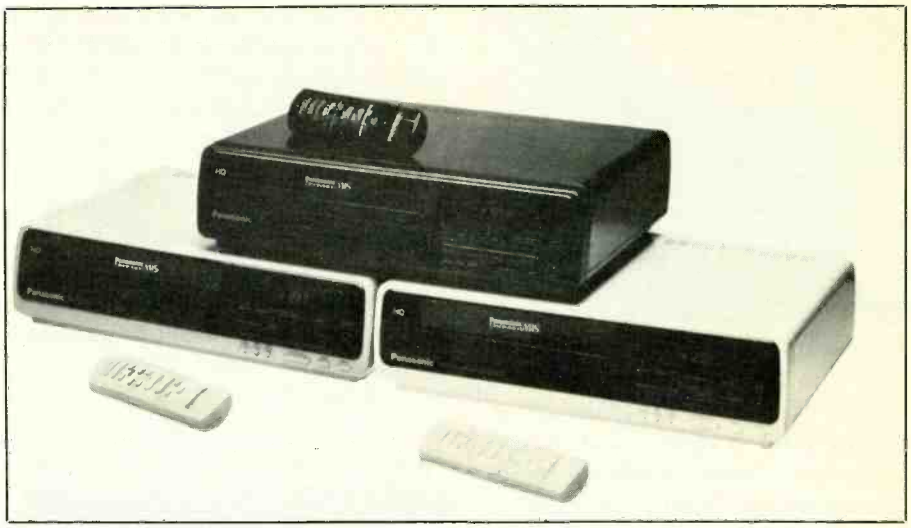

Designer VCRs

Panasonic's new PV-2700 series is a new line of "designer" VHS videocassette recorders that are designed to complement almost any decor. Rounded contours are claimed to soften the presence of the recorder, while cabinets come in dusty rose, ivory and black with gold and silver accents. Complementing the VCRs are the 14-function wireless remote controllers that have rounded lines for better "feel" in the hand and colors that match the VCR cabinets.

On a more technical plane, the series offers 100-channel cable-compatible tuners, high-speed search (at 17-times normal speed in SLP) and automatic power functions. A search-lock feature eliminates the need for the user to continuously hold the controller during scan. Automatic power operations include: automatic power-on when a cassette is inserted into the front-loading bay; automatic rewind; automatic eject; and automatic power off.

CIRCLE 70 ON FREE INFORMATION CARD

Logic Analyzer/Storage Scope Analog Pod

New from Bitwise Designs, Inc. (Troy, NY) is the Analog Pod that enhances the company's Logic-20 family of PC-based logic analyzers. The pod enables simultaneous analysis of both analog and digital signals in the same circuit to provide a logic analyzer and digital storage scope capability on one board inside an IBM PC or compatible computer. Features of the Analog Pod that widen the variety of applications for the Logic-20 Series include: analysis of power supply, transmission line and other noise phenomena in digital systems; debugging data-acquisition and control systems; and monitoring high-speed communication signals.

The Analog Pod replaces the standard eight-channel digital input pod

to provide seven bits of resolution for analog and one bit for digital data. (The 16-channel logic analyzers can use up to two pods to obtain two analog and two digital inputs.) Either synchronous or asynchronous sampling can be performed at rates up to 20 MHz. Input voltage ranges are software selectable with a maximum resolution of 20 mV. $295.

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(Continued on page 91)

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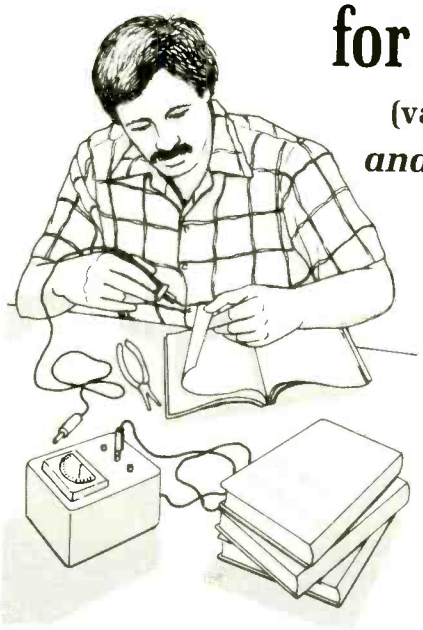

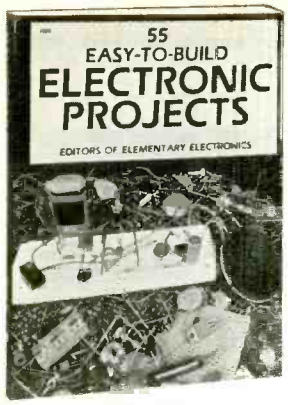

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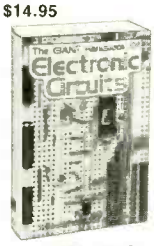

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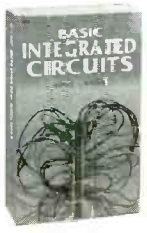

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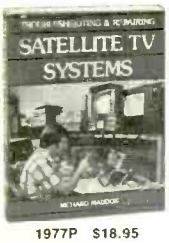

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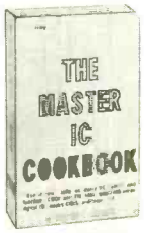

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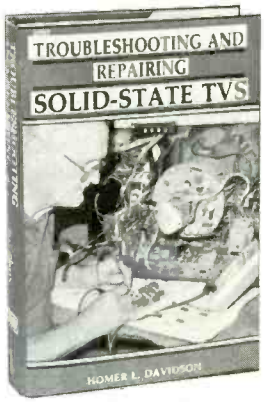

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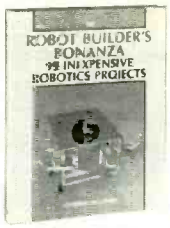

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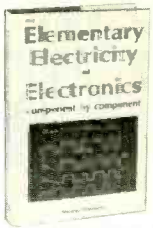

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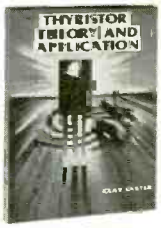

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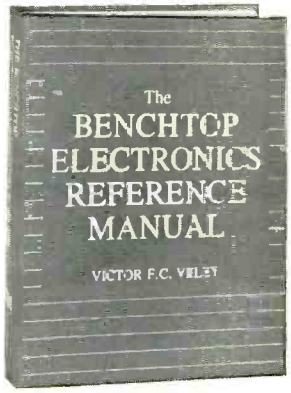

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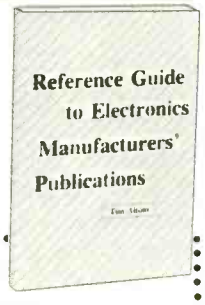

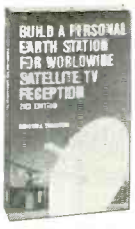

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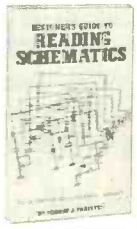

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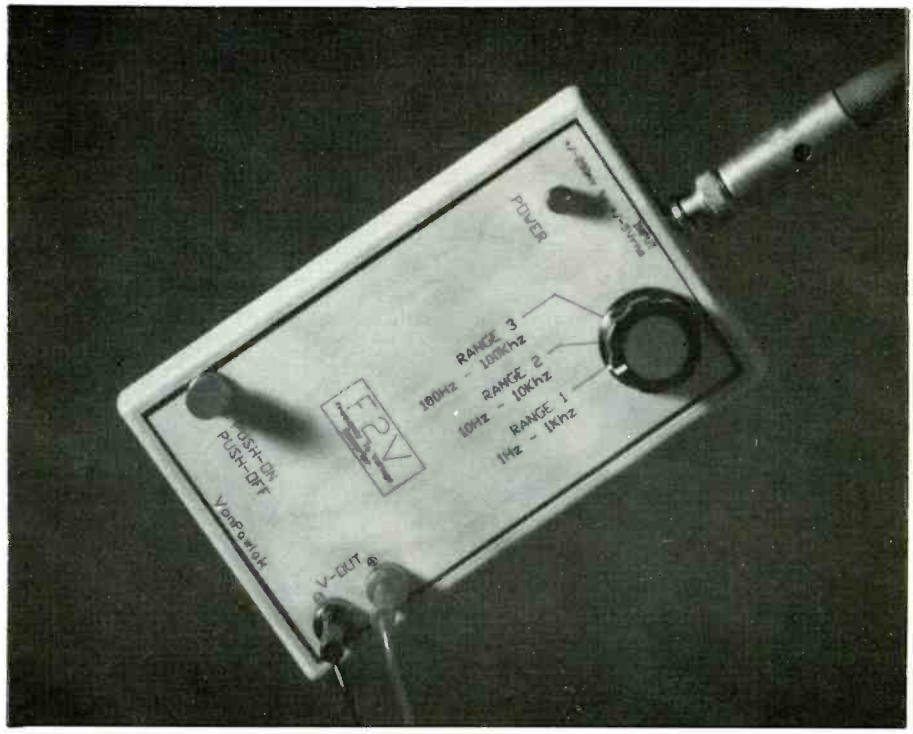
Frequency-Counter Adapter for Digital Multimeters

Adapter enables almost any waveform up to 1 MHz to be read accurately on a DVM or DMM

By Crady VonPawlak



Virtually everyone involved in electronics today owns a digital voltmeter or multimeter. A significant portion of these people would also like to, but do not yet, have a frequency counter. This project can change all this. I will show you how to build an inexpensive, handheld adapter that can provide accurate frequency measurements when plugged into either a DMM or DVM.

The basic adapter is actually a voltage-to-frequency converter. It enables the user to directly read frequencies from 1 Hz to 100 kHz on a DMM. In addition, if you want to accurately measure frequencies up to 1 MHz, you can add an optional subassembly that both conditions the input signal as well as divides it by any number from 2 to 10 to bring it within the range of the converter.

Our F/V converter is a relatively simple device built around a universal voltage-to-frequency/frequency-to-voltage chip from Teledyne Semiconductor. It is about the size of a hand-held DMM and is battery powered for portability. Best of all, you can build it for a fraction of what you would have to pay for a full-blown frequency counter. To provide maximum reading accuracy, the converter accessory should be used with a DMM that has a display with at least 3½ digits. Input sensitivity is about ±200 millivolts to ±15 volts rms without modification.

About the Circuit

As Fig. 1 illustrates, the frequency adapter circuit is really quite simple in terms of component count. Almost all of the circuit's complexity is contained inside the Teledyne 9400CJ universal voltage-to-frequency (V/F) converter chip, shown here as *U1*. This integrated circuit has a guaranteed 0.05-percent linearity, which makes it ideal for upgrading a DVM (or DMM set to a low dc voltage range) to give the latter a frequency-counting capability.

When used as shown in Fig. 1, the 9400CJ chip will accept virtually any waveform shape throughout its 1-Hz to 100-kHz counting range. The only proviso is that a minimum 20-per-

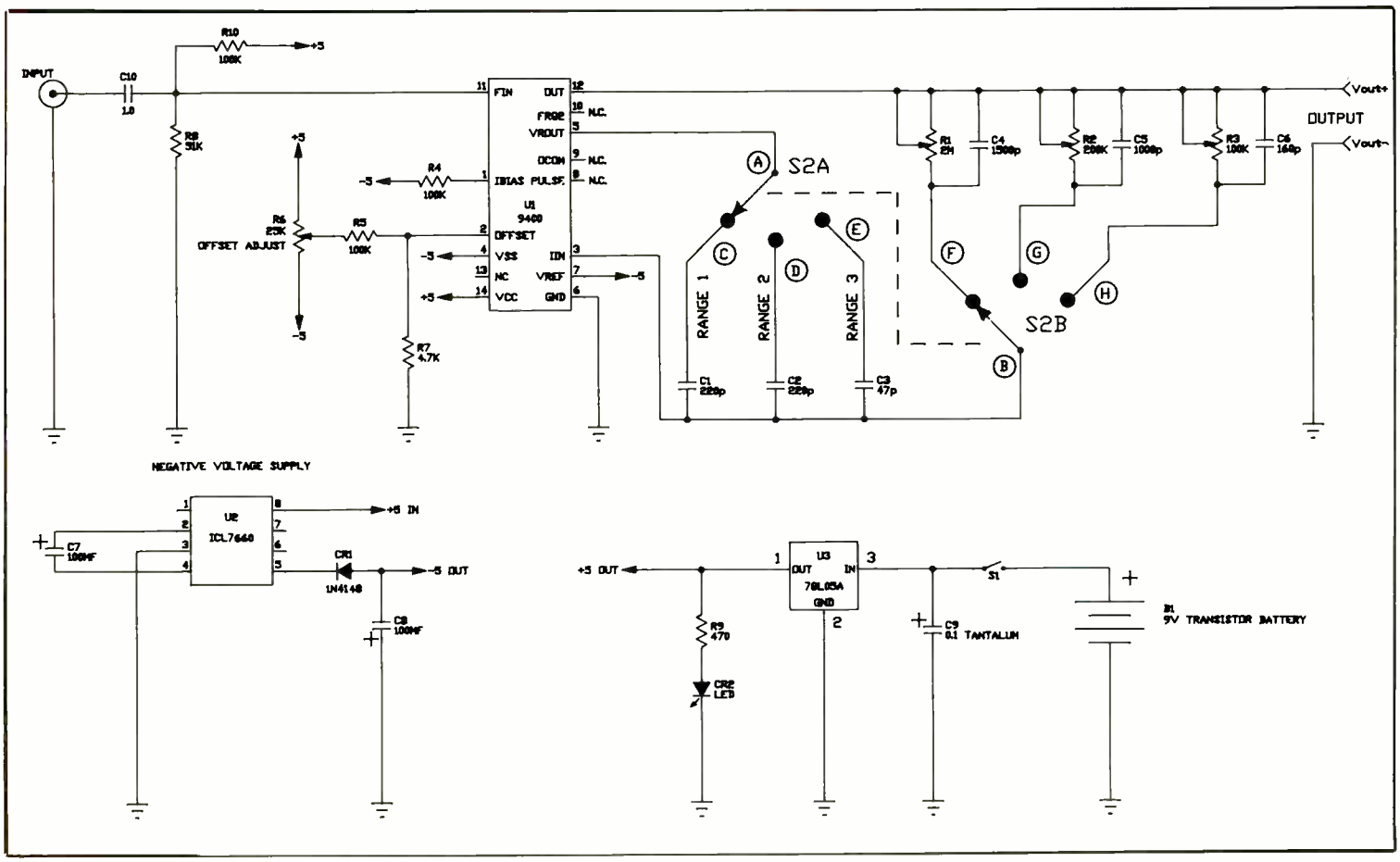


Fig. 1. Schematic diagram of frequency-to-voltage converter, including its split ±5-volt battery power supply.

cent duty cycle be maintained for the input waveform. Because of this, the 9400CJ is well suited to measuring the outputs from a wide variety of oscillators and clock circuits.

Although the V/F converter can function well with a single supply voltage, use of a ±5-volt split supply is much preferred because this arrangement maintains tight accuracy as delivery of the battery supply used with the project drops to about 6.5 volts. Hence, a split supply increases overall circuit stability and prolongs battery life. Ideally, an 8-volt or so nickel-cadmium battery supply could be used with this circuit, along with a simple charger circuit to restore the charge on the battery as needed.

In the Fig. 1 circuit, the positive rail of the power supply is maintained at +5 volts with fixed +5-volt regulator *U3*. The negative rail of the supply is obtained by feeding the +5-volt output from *U3* into voltage inverter *U2*. This arrangement yields a well-regulated split supply from one 9-volt battery.

The 9400CJ F/V converter is unique in that it generates an input voltage that is linearly proportional to the input frequency. That is, whatever numbers appear in the display of the dc voltmeter with which it is used will be the absolute numeric value of the waveform being counted, though you will have to mentally multiply the reading by some convenient figure (×1K on Range 1, ×10K on Range 2 or ×100K on Range 3 for the arrangement shown in Fig. 1). Consequently, if switch *S2* is set to range 1 and the meter displays 1.234 volts, the measured frequency would be 1.234 × 1,000, or 1,234 Hz. If *S2* is set to Range 2 or Range 3 and the voltage displayed on the meter remained the same, the actual frequency would be multiplied by 10,000 (Range 2) or 100,000 (Range 3) to yield 12,340 or 123,400 Hz, respectively.

Shown in Fig. 2 are the internal details of the 9400CJ chip. In operation, each time the waveform applied to the input of the chip passes through zero at the comparator's noninverting (+) input, reference capacitor C_{ref} charges to the reference voltage. This charge is applied to integrating resistor R_{int} to produce voltage pulses at the output of the amplifier. Integrating capacitor C_{int} across R_{int} averages these pulses into a dc voltage that is linearly proportional to the input frequen-

PARTS LIST (Converter)

Semiconductors

CR1—1N4148 or similar switching diode

CR2—Light-emitting diode

U1—9400CJ F/V and V/F converter (Teledyne)

U2—ICL7660CPA voltage inverter (Intersil)

U3—78L05 + 5-volt regulator (National Semiconductor or Motorola)

Capacitors

C1,C2—220-pF, 6-volt ceramic

C3—47-pF ceramic

C4—1,500-pF polypropylene or polyester

C5—1,000-pF polypropylene or polyester

C6—160-pF polypropylene or polyester

C7,C8—100-μF, 16-volt electrolytic

C9—0.1-μF, 25-volt tantalum

C10—1.0-μF Mylar

Resistors (¼-watt, 5% tolerance)

R4,R5,R8—100,000 ohms

R7—4,700 ohms

R9—1,000 ohms

R10—51,000 ohms

R1—2-megohm, 15-turn cermet potentiometer

R2—200,000-ohm, 15-turn cermet potentiometer

R3—100,000-ohm, 15-turn cermet potentiometer

R6—25,000-ohm, 15-turn cermet potentiometer

Miscellaneous

B1—9-volt transistor or 8-volt Ni-Cd battery (see text)

S1—Spst slide, toggle or push-on/push-off switch

S2—2-pole, 3-position nonshorting rotary switch (Radio Shack Cat. No. 275-1386 or similar)

Printed-circuit board; panel-mount female BNC socket for input (Radio Shack Cat. No. 278-105 or similar); red and black banana jacks for outputs; 14- and 8-pin IC sockets; 9-volt battery snap; suitable enclosure (Pactec No. HP-9VB-002 or similar—see text); pointer-type control knob for S2; small-diameter coaxial cable; LED mounting hardware or cement; lettering kit; clear acrylic spray; machine hardware; hookup wire; solder; etc.

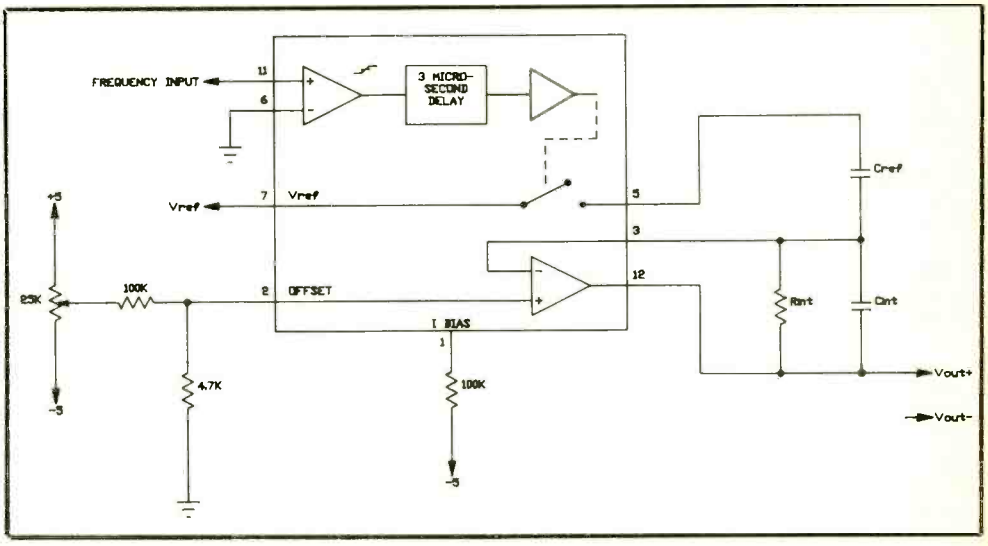


Fig. 2. Internal details of 9400CJ universal voltage-to-frequency/frequency-to-voltage chip that does all the work in this project.

cy. This can be expressed as: $V_{out} = R_{int} \times C_{ref} \times V_{ref} \times$ Frequency. For our application, the ranges are as follows:

	Frequency In (Hz)	Dc Output (Volts)
Range 1	1.0	0.001
(×1000)	500	0.500
	1k	1.000
Range 2	10.0	0.001
(×10K)	5k	0.500
	10k	1.000
Range 3	100	0.001
(×100K)	50k	0.500
	100k	1.000

The F/V converter accessory connects to the meter with which it is to be used via the OUTPUT jacks shown at the top-right in Fig. 1, with VOUT+ going to the meter's "hot" input and VOUT− going to the meter's common or ground input. The waveform whose frequency is to be measured is coupled into the converter via the INPUT jack shown at top-left in Fig. 1.

Greater versatility can be achieved by adding the Fig. 3 circuit to the basic Fig. 1 converter circuit. The Fig. 3 circuit conditions the input signal and gives the basic converter a high sensitivity to low-level signals.

The Fig. 3 circuit precedes the Fig. 1 circuit. In this circuit, CA3130 high-speed comparator *U1*, with hysteresis and adjustable threshold, gives the front end of the converter accessory a high sensitivity. Added insurance is provided by overvoltage diodes *CR1* and *CR2*.

CMOS decade counter/divider *U3*, a CD4017BC integrated circuit, has selectable outputs. By setting *S1* to the appropriate position, the input frequency can be divided down by a factor of 2, 3, 4, 5, 6, 7, 8, 9 or 10 before being coupled into the converter accessory. This feature greatly enhances the accessory, allowing it to measure frequencies to 1 MHz.

Note that this circuit has two outputs. The lower (DIVIDED) output couples the signal to be measured to the converter accessory after it has gone through the entire conditioning/dividing arrangement. However, should only the comparator's conditioning and overvoltage protection be required, the upper (UNDIVIDED) output can be used instead.

CMOS hex Schmitt-trigger inverter *U2*, a CD14106BC device, serves three purposes in the Fig. 3 circuit. Firstly, it cleans up the output from

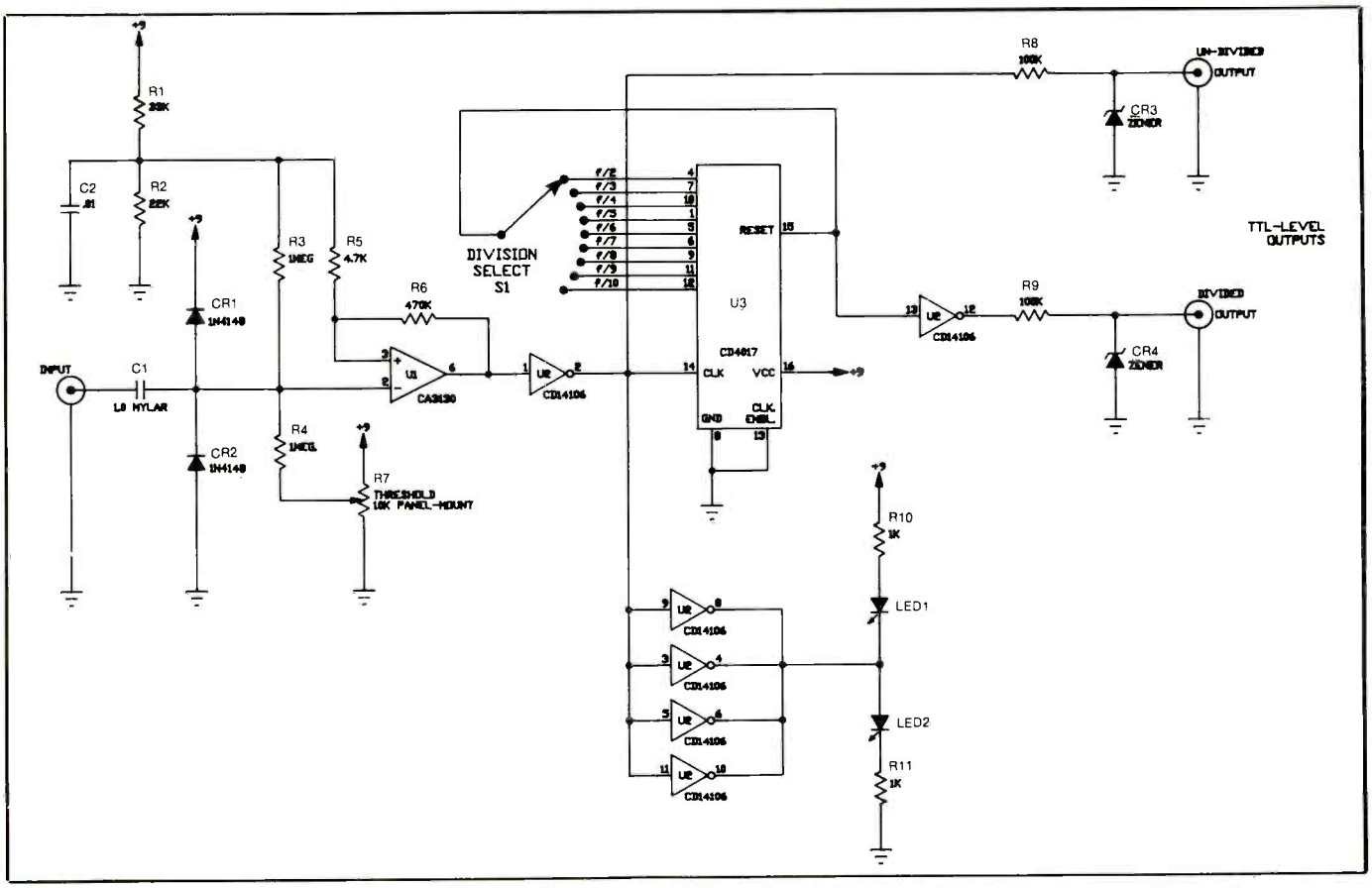


Fig. 3. An optional input signal-conditioner/frequency-divider circuit that can be used to increase the performance of the basic F/V converter.

U1 to provide a glitch-free square wave to the clock input of *U3*. Secondly, three inverters are connected in parallel to provide sufficient drive current to drive "signal present" light-emitting diodes *LED1* and *LED2*, which give a visual indication of the triggering action of *U1*. (Proper triggering is indicated when both LEDs are flashing or appear to be continuously on.) Finally, the last inverter changes the polarity of the low duty-cycle pulses from *U3* into the higher duty-cycle waveform required by the converter accessory.

Ideally, the Fig. 3 circuit should also be powered from a 9-volt battery. The only consideration here is that the final output must remain at a constant TTL level (switch between 0 and 5 volts) to insure compatibility with a wide array of test equipment. This is most easily accomplished with the zener diodes that immediately precede both outputs.

PARTS LIST (conditioner/divider)

Semiconductors
CR1,CR2—1N4148 switching diode
CR3,CR4—4.7-volt, 1-watt zener diode
LED1,LED2—Light-emitting diode (one red, one green)
U1—CA3130 high-speed comparator
U2—CD4106 hex inverter/buffer
U3—CD4017 decade counter/divider with selectable outputs

Capacitors
C1—0.01-μF disc
C2—1.0-μF Mylar

Resistors (¼-watt, 5% tolerance)
R1—33,000 ohms
R2—22,000 ohms
R3,R4—1 megohm
R5—4,700 ohms
R6—470,000 ohms
R8,R9—1,000 ohms
R10,R11—100,000 ohms
R7—10,000-ohm linear-taper, panel-mount potentiometer

Miscellaneous
S1—10-position, nonshorting rotary switch
Printed-circuit board; suitable enclosure (see text); sockets for ICs; three chassis-mount female BNC connectors; small-diameter coaxial cable; machine hardware; hookup wire; solder; etc.

Construction

Though it is possible to assemble the basic converter using just about any traditional wiring technique, use of a printed-circuit board is highly recommended to ensure operating stability and minimize noise. Fabricate

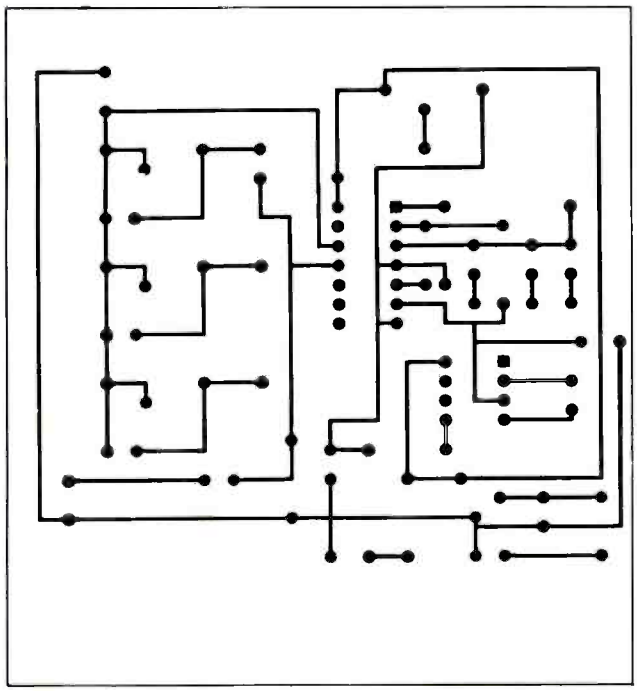


Fig. 4. Actual-size etching-and-drilling guide for F/V converter circuit.

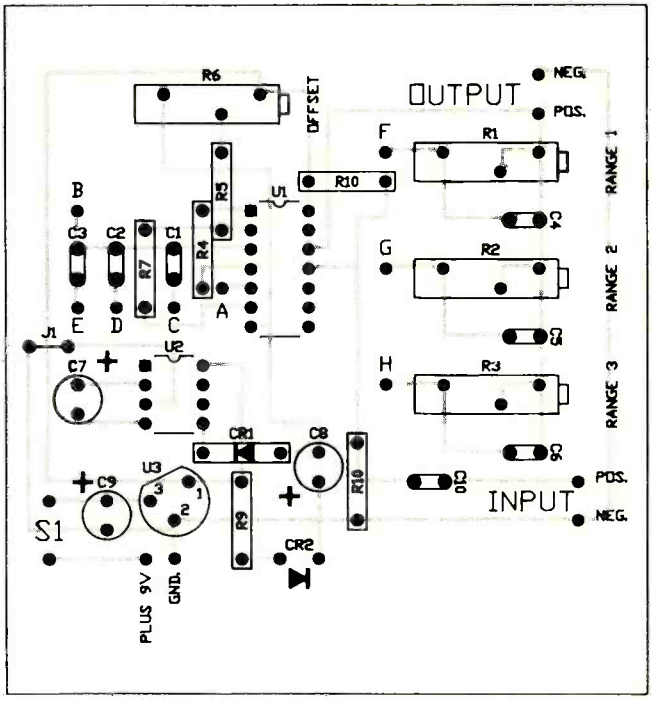


Fig. 5. Wiring guide for F/V converter pc board.

a pc board using the actual-size etching-and-drilling guide shown in Fig. 4.

After etching, drilling and trimming to size the board, wire it exactly as shown in Fig. 5. Begin populating the board by installing and soldering into place the DIP sockets for *U1* and *U2*. If you wish, you can also use a transistor socket for *U3*, though it would probably be easier and better to simply plug the leads of this IC into the U3 holes in the board, solder them to the copper pads and trim off excess length.

Continue populating the board by installing and soldering into place first the resistors and 15-turn trimmer potentiometers. Then proceed with the capacitors and diode. Make sure *C7, C8* and *C9* are properly polarized and *CR1* is properly oriented before soldering their leads to the copper pads.

Install *U2* in its socket (make sure no pins overhang the socket or fold under between IC and socket) and either install *U3* directly on the board or trim its leads to about ½" in length and plug them into the transistor socket. Do *not* install *U1* in its socket at this time.

Install and solder into place a short wire jumper in the location indicated by *J1* in Fig. 5. Use either a cut-off resistor or capacitor lead or a bare solid hookup wire.

Now prepare 12 5" lengths of stranded hookup wire by removing about ¼" of insulation from both ends. Tightly twist together the fine wires at both ends of all wires and sparingly tin with solder. Plug one end of these wires into the POS and NEG OUTPUT and S1 holes (four wires) and solder them to the pads on the bottom of the board. Similarly, plug the remaining eight wires into the holes labeled A through H and solder them into place.

Trim ¾" of outer insulation from both ends of a 5" length of small-diameter shielded cable. Separate or peel the shield back to the insulation at both ends. Then trim ¼" of insulation from the inner conductor at both ends. Tightly twist together the fine wires of the inner conductor and lightly tin with solder. If your cable has a wire-mesh shield, do the same for the fine wires that make it up. Plug the inner conductor and shield at one end of the cable into the holes labeled INPUT POS and NEG, respectively, and solder them into place. When you are finished, there should be two holes, labeled PLUS 9V and the GND near it that are unoccupied.

If you decide to incorporate the optional Fig. 3 conditioner/divider circuit in your project, assemble it now. As with the F/V converter assembly, the recommended wiring medium for the Fig. 3 circuit is a printed-circuit board, the actual-size etching-and-drilling guide (the same size as that for the basic converter assembly) for which is shown in Fig. 6. Once you have fabricated the board, refer to Fig. 7 and mount the three DIP IC sockets—*not* the ICs themselves—in the indicated locations. Then install the two switching and two zener diodes in their respective locations, taking care to properly

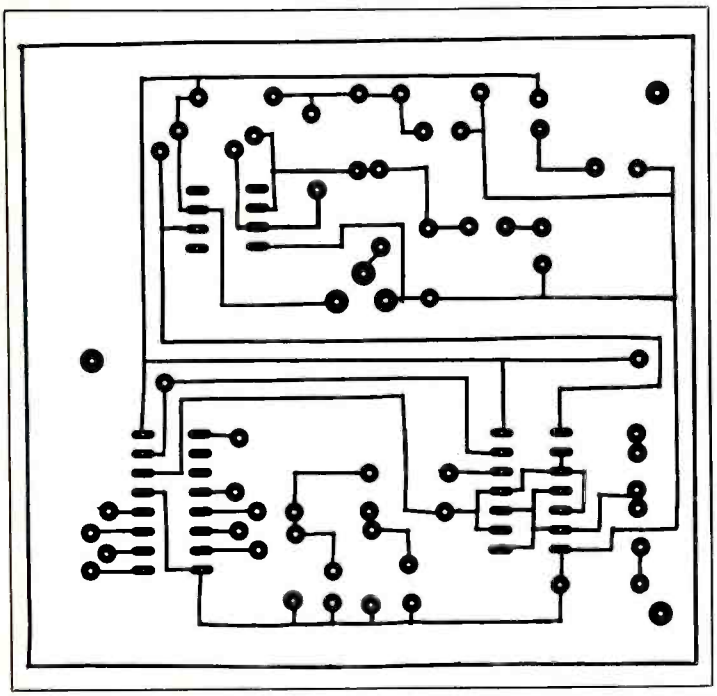


Fig. 6. Actual-size etching-and-drilling guide for conditioner/ divider circuit.

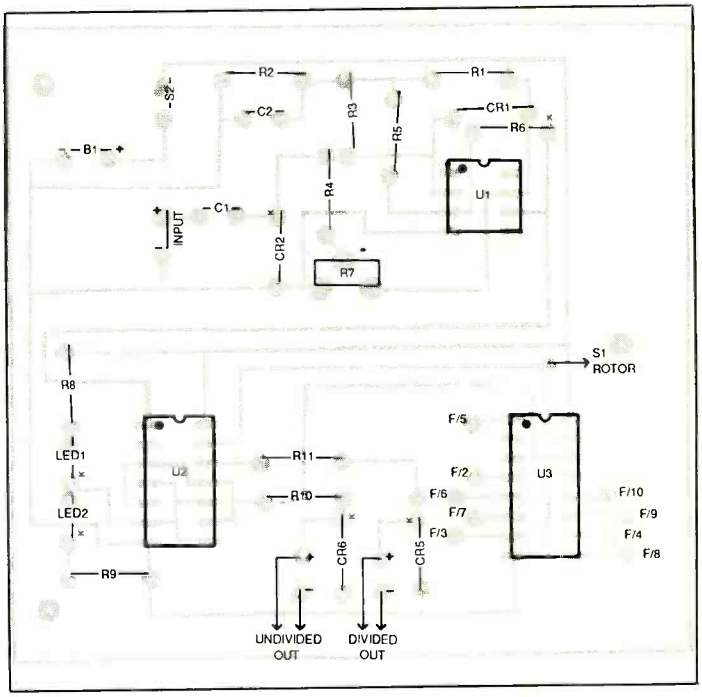


Fig. 7. Wiring diagram for conditioner/divider board.

orient them before soldering their leads to the copper pads. This done, install and solder into place the capacitors and fixed resistors.

Trim to about 5 " length 17 hookup wires and strip from both ends ¼ " of insulation. Install and solder into place one end of each of these wires in the holes labeled F/2 through F10, S1 ROTOR, R7 and LED1. Then prepare three 5 " lengths of small-diameter coaxial cable as described above for the converter assembly. Plug one end of one of these cables into the board holes labeled INPUT with the center conductor in the + and shield in the GND holes and solder into place. Repeat with the other two cables for the UN-DIV and DIV and their nearby GND holes.

Note that the Parts List that accompanies Fig. 1 calls for a PacTec project box to serve as the enclosure for the basic converter accessory. This type of box was selected for the prototype because it has a battery compartment that is large enough to accommodate a 9-volt battery. The compartment has its own separate slide-off cover that eliminates having to remove screws to open the box whenever the battery has to be replaced. If you prefer, you can substitute any other box that is large enough to accommodate the circuit-board assembly and battery in its holder and has enough panel room on which to mount the power and range selector switches, BNC INPUT jack and OUTPUT banana jacks without interference.

If you are planning to build the optional signal-conditioner/divider assembly into the same enclosure with the basic F/V converter, plan on using a larger box. Though the two circuit-board assemblies are the same size and can be stacked to obtain a compact project, the extra switches, panel-mount potentiometer and two LEDs, along with their legends, will require much more layout area on the panel.

When building just the basic F/V converter, it is a good idea to mount the BNC INPUT connector at the top of the box, as shown in the lead photo. You can then mount the rotary RANGE switch on the front panel with the OUTPUT banana jacks spaced well away from it. Machine the enclosure as necessary to facilitate circuit-board assembly and component mounting.

Start final assembly by twisting together the fine wires of each of the battery snap's conductors and lightly tin with solder. Now, assuming you are using the specified PacTec box, feed the free ends of the battery snap connector's conductors through the slot in the battery compartment and plug them into the two unoccupied component holes in the converter board, red to the PLUS 9V hole and black to the GND hole. Solder both connections securely into place.

If you choose a different type of enclosure, one that does not have a separate battery compartment, mount the battery in a clip inside the enclosure proper. (In this event, you might want to substitute a nickel-cadmium battery in place of the stan-

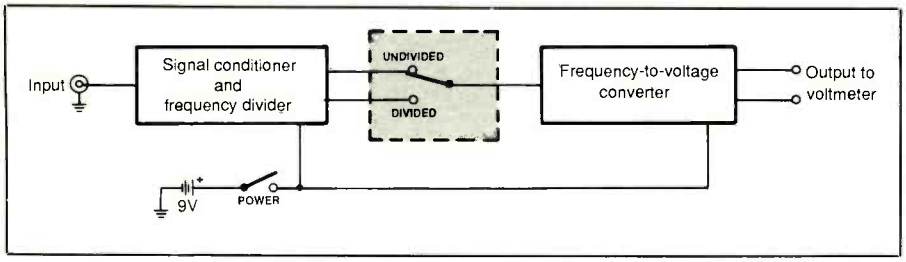


Fig. 8. Switching arrangement permits internal selection of divided or un-divided signal to be fed from output of conditioner/divider into input of F/V converter and eliminates three BNC connectors.

dard non-rechargeable 9-volt transistor battery and incorporate into the project a simple recharging circuit. If you go this route, be sure to include a jack into which the recharging source can plug.)

Once the circuit-board assembly is mounted, mount the BNC connector, banana jacks and the rotary and toggle or slide switches in their respective holes. Make the nut on the switch only finger tight. Place a knob on the shaft of the rotary switch and rotate it through each of its three positions and note where the knob's pointer is aimed for each position. If necessary, readjust the orientation of the switch so that the knob's pointer stops at locations as shown in the lead photo. Securely tighten the nut, without allowing the switch to move as you do so.

Connect and solder the center conductor at the free end of the coaxial cable to the center contact of the BNC connector. Then connect and solder the shield to the connector's ground lug. Next, connect and solder the free end of OUTPUT POS wire to the red banana jack and the OUTPUT NEG wire to the black banana jack. Finally, connect and solder the free ends of the remaining wires to the rotary switch, referring back to Figs. 1 and 5 for details.

Snap a 9-volt battery into its connector and set the POWER switch to ON. Use a meter to measure the voltages at the pins of *U1*'s socket. With the meter's common lead connected to circuit ground (pin 6 of *U1*), you should obtain the following readings: + 5 volts at pin 14 and − 5 volts at pins 1, 4, 7 and 11. If everything checks out this far, set the POWER switch to off. Plug *U1* into its socket (observe orientation), making sure that no pins overhang the socket or fold under between IC and socket.

After assembling the project, label its connectors, range switch and power switch with appropriate legends. The lead photo gives one suggested way of arranging the legends for the basic F/V converter accessory.

Assuming you have decided to build the optional signal-conditioner/frequency-divider circuit shown in Fig. 3 proceed as follows. First prepare a printed-circuit board on which to mount its components, using the actual-size etching-and-drilling guide shown in Fig. 6. When the board is ready, mount DIP sockets in the U1, U2 and U3 locations shown in the Fig. 7 wiring diagram. Do *not* install the ICs themselves in the sockets at this time.

Plug into the appropriate holes and solder into place the leads of the fixed resistors and the two capacitors. Then do the same for the switching and zener diodes, making sure to properly orient them before soldering their leads into place.

Now strip ¼ " of insulation from both ends of 17 5 " lengths of hookup wire. Plug one end of 10 of these wires into the holes labeled S1 ROTOR and F/2 through F/10 and solder into place. Plug one end of three more wires into the holes labeled R7 and solder them into place. Do the same with four more wires and the holes labeled LED1 and LED2.

Prepare both ends of three 5 " lengths of small-diameter coaxial cables by removing ¾ " of outer insulation, peeling or separating the shields back to the insulation cut-off points and stripping ¼ " of insulation from the inner conductors. Tightly twist together the fine wires of the inner conductors (and the shield wires if they are mesh) and sparingly tin with solder. Then plug one end of one of these cables into the holes labeled INPUT + (inner conductor) and nearby GND (shield). Repeat with the remaining two cables and the UN-DIVIDED + and DIVIDED + OUTPUT holes and their nearby ground holes.

Tightly twist together the fine wires at the free ends of the battery snap connector and sparingly tin with solder. Plug the free ends of the wires into the holes labeled B1 + (red-insulated wire) and B1 − (black-insulated wire) and solder them into place. This assumes you plan to power the optional conditioner/divider from a separate 9-volt battery. If you plan to use the same battery that powers the basic F/V converter, use hookup wires to bridge from the B1 + and B1 − pads on the optional board to the converter board.

Having wired the conditioner/divider circuit board, you are ready to mount it inside its enclosure. For the stand-alone version, use an enclosure that is large enough to accommodate the circuit-board assembly and a 9-volt battery clip without crowding and has enough panel space for the POWER and DIVISION SELECT switches, two LEDs, THRESHOLD control and whatever INPUT and OUTPUT connectors you decide to use. All connectors should be female BNC types, and all switches, if possible, should be miniature types to conserve space so that the project can be made as compact as possible.

Machine the box as needed and then mount the circuit board assem-

bly. Mount the switches, LEDs and connectors in their respective locations. When you plan your layout, make sure the rotary switches in both modules do not interfere with each other. Also, if you are using a separate 9-volt transistor (or rechargeable Ni-Cd) battery for each circuit board, it is more convenient to use a dpdt slide or toggle switch to power up and down both circuits simultaneously, rather than separate spst switches for each.

Make the DIVISION SELECT switch only finger tight. Place a knob on the shaft of this switch. Rotate the knob and note where the pointer stops for each position. If necessary, adjust the orientation of the switch for balanced positioning and then tighten the mounting nut.

Referring to Figs. 3 and 8, wire the free ends of the S1 ROTOR and F/2 through F/10 wires to the appropriate switch lugs. Next, connect and solder the free ends of the S2 wires to the POWER switch. Then, taking care to observe proper polarity, wire the LEDs into the circuit, using the free ends of the appropriate wires on the board to make the connections. Finally, connect and solder the free ends of the three coaxial cables to the INPUT and OUTPUT BNC connectors, center conductors to center contacts and shields to ground lugs.

You can simplify operation of the combined instrument with an UN-DIVIDED/DIVIDED switch that replaces the OUTPUT BNC connectors indicated in Fig. 3 to let you select only signal conditioning (UN-DIVIDED) or both conditioning and division (DIVIDED). Wire this switch as shown in Fig. 8. The original INPUT BNC connector now becomes the INPUT connector for the conditioner/divider module and, thus, the entire accessory. Making this modification eliminates three BNC connectors. It also saves your the task of having to plug and unplug cables to bridge modules and select different outputs.

Another modification you might wish to incorporate, illustrated in Fig. 9, makes it possible to use the signal conditioner/frequency divider as a stand-alone unit to condition (and divide) waveforms that might not otherwise reliably trigger a logic probe or other digital instrument. In this case, you should use separate battery supplies and POWER switches for each subassembly and install a female BNC connector after the UN-DIVIDED/DIVIDED switch just discussed followed by a second switch that allows you to route the output of the conditioner/divider to either the new BNC connector or the input of the F/V converter.

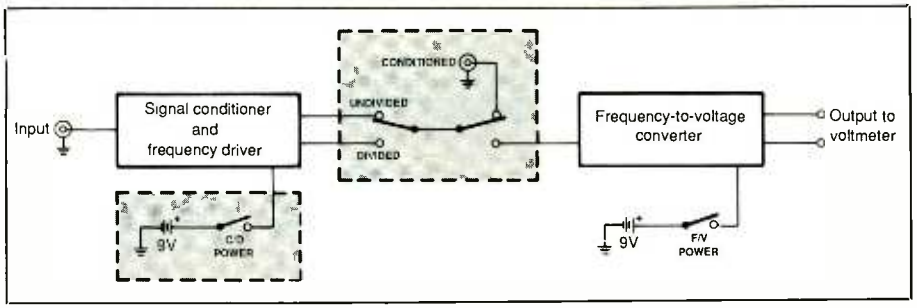
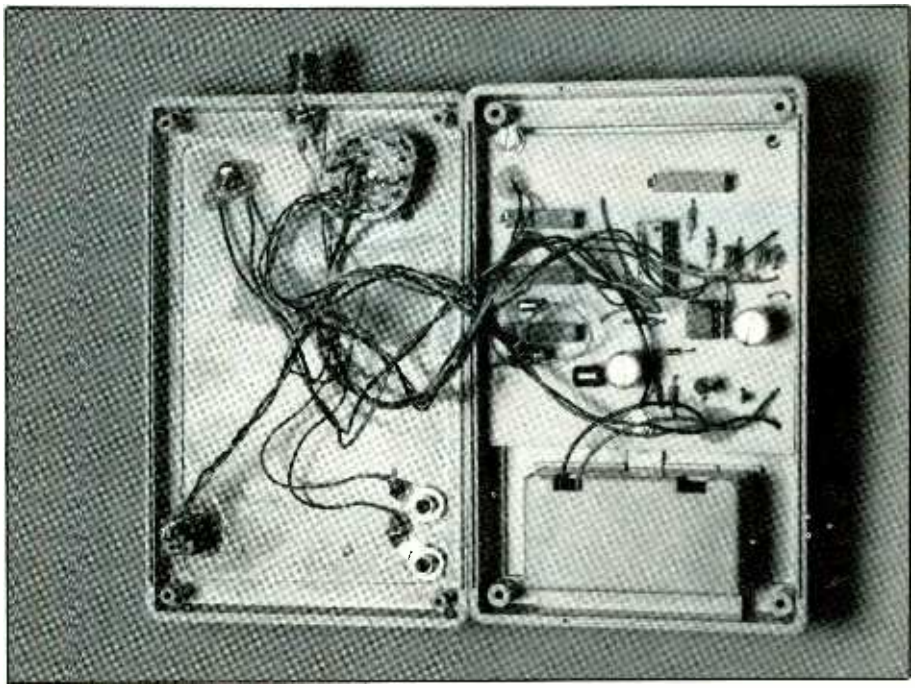


Fig. 9. By adding yet another switch and separate switched battery supply, you can choose between signal conditioning/frequency division and F/V conversion or just conditioning/division for other instruments.

When you want to use only the conditioner/divider, you set the just installed CONDITION/COUNT switch to CONDITION, select either the UN-DIVIDED or UNDIVIDED function with the previous switch, and flip on only the conditioner/divider's POWER switch. Now you simply connect the signal source to the INPUT con-

(Continued on page 87)



Interior view of assembled basic converter project inside PacTec box that has separate outside-access battery compartment.

Choosing Op Amps For Specific Applications

Examining the important specifications for making intelligent choices of what operational amplifier to use in a given application

By C.R. Fischer

There can be little doubt that the popular operational amplifier—or op amp, for short—has become one of the most important integrated-circuit devices in analog electronics over the past 15 years or more. The incredible versatility of this device has greatly simplified the design and building tasks of analog circuits for both hobbyists/experimenters and professional manufacturer alike. Even so, confusion can reign when it comes time to make a choice of a specific device from among literally dozens of different types of op amps available to suit the needs of a specific circuit design. Faced with a confusing variety of op amp types, many experimenters simply choose traditional favorites and, in so doing, frequently lose out on what newer IC op amps have to offer.

While you don't have to fully understand the technical details of what goes on inside an op amp chip to make use of this device in your projects, it's helpful to have some idea of why such a variety of op amps exist. If you'd like to design circuits for fun or profit, this knowledge can save you a lot of time and trouble in the long run. Toward this end, let's look at some of the parameters used in specifying op amps and compare some of the strong and weak points of a dozen commonly used devices. Then we'll follow up with some tips on choosing an op amp by specific application.

A Matter of Versatility

The major reason why so many different types of op amps are available is the tremendous versatility of this device. In addition to providing amplification, the op amp can be used as a buffer, a filter, a comparator and a lot of other electronic elements. The op amp also does a lot

Typical Specifications For Popular Experimenter Op Amps

	741	1458 (dual)	LM324 (quad)	LM301	LM308	LM318	TL071	LM351	AD712 (dual)	NE5534	4136 (quad)	OP.42E
Input impedance/ resistance (ohms)	2M	1M	4M	2M	40M	3M	10^{12}	10^{12}	10^{12}	100k	5M	10^{12}
Slew rate (V/μs)	0.5	0.5	0.5	0.5	0.3	50	13	13	13	13	1	50
Unity-gain bandwidth (Hz)	1.5M	1M	1M	1M	1M	15M	3M	4M	3M	10M	3M	10M
CMRR (dB)	90	90	70	90	100	100	86	100	66	100	90	98
PSR (dB)	96	96	100	96	96	80	86	100	86	10	30μV/V	9
Offset voltage (mV)	2	1	2	2	2	4	3	10	0.25	0.5	10	0.4
Noise voltage (nV/$\sqrt{Hz}$)	*	*	*	*	60	15	18	16	18	4	10	13
Average quiescent current (mA)	1.7	3.0	1.5	18	0.3	5	1.4	1.8	5	4	7	5.1

*Accurate noise data is not available for some earlier op amps, but it is safe to assume that none of these ICs should be used in applications that require low-noise devices.

with very little, namely two differential inputs, an output and very high gain. To control the amount of gain, a portion of the op amp's output can be fed back to its inverting (−) input. By shaping the frequency response of the feedback signal, you can control the frequency response of the amplifier for active filtering and other applications.

Originally, the op amp was created to process dc voltages because early amplifiers suffered from high levels of noise and a limited bandwidth that made them useless in ac circuitry. As time passed, though, customer demand and constant competition forced improvements to the point where, today, op amps can be found in top-of-the-line audio and video equipment where wide bandwidth and low noise are of paramount importance.

In spite of all of the upgrading that has occurred in op-amp technology, things are still far from perfect. Even today, we must make compromises in performance to achieve the near-ideal in specific areas. For example, you can get a higher input impedance from an op-amp circuit in exchange for increased offset voltage; or you can reduce the offset by using expensive laser-trimmed resistors inside the chip; or put up with more noise to obtain greater speed; and so on. Needless to say, even though the current state of the technology is much greater than it was back in the days when op amps first emerged, you still have to choose the op-amp type that best suits the needs of your circuit design. If you make the wrong choice, the op amp will seriously degrade circuit performance.

If you know exactly what kind of performance you want from a circuit to be built around op amps, you'll find it much easier to trade off unimportant parameters to enhance those that are important. With careful thought to judicious tradeoffs and a bit of design experience, you'll find using integrated-circuit operational amplifiers a definite plus in solving analog circuit design problems.

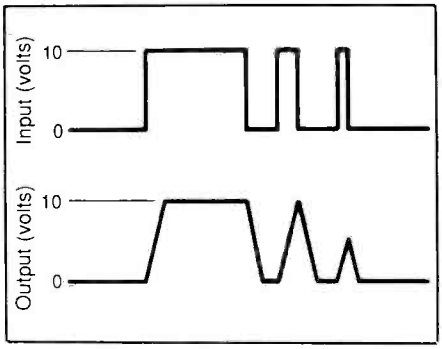


Fig. 1. These curves show how a train of varying width 10-volt pulses applied to the input of an imaginary amplifier (upper) emerge distorted at the amplifier's output (lower) as a result of slew-rate effects.

Some Important Parameters

A glance at a typical specifications sheet will give you an idea of what parameters are important in choosing an IC op amp for a given application. A typical data sheet will list more than 25 parameters. Some are closely related to each other, while others are important only to a small minority of users of the device. The table shown elsewhere in this article charts the specifications you'll find important in your design work for a dozen popular IC op amps. Let's look at the most common op-amp specifications listed in this table and discuss op amps in terms of their typical characteristics:

• *Supply Current.* This is the quiescent current required by an op amp in a no-load condition. Op amp technology has been optimized to the point that recent op amps can work on minuscule amounts of current (Precision Monolithics' new OP-90 has a typical supply current rating of only 20 microamperes). Low current drain is most advantageous in battery-powered circuitry, but it can be important in line-powered equipment as well.

Most op amps have fixed current demands. Others, like National Semiconductor's LM346, however, include a biasing input that allows the user to change the supply current from some optimum to obtain more optimal results in other parameter areas.

• *Offset Voltage.* All op amps have an offset—or error—voltage that cannot be differentiated from an input signal. An offset is usually important in dc circuitry, as capacitive coupling will remove offsets in ac circuits. What can make offset voltages especially troublesome is that they can drift with variations in temperature and supply voltage.

Offsets in op amps can vary from 10 mV or more in early versions to a more reasonable 2 mV in a garden-variety 741 to 25 μV maximum in Precision Monolithics' OP-07. A new family of op amps that use chopper-stabilization techniques reduces the offsets even more. While almost every manufacturer has premium-grade op amps that are chosen for minimal offset, these devices are difficult to find through the normal experimenter sale channels and even when they are located are usually prohibitively expensive. If minimal offset and cost are both important, remember that most single op-amp ICs have pins that allow you to trim out offsets when necessary.

Input Impedance. Many applications (like buffer, timer and sample/hold circuits) require an ultra-high impedance input to achieve optimal performance. While an ideal op amp has an infinitely high input impedance, real-life devices fall far short of the mark. The old standard 741 op amp, for example, had an impedance of roughly 10^6 ohms, which is considerably less than the input impedance of the typical FET or vacuum-tube amplifier. JFET and CMOS op amps fare much better in this depart-

ment, with common IC op amps like the LM351 and TL081 weighing in in the 10^{12}-ohm range.

Using op amps with high input impedances lets you shave your parts cost and reduce real estate requirements because they allow you to use large-value resistors with small-value capacitors (larger-value capacitors cost a lot more and consume a lot more circuit space than do smaller-value ones) in time-constant networks.

• *Slew Rate.* All amplifiers, including op amps, have an upper frequency-response limit. Input signals approaching this limit will be attenuated and distorted by the op amp. The time that it takes for an amplifier's output to respond to an input signal is known as the "slew rate," which is usually specified in volts per microsecond. In Fig. 1, a 10-volt pulse is applied to the input of an imaginary op amp. When the amplifier sees this pulse, it begins creeping toward 10 volts. If the input signal lasts long enough, the output eventually reaches 10 volts—but the input and output signals hardly resemble each other! Shorter pulses can be completely swallowed up by a slow amplifier.

Slew rates of common IC op amps range from a weak 0.5 V/μs for the 741 op amp to 50 V/μs and up for the LM318. Slew rate is especially critical whenever high speed or/and low distortion are needed.

• *Unity-Gain Bandwidth.* This parameter specifies the highest frequency that an amplifier will pass at a gain of 1 (unity) without suffering attenuation in the amplification process. Unity-gain bandwidth, related to slew rate, can be confusing. For example, the unity-gain bandwidth of a common 741 is 1.5 MHz, which on the surface appears to make this op amp a great choice for audio and other low-frequency applications. But remember that most op amp applications require greater than unity gain. As the gain of an op amp is raised, bandwidth drops accordingly. A gain of 10 will reduce the 741's bandwidth to 150 kHz, a gain of 100 reduces the bandwidth to 15 kHz, and so on. All of a sudden, the 741 isn't quite as great a low-frequency amplifier as you first thought. Consequently, it's a good idea to keep the gains and frequency responses of your circuits in mind when you select op amps.

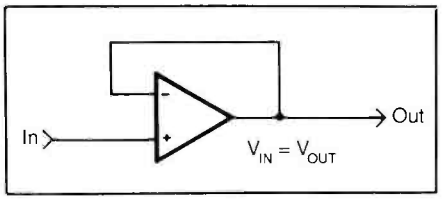


Fig. 2. An op amp used in a buffer arrangement.

• *Common-Mode Rejection Ratio (CMRR).* In an ideal op amp, a signal applied to both the noninverting (+) and inverting (−) inputs simultaneously will be completely canceled out within the device as a result of the differential action of the inputs. The inability of a real op amp to do this is known as its "common-mode rejection ratio." CMRR spells out the amplifier's performance in canceling out a common-mode input. It is usually expressed in decibels (dB), with a higher figure considered to be better.

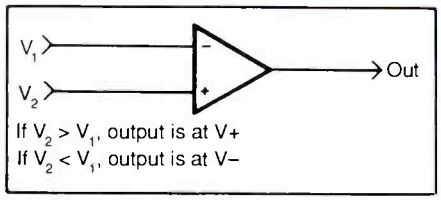


Fig. 3. An op amp used in a typical inverting amplifier arrangement is shown in A. The arrangement shown in B shows how, by adding a series of input resistors to the original single one, the same circuit can be used as a summing amplifier.

• *Supply-Voltage Rejection Ratio.* Though similar to CMRR, this parameter differs from it in that it expresses the ability of the op amp to ignore fluctuations in supply voltages (and keep them from showing up in the output signal). While often ignored in these days of regulated power supplies, there are still a few places where the supply-voltage rejection (or PSR for power-supply rejection) ratio can become a critical factor, such as in circuits where offset voltages must be kept to a minimum. In these situations, a change in supply voltage can cause a shift in the offset voltage. Another area is in battery-powered circuits. Since a battery's output voltage drops over its lifetime, changing supply voltages can often affect operation in various (and undesirable) ways. As with CMRR, PSR is often specified in decibels.

• *Noise Level.* Low noise is mandatory in professional audio and video work. Hence, the choice of amplifiers can have a large effect on the noise levels in otherwise identical circuitry. Defining the various ways of measuring noise in op amps is way beyond the scope of this article. However, a common measurement is noise voltage/$\sqrt{\text{Hz}}$. A voltage/noise figure of 10 nV/$\sqrt{\text{Hz}}$ is considered to be excellent, and with a figure of 4 nV/$\sqrt{\text{Hz}}$, the Signetics NE5334 is considered to be the best among the popularly used op amps.

Some Applications

Let us now see how the important specifications we've detailed here affect some of the most common uses of the op amp itself. We'll discuss *generic* uses here; so some of our choices may not always be appropriate for every situation. For example, the buffer to be described could be used to isolate a capacitor in a very long-period timer, where an ultra-high input impedance and low offset

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voltages would be needed. In another circuit, the same buffer might be used as a high-fidelity audio preamplifier in which low noise and distortion are of critical importance. In each of our examples, the basic circuits may be the same, but the parameters of interest will change with the end uses.

• *Buffer* (Fig. 2). Also known as a voltage follower, the buffer is used to isolate a high-impedance circuit and drive other electronics from a low-impedance source. In general, a very high input impedance is a must and low offsets and slew rate are desirable. A couple of good op amp choices here would be the CA3140 and LM308. The TL071 has a high input impedance and good noise and slew-rate figures that make it a good candidate for audio electronics.

• *Inverting Amplifier* (Fig. 3A). This circuit configuration has some very different characteristics from those of the common buffer. Due to feedback via R_f, input impedance, no longer very high, is the same as R_i, which means that you will usually not have to worry about the impedance of your amplifier. Keep in mind that slew rate can become important whenever high gains or/and high frequencies are involved. It's also important to keep in mind that noise and distortion are undesirable in audio and video circuitry. Some good op amp choices here include the LM318, TL070 and TL080 series, LM351 series and OP-7 series.

An inverting amplifier can be used to mix multiple inputs in a special configuration known as a "summing amplifier" (Fig. 3B). Because the output of the amplifier is the sum of the input signals, slew rate becomes more important with the op amp carrying a larger output signal.

• *Active Filters.* A very important use for op amps is in active-filter circuits, where op amps are used to selectively remove portions of an input signal. This is a very broad range of signal processing. Choice of the right op amp for a given application depends on the frequencies to be removed as much as on the type of filter (low-pass, high-pass, bandpass, etc.) being designed. As a general rule, the selected op amp should not degrade any signals you want to come through the circuit. NE5334 and LM318 op amps work very well for precision audio filtering, and the reasonably priced and readily available TL070 and LM350 series work okay for general-purpose filtering.

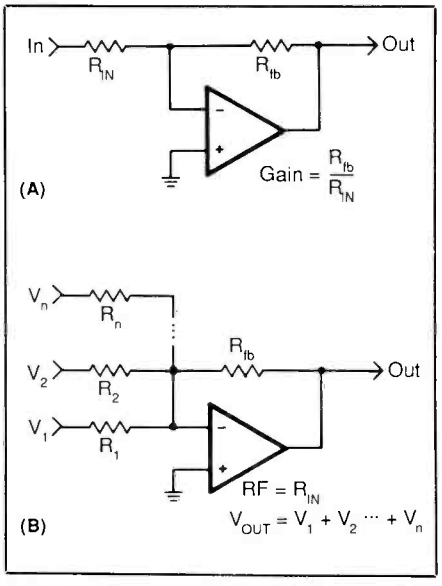


Fig. 4. The op amp is shown here used as a comparator.

• *Comparators* (Fig. 5). A large family of ICs are designed to work specifically as comparators, though many so-called "general-purpose" op amps will work just as well. Sometimes a circuit will require several amplifiers and comparators, each of which can be made up of a single-amplifier IC package. Fortunately, there are a number of dual and quad op-amp ICs on the market that can be used to handle more amplifier functions in a much smaller area (and at lower cost) than do the single-amplifier devices.

In comparator applications, any op amp with a good slew rate will usually deliver good performance results. Even a slow op amp like the popular 741 will work reasonably well where speed isn't a problem. Sometimes, a high input impedance can be desirable as well. Op amps like the LM351 and TL081 seem to work fairly well as comparators.

With such a large variety of integrated-circuit operational amplifiers on the market, it's virtually impossible to subjectively grade each one. It would be hasty (and incorrect) to rate one op amp as great and another only passable or useless because there are plenty of instances where a mediocre op amp will do the job as well as a super-hot performing op amp. To use an expensive op amp in an application that can just as easily be fulfilled by a low-cost device is economically foolish.

Integrated circuit technology, including that of the operational amplifier, continues to improve by leaps and bounds. It's possible, therefore, that today's limits in op amps will be forgotten in just a year or two as new super-performing devices now on the drawing boards become available in the electronics parts marketplace. The best advice, then, is to actually use and experiment with the op amps now available to become familiar with their capabilities and deficiencies. With only a little experience in experimenting with these devices, you should have no trouble in selecting the one or more that suit any given application.

If you would like to learn more about IC op amps, read Walter G. Jung's *IC Op Amp Cookbook* (Howard W. Sams, 1974); Robert A. Witte's "Using Op Amps" (*Modern Electronics*, October 1985); and R. Fleischman's "Designing Active Filters" (*Modern Electronics*, June and July 1986). The more you know about op amps, the better prepared you'll be to match specific devices to specific applications. **ME**

An Off-Hook Phone Alert

This device warns you when your telephone is off the hook with an attention-getting external audible signal

By Peter A. Lovelock

An off-the-hook telephone can cut you off from the outside world. When the instrument is left off the hook for more than 20 seconds, most telephone exchanges replace the normal dialtone with a recorded message. If there is still no response after an additional 20 seconds, an attention-getting signal composed of 1,400-, 2,026-, 2,450-, and 2,600-Hz frequencies, pulsed at a 5-Hz rate, is placed on the line for 50 seconds. This irritating brew is known in the trade as "the Howler." It's delivered to the telephone instrument's earpiece at 0 dBm—the loudest signal that phone company standards permit. If all this fails to get your attention after a minute or so, service on the line is suspended! To restore service, you must hang up the phone for about 10 seconds before dialing.

As most of us have experienced at one time or another, the off-the-hook phone message and subsequent Howler often play to a person who's no longer within hearing range. By the time one returns to the area where the phone is located, the alert signals have likely ceased. To avoid being unaware of this problem, and missing an important incoming phone call, the Howler Alert project to be described picks up where the telephone left off. It plugs into the telephone line and, when a Howler signal is detected, waits until the Howler signal from the tiny phone earpiece ceases. At this point, it takes over the Howler function by sounding an attention-getting audible signal of its own.

About the Circuit

Figure 1 is a block diagram of the Howler Alert. The telephone line is coupled to two phase-locked-loop (PLL) tone decoders, one of which is tuned to 2,026 Hz and the other to 2,600 Hz. These frequencies were selected because 1,400 Hz was just too close to the 1,477-Hz dial tone the telephone company puts on the line. Using two frequencies was a compromise between circuit complexity/cost and reliability. A single decoder could have been used, of course, but it is possible that some voice component during normal conversation might match the decoder frequency and cause the alarm to activate. Twin decoders reduce the possibility of this "falsing" to a very small probability because the choice of the two frequencies occurring is very unlikely in vocalization.

The telephone line is coupled to the decoders through a balanced-to-unbalanced RC network. This network maintains a balanced interface to the telephone line, provides a high-pass characteristic that attenuates by 40 dB the 20-Hz ring voltage to prevent damage to the circuit, and provides a means for varying the at-

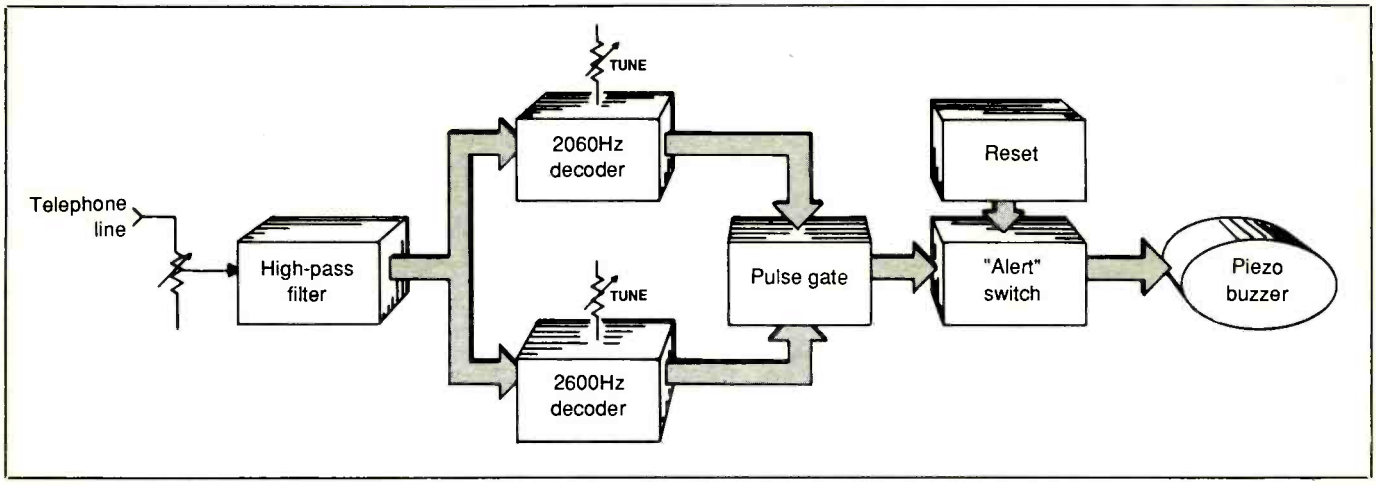


Fig. 1. Block diagram of Howler Alert.

tenuation to set the project's tones to optimum input level.

Pulsed outputs from the decoders are sent to a pulse gate that has a pulsed output only when both decoders simultaneously deliver pulses to the inputs. The output pulses from the pulse gate then trigger a 2-second timer. The first pulse starts the timing cycle. Then each succeeding pulse resets the timer so that it cannot time out until the Howler input from the telephone line ceases.

When input to the Howler Alert ceases, the timer completes its time-out sequence and sends a positive pulse to the "Alert" control. Upon receipt of this pulse, the Alert control turns on the piezo buzzer and keeps it on until the telephone is hung up and the reset button on the project is pressed and released. This puts the Howler Alert in standby, ready for the next occurrence of an off-hook condition.

Shown in Fig. 2 is the complete schematic diagram of the Howler Alert, minus its plug-in dc power supply. Notice that this arrangement combines both analog and digital circuits to provide best performance and minimum complexity.

Tone decoders *IC1* and *IC2* are the phase-locked loops that are tuned to exact lock frequencies by 15-turn trimmer potentiometers *R5* and *R8*, respectively. When an appropriate Howler frequency (2,026 or 2,600 Hz) is received the PLLs phase lock so that the outputs at pin 8 drop from the normal +5 volts to near ground potential. The pin 8 outputs of *IC1* and *IC2* separately go to the inputs (at pin 8 for the *IC1* output and pin 9 for the *IC2* output) of one of the four NOR gates contained inside *IC3*.

Both inputs to the selected gate of *IC3* must be low (logic 0) to cause the gate's pin 10 output to go high (logic 1). Thus, both PLL filters must have a tone-induced 0 output for the gate's output to go high.

A 555 timer (*IC4*) is used in this circuit to produce a 2-second time delay, which is set by the time constant of *R11* and *C14*. The capacitor is normally in a fully charged condition, and the output of *IC4* at pin 3 is low. The first pulse at pin 10 of *IC3* sends *Q1* into conduction, causing the transistor to discharge *C14* and sending pin 3 of *IC4* high. Though *C14* now starts to recharge through *R11*, the next pulse from *IC3* will discharge the capacitor. Hence, while a train of pulses is being received from *IC3*, *IC4* will be repeatedly reset, preventing it from completing the 2-second time-out cycle.

When the train of pulses stops (the phone company removes the signal from the telephone line), the timer circuit can and does complete its charge cycle to cause pin 3 of *IC4* to be toggled low.

The logic drop at pin 3 of *IC4* applies a short-duration negative-going pulse to be coupled to one input of a second gate in *IC3* at pin 12. With the other input (pin 13) of this gate tied to ground, a positive pulse is generated at the gate's output at pin 11. This pulse toggles a flip-flop made up of the remaining two gates in *IC3* so that the output of this arrangement at pin 3 goes high. This turns on *Q2*. With *Q2* conducting, the power circuit to the piezoelectric buzzer in the transistor's collector circuit is completed and the buzzer sounds. The buzzer will continue to sound until the flip-flop is toggled off by a reset signal that is applied to it by momentarily closing pushbutton switch *S1*.

It would have been convenient to power the Howler Alert from the telephone line so that only one pair of wires would have taken care of everything. However, the 567 PLLs used for *IC1* and *IC2* and the 555 timer used for *IC4* draw approximately 15 mA at 5 volts. This current drain is great enough to cause interference with the phone loop-actuating current. Therefore, the project is designed to draw its operating power from the ac line. This is done with a common plug-in dc power supply

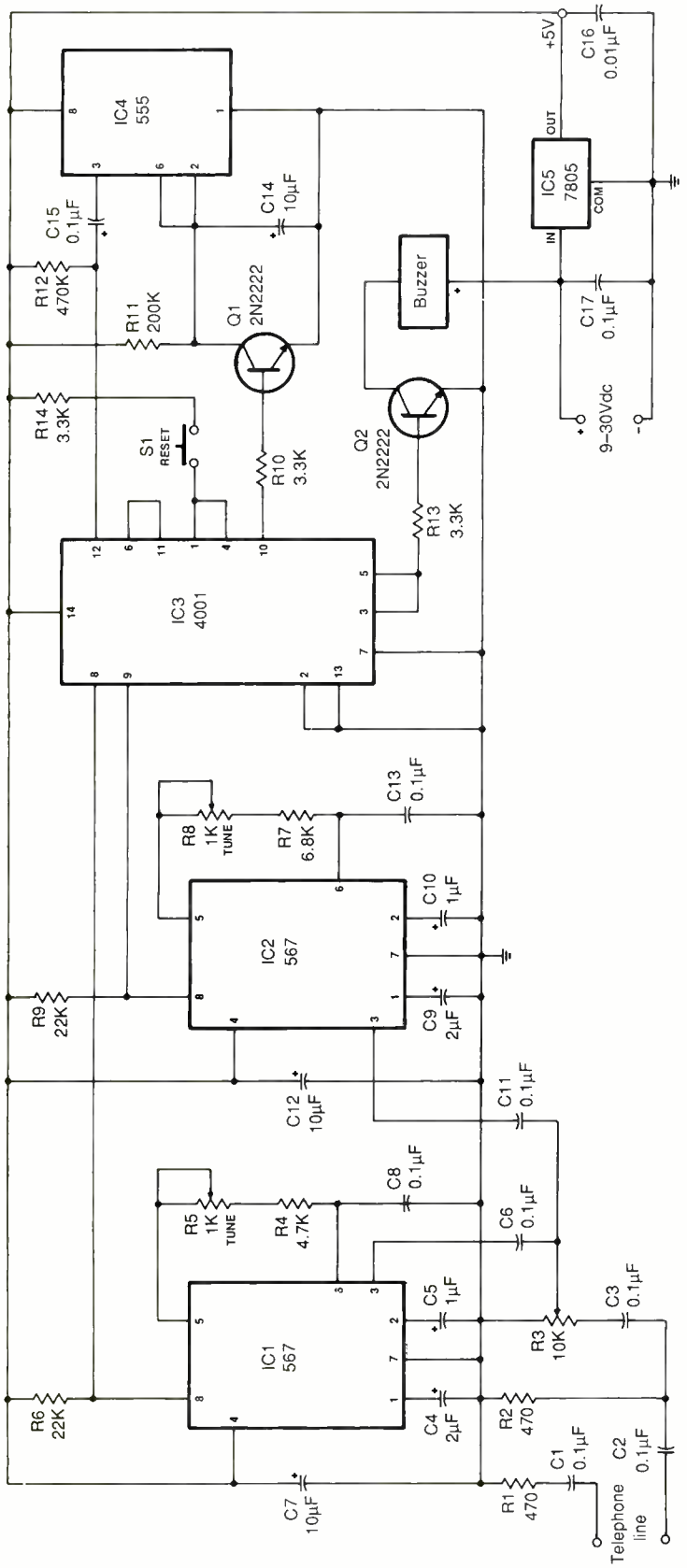


Fig. 2. Overall schematic diagram of project, minus its plug-in dc power supply.

PARTS LIST

Semiconductors

IC1,IC2—LM567 tone decoder
IC3—4001 quad 2-input NOR gate
IC4—555 timer
IC5—7805 5-volt regulator
Q1,Q2—2N2222 or similar npn silicon transistor

Capacitors

C1,C2,C6,C11—0.1-µF, 50-volt disc
C3,C16—0.01-µF, 35-volt disc
C4,C9—2.2-µF, 35-volt tantalum
C5,C10—1-µF, 35-volt tantalum
C7,C12,C14—10-µF, 16-volt tantalum
C8,C13,C15,C17—0.1-µF, 35-volt tantalum

Resistors (¼-watt, 5% tolerance)

R1,R2—470 ohms
R4—4,700 ohms
R6,R9—22,000 ohms
R7—6,800 ohms
R10,R13,R14—3,300 ohms
R11—220,000 ohms
R12—470,000 ohms
R3—10,000-ohm trimmer potentiometer (Radio Shack Cat. No. 271-333)
R5,R8—1,000-ohm, 15-turn trimmer potentiometer (Radio Shack Cat. No. 271-342 or similar)

Miscellaneous

S1—Spst normally open, momentary-action pushbutton switch
Plug-in 9-volt dc, 25-mA transformer (Radio Shack Cat. No. 273-1435 or any other 9- to 30-volt dc plug in power supply—optional; see text); panel-mount power jack for plug-in transformer; piezoelectric buzzer Radio Shack Cat. No. 273-060); printed-circuit board or perforated board and suitable soldering or Wire Wrap hardware; sockets for IC1 through IC4; suitable enclosure (Radio Shack Cat. No. 270-231 or similar 4″ × 2⅛″ × ⅝″ project box); telephone cord with modular connectors at both ends (optional); spacers; machine hardware; hookup wire; solder; etc.

Note: The following are available from T.R. Associates, 3160 Glendon, Los Angeles, CA 90034: Etched and drilled pc board, $4.75; complete kit of parts except power supply and optional items but including pc board and project box, $14.75. Add $1.50 P&H each order. California residents, please add state sales tax.

whose output goes to the input of voltage regulator *IC5*. The power supply used can have an output between 9 and 30 volts dc.

Construction

There is nothing critical about component layout. Therefore, any traditional wiring method can be used to assemble the circuit. Though a printed-circuit board is recommended, you can substitute for it perforated board with holes on 0.1″ centers and suitable soldering or Wire Wrap hardware. Whichever wiring method you choose, it is a good idea to use sockets for *IC1* through *IC4*.

You can fabricate your own pc board from the actual-size etching-and-drilling guide shown in Fig. 3. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

Wire the board exactly as shown in Fig. 4, starting with the IC sockets—*not* the ICs themselves. Install and solder into place the resistors. Most resistors mount on-end, rather than flat against the board, to conserve space. When installing the capacitors, make sure to observe polarity with the tantalums. Before soldering their leads and pins to the copper pads on the bottom of the board, make sure that the transistors and voltage regulator *IC5* are properly installed. Finish stuffing the board by installing and soldering into place the trimmer potentiometers. Note that three jumper wires are required. These must be *insulated* hookup wire, since they go on the bottom (copper side) of the board.

Strip ¼″ of insulation from both ends of two 4″ hookup wires. Plug one end of each wire into the holes labeled S1 in Fig. 4. Then connect and solder the other ends of these wires to the lugs on the miniature pushbutton switch.

Examine your piezoelectric buzzer. If it doesn't come with wire leads already attached, you must prepare hookup wire leads for it. This time, strip ¼″ of insulation from both ends of two 6″-long wires, preferably with different-color insulation. Plug one end of these wires into the holes labeled BUZZER(+) and BUZZER(−). The other ends of these wires will be connected after the buzzer and circuit-board assembly have been mounted to the enclosure's front panel. If your buzzer comes with leads already attached, do *not* wire it to the board just yet.

A standard 4″ × 2⅛″ × 1⅝″ plastic project box with removable aluminum plate was used to house the prototype of this project. You can substitute any other type of box that has adequate room to accommodate the circuit-board assembly inside and enough panel and/or wall space on which to mount the RESET switch (*S1*) and piezo buzzer.

Now prepare the aluminum panel of the project box by drilling the mounting holes for the circuit-board assembly, pushbutton switch, power jack and piezo buzzer, as illustrated in Fig. 5. Locations of the #4 CLR holes should be exactly as shown to assure that the board will be centered in the panel. Other hole locations and sizes may have to be adjusted to suit any components you substitute for those called for in the Parts List

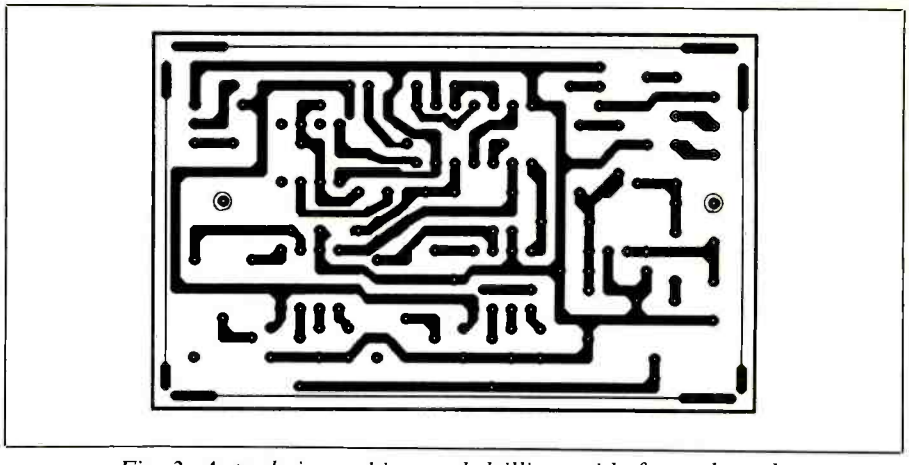


Fig. 3. Actual-size etching-and-drilling guide for pc board.

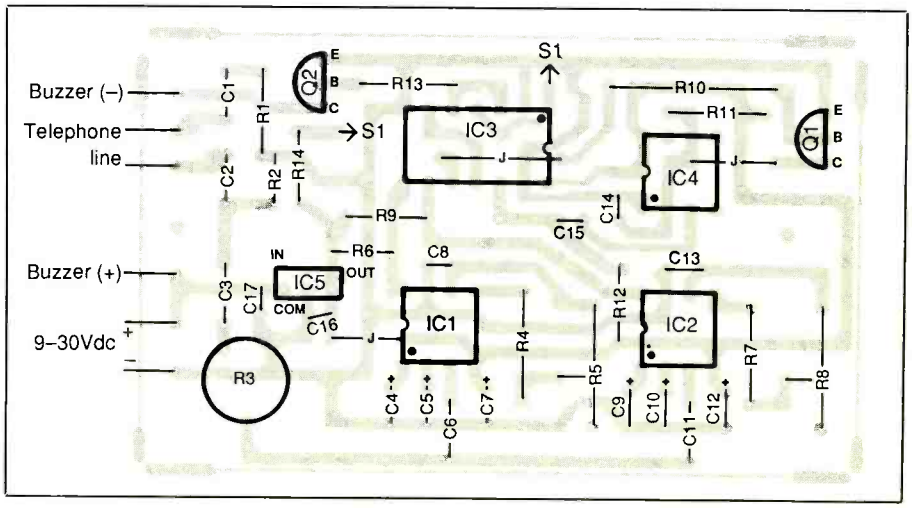


Fig. 4. Wiring guide for pc board.

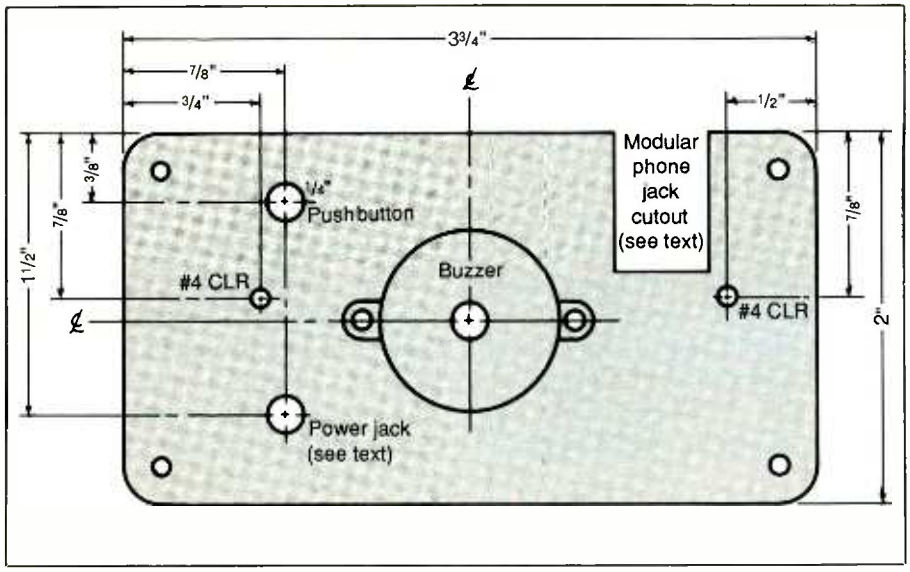


Fig. 5. Machining details for project's front panel.

(for example, a larger piezo buzzer) to avoid interference with the other components mounted on the panel.

A cutout to accommodate a modular phone jack with slotted sides is shown (see "Options & Adjustments" below for more details). If you can't locate this type of jack, you can substitute any other type of modular jack and adjust the mounting hole arrangements as needed. Alternatively, you can eliminate the jack altogether by wiring the phone cord directly to the appropriate pads on the pc board. Doing this, all you need is a single hole through which the cord can enter the box.

If you drill the entry hole for the phone cord in the aluminum panel, line it with a rubber grommet to prevent the cord from becoming frayed against the sharp edges. Otherwise, drill the entry hole in one of the box's plastic walls, in which case no grommet is needed. In either case, pass the free end of the cord through the hole and tie a strain-relieving knot about 4" from the free end inside the box.

You can also eliminate the power jack/plug arrangement by wiring the plug-in power supply's cord directly to the appropriate points on the pc board. To do this, you need an entry hole (grommet-lined if through the aluminum panel or grommet-less if through one of the box's plastic walls). Once again, tie a strain-relieving knot in the cord inside the box.

When it comes time to wire the jack or cord into the circuit, use the green- and red-insulated conductors. Some modular phone jacks come with leads attached. If you get one with solder leads, connect the wires to the two center pins. Also, make sure you connect the plug-in power supply's cord or panel jack into the circuit in the proper polarity.

If you are using the specified Radio Shack piezoelectric buzzer, pass its leads through the hole in the center of the panel and mount it in place with machine hardware, including lockwashers. Mount the pushbutton switch, power jack (if used) and modular phone jack (also if used) in their respective locations on the panel. Then, referring back to Fig. 4, connect and solder the free ends of the wires coming from the circuit-board assembly to the lugs of the switch, jack and connector. Plug into the appropriate holes (observe polarity) the leads of the piezo buzzer and solder into place.

Mount the circuit board assembly to the front panel with ⅜" or ½" spacers and machine hardware. The copper-trace side of the board should be facing toward the inside surface of the aluminum panel. At this point, *IC1* through *IC4* should still not be installed in their sockets. Only regulator *IC5* should be in place.

Checkout and Use

Plug the dc power supply into an ac outlet. Connect the negative or common lead of a multimeter, set to read dc voltage, to circuit ground (negative side of power jack). Now touch the meter's positive probe to the pin 4 contact of the *IC1* and *IC2* sockets, pin 14 contact of the *IC3* socket, pin 8 contact of the *IC4* socket and output pin of *IC5*. In all cases, the reading obtained should be +5 volts. If you do not obtain the proper readings, check for a +9- to +30-volt reading at the input pin of *IC5*. (If you're using a 10-volt dc plug-in power supply, your reading at the input pin of *IC5* should be roughly +10 volts.) If you still don't obtain the proper readings, power down the circuit and check your wiring and component placement, identification and orientation. Carefully check for poor soldering and solder bridges, especially between the closely spaced pads for the ICs.

Once you're sure that the circuit is properly wired and soldered and that the correct voltages are present at the key points in the circuit, power down the project by disconnecting the plug-in power supply from the ac outlet. Plug the ICs into their respective sockets, taking care to properly orient each and to prevent any pins from overhanging the sockets or folding under between sockets and IC bodies.

Before hooking up the Howler Alert to the telephone line, you must adjust PLL tuning and input level. Connect an audio signal generator to the telephone line input of the Howler Alert and a dc voltmeter or logic

probe to pin 8 of *IC1*. Plug the project into an ac outlet and observe the meter or logic probe. You should obtain a reading of +5 volts on the meter or a logic 1 on the probe.

Set trimmer control *R5* to either of its extremes (a faint "clicking" sound indicates when you have reached the end of the pot). Set *R3* fully clockwise. Then set the audio generator for an output frequency of 2,026 Hz and high level. Now slowly adjust the setting of *R5* until you reach a point (hopefully at about midrange) at which pin 8 of *IC1* drops to zero on the meter or logic probe. This is the point at which the circuit has phase-locked onto the 2,026-Hz signal.

With a high-level input from the signal generator, initial adjustment might be quite broad. Therefore, it is a good idea to reduce the signal level entering the project until the potential at pin 8 of *IC1* once again goes to +5 volts (or logic 1) and readjust the setting of *R5* until phase-lock occurs. Repeat this procedure with lower levels of 2,026-Hz input until the adjustment effect of *R5* is quite sharp to ensure accurate lock tuning.

Repeat the tuning procedure for *IC2*. This time, however, connect the meter or logic probe to pin 3 of *IC2* and do your trimming with *R8*.

If you don't have an audio signal generator, you can inject the "Howler" tones from the telephone line at the telephone line input to the project and adjust *R3* and *R8* for a logic-0 at pin 3 of both *IC1* and *IC2*. This is a trial-and-error procedure, but the values of the *R4/R5* and *R7/R8* networks have been selected so that they trim only a narrow range of frequencies to simplify your task.

Now test the project with the Howler tones that the telephone company puts on the line. If possible, to avoid over-use of the phone line for testing, it is a good idea to record the tones on tape and use their playback instead of the actual tones on the line during your tests.

Connect the Howler signal source —whether from the phone line or a tape recorder—to the Howler Alert via the project's telephone line inputs. Plug the project's power supply into an ac outlet and turn on the howler tones. Check the outputs of the PLLs at pin 8 of *IC1* and *IC2*. If this portion of the circuit is properly tuned, you should observe on a logic probe or oscilloscope screen activity that indicates a series of rapid pulses at both pins. You should also observe the same pulse activity at pin 11 of *IC3*.

With a dc voltmeter connected to pin 3 of *IC4*, you should obtain a reading of +5 volts. Within 2 seconds of disconnecting or turning off the Howler tones, the potential at this pin should drop to 0 volt and the buzzer should sound. If the buzzer remains silent, check the potential at pin 10 of *IC3*, which should be 0 volt. Connecting and disconnecting or switching on and off the Howler tones should cause a short positive pulse to occur at this pin. If the buzzer still Fails to sound, check pin 4 of *IC3*, which should normally be at ground potential, or 0 volt. Within 2 seconds of stopping the Howler input signal, this pin should go to and remain high (about +5 volts) to turn on *Q2*.

Once you're satisfied that the project is working as it should, connect the Howler Alert to the telephone line (if it is not already connected to it). Then connect your voltmeter to pin 10 of *IC3*. Now remove the handset of your telephone from on-hook and wait for the phone company-generated Howler signal to start. When this signal does come through, adjust input attenuator control *R3* until the pulses at pin 10 of *IC3* stop (input signal too low to phase-lock the PLLs). Back off *R3* until the pulses reappear; this is the threshold input setting. Adjustments of the project are now complete and should not require changing.

Leave the Howler Alert permanently connected to the telephone line via a modular jack used to connect your telephone instrument(s) to the telephone company. If your installation has only one modular receptacle, plug into it a duplex adapter to provide separate receptacles for the phone and the Howler Alert.

If no modular jacks are used in your telephone installation, connect one end of a green- and red-insulated wire pair directly to the telephone line inputs on the project's circuitboard assembly and the other end to the terminals on the wall connector block to which like-color wires are connected. The connector block is usually found directly behind the wall plate to which the phone's cord goes. Simply remove the wall plate by backing out on the single screw in the center of it to get at the block.

Options & Adjustments

Modular telephone jacks that mount into a metal panel may be difficult to find through normal retail outlets. Jacks sold by retail stores are usually attached to plates that mount to wall boxes. Some of these can be disassembled, though it may take some ingenuity to mount them into a panel cutout.

Some electronic parts stores carry pc-mount versions of these modular jacks. If you get one of these, use the center contacts in the upper and lower rows on them to make the connections for a single-line installation. If all else fails, use any two-wire jack, though this requires soldering two end wires of the phone cord to the matching plug.

Select the power jack to match the plug at the end of the output cable from the particular plug-in dc power supply you are using. The Radio Shack plug-in dc power supply specified in the Parts List, for example, requires a $\frac{3}{32}$" subminiature phone jack. A supply from a different source might require a different type of jack or connector.

You can use any of the plug-in dc power supplies sold through mail-order houses and electronic parts stores as long as the one selected has an output in the range of from 9 to 30 volts dc. Any supply in this range will yield +5 volts at the output of the 7805 voltage regulator shown as *IC3*.

The piezoelectric buzzer specified in the Parts List is typical of this type of audible signaling device. The Radio Shack buzzer was selected for its low current requirements. However, you can substitute any other piezo buzzer that emits a louder alert or even a two-tone "warble" alert. You can also substitute a light, with a suitable amplifier circuit to drive it, for elderly people whose hearing is deficient for the buzzer.

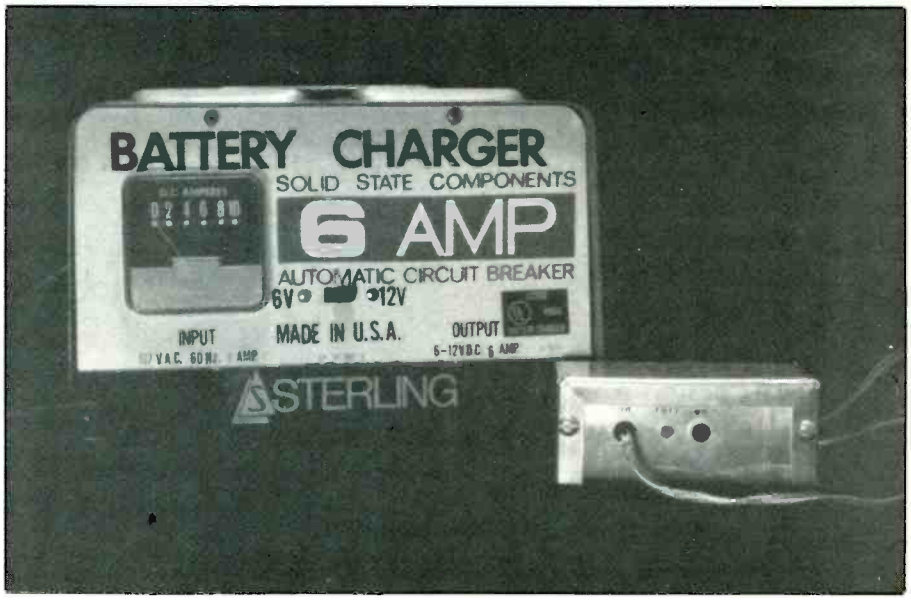
The phone company "Howler" is a standard "Network Call Progress" tone signal used throughout the U.S. If your local telephone company uses a single tone, such as 1,600 Hz, instead of the pulsed Howler signal described earlier, simply omit *IC2* from the circuit and connect the output from *IC1* to both pins 8 and 9 of *IC3*. Whether the off-hook warning signal delivered over the telephone line is pulsed or continuous. The time-out function of *IC4* will be inhibited in either case. The value of *R4* will have to be changed for the frequency of the single-tone Howler signal, however. The formula for calculating the value is: $R = (1/C1F_O) - 100$, where F_O is frequency. For example, if F_O = 1,600 Hz, $R = (1/0.0000001 \times 1{,}600) - 1{,}000 = 5{,}250$. In this example, the "– 1,000" is the 1,000-ohm value of trimmer potentiometer *R5*, which makes up the trimming element of the resistance in the RC network for *IC1* in Fig. 2. A 5,250-ohm resistor is not exactly a "standard" value. Instead, you could use a 4,700-ohm resistor that, with the 1,000-ohm value of R5, can be adjusted to provide the required 5,250-ohm value.

With the Howler Alert feature built and connected to your phone, you'll never again learn from frustrated callers that they've been trying to reach you for hours but always got a busy signal. Note that a very few local phone companies do not employ any kind of Howler system. Our Howler Alert can't help you in this case, of course. **ME**

A Battery Charger Controller

Ensures proper and safe charging of liquid-electrolyte lead-acid batteries

By Dennis Eichenberg



Twelve-volt lead-acid batteries are commonplace. They are used in automobiles, snowmobiles, motorcycles, and similar equipment. More and more people have bought battery chargers to conveniently recharge such batteries when they are run down, which avoids having to call a service station to make a "house call." Unfortunately, many of these chargers are inexpensive types that do not incorporate automatic control functions to prevent damaging the lead-acid battery during the charge period. The controller project presented here corrects this problem.

This automatic controller, which can be added to any non-automatic 12-volt battery charger, ensures proper charging conditions. It automatically switches on the charger when the voltage at the battery's terminals falls below a preset minimum and then switches it off again at a preset maximum to prevent life-sapping overcharging and the hazards attendant to overcharging. Indicators tell you when the battery is charging and when the charging cycle is complete.

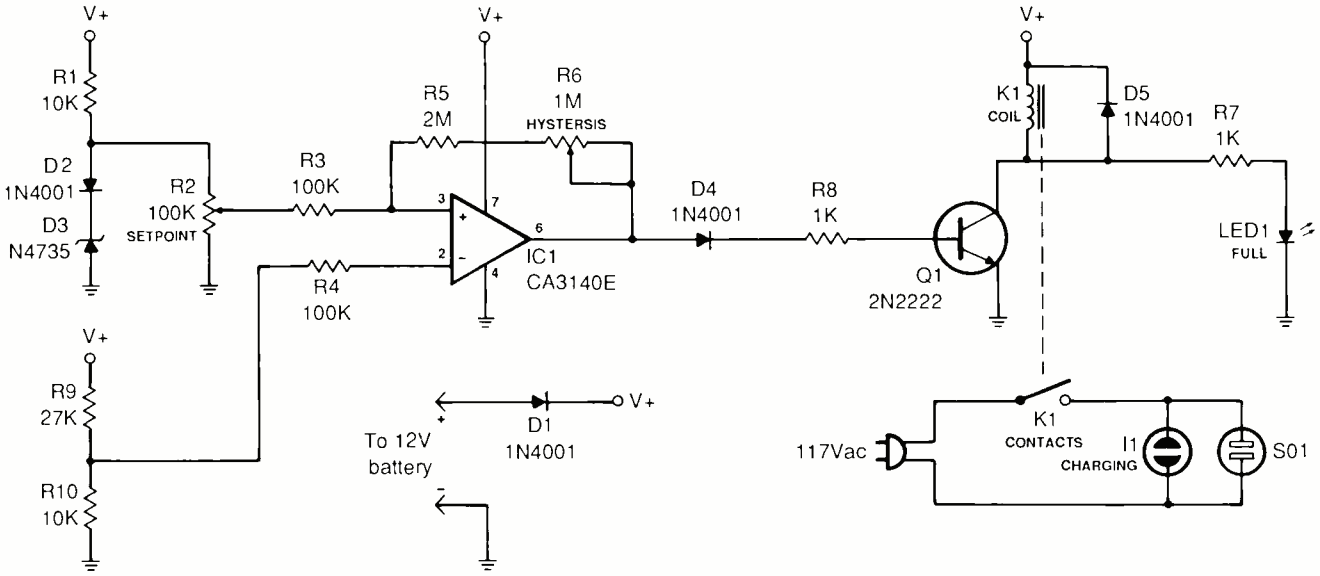
The project can be built into its own separate enclosure. Alternatively, if space permits, it can be built into your present battery charger.

Some Basics

The modern liquid-electrolyte lead-acid battery is extremely reliable when given proper attention. This includes cleaning the battery's terminals and case, maintaining proper electrolyte level, preventing physical abuse and keeping the battery properly charged. Not maintaining a proper charge can result in a permanently damaged battery due to a process termed "sulphation." A battery is discharged when lead-sulphate accumulates on its plates. Allowing a lead-acid battery to become severely discharged may cause sulphation to a degree great enough to make charging impossible. In a case like this, you have to junk the battery and replace it with a new one.

Sulphation can sometimes be eliminated by charging a battery for a long period of time or with a very high current. However, a sulphated battery is frequently beyond salvage.

Overcharging a battery can also permanently damage it. If a battery is fully charged, continuing to charge it will permanently damage the plates as well as raise battery temperature to an unsafe level. Moreover, the battery's electrolyte will generate dangerous, extremely explosive hydrogen. As long as overcharging is maintained, the battery will continue to give off hydrogen. This condition will persist until the charging current is removed or the electrolyte is completely boiled away. Should the latter occur, the dry battery runs the risk of plate oxidation, which will permanently damage the battery.



PARTS LIST

Semiconductors
D1,D2,D4,D5—1N4001 rectifier diode
D3—1N4735 or similar 6.2-volt, 1-watt zener diode
LED1—Green light-emitting diode
IC1—CA3140E operational amplifier
Q1—2N2222 npn transistor

Resistors (¼-watt, 10% tolerance)
R1,R10—10,000 ohms
R3,R4—100,000 ohms
R5—2 megohms
R7,R8—1,000 ohms
R9—27,000 ohms
R2—100,000-ohm, pc-mount trimmer potentiometer
R6—1-megohm, pc-mount trimmer potentiometer

Miscellaneous
I1—117-volt ac panel-mount neon-lamp assembly with built-in current-limiting resistor
K1—12-volt dc relay with spst contacts rated at 3 amperes or more (see text)
SO1—Chassis-mount ac receptacle
Printed-circuit board or perforated board with holes on 0.1″ centers and suitable soldering or Wire Wrap hardware (see text); 8-pin DIP socket for IC1; suitable enclosure (see text); large alligator clips (one red, one black) for battery cable; ac line cord with plug; 18-gauge two-conductor zip cord for battery cable; small rubber grommets (2); machine hardware; hookup wire; solder; etc.

Fig. 1. Overall schematic diagram of battery-charger controller.

The task of keeping a battery properly charged can be simplified if you use an automatic battery charger. If your charger is not fully automatic, you can get the same (or better) results by adding to it the controller to be described.

Our controller can be used with any 12-volt lead-acid battery charger. It has been designed to be fail-safe so that a component or connection failure will terminate charging. It includes temperature compensation to provide accurate charging control under varying ambient-temperature conditions, and built-in indicators to keep you informed of its charging status.

About the Circuit

As shown in Fig. 1, the battery charger controller is built around a BiMOS operational amplifier (*IC1*), shown here configured as a comparator with hysteresis. This particular IC op amp was selected because it permits single-ended power-supply operation and it has very low power requirements.

The positive (+) terminal of the battery to be charged is connected to the anode of reverse-polarity protection diode *D1*. All positive circuit voltage (V+) is available from the cathode of *D1*.

The voltage divider composed of *R9* and *R10* provides the input voltage for the *IC1* comparator, while *IC1*'s reference voltage is derived from SETPOINT trimmer potentiometer *R2*. The voltage supply for *R2* is from zener diode *D3*, rectifier diode *D2* (which provides temperature compensation for *D3*) and current-limiting resistor *R1*. Resistors *R3* and *R4* provide current limiting for *IC1*, while resistor *R5* and trimmer

potentiometer *R6* provide hysteresis for the comparator. For this application, you want the battery charger to turn on at 12 volts or less and turn off at 14 volts or more. Thus, a hysteresis of 2 volts is required. The hysteresis curve is shown in Fig. 2.

A comparator input voltage at pin 2 of *IC1* that is less than the comparator reference voltage at pin 3 causes the *IC1* output at pin 6 to go high. This turns on transistor *Q1* via current-limiting resistor *R8* and diode *D4*. When *Q1* conducts, relay *K1*'s contacts close, turning on CHARGING indicator lamp *I1* to light and delivering 117-volt ac line power to ac receptacle *SO1* and to the battery charger plugged into the receptacle.

Diode *D5* in parallel with *K1*'s coil provides protection for *Q1* when the relay is energized. It conducts away the bucking voltage that results when the deenergized relay coil's electromagnetic field collapses and induces a reverse voltage in the coil.

Resistors *R5* and *R6* feed the output voltage from *IC1*'s pin 6 output back to the noninverting (+) input of the comparator at pin 3 to raise the setpoint voltage from the original 12 volts to the desired shutdown value of 14 volts. When the battery's potential reaches 14 volts, the output of *IC1* goes low. This turns off *Q1*, deenergizes *K1* and extinguishes *I1*. It also removes power from *SO1* and

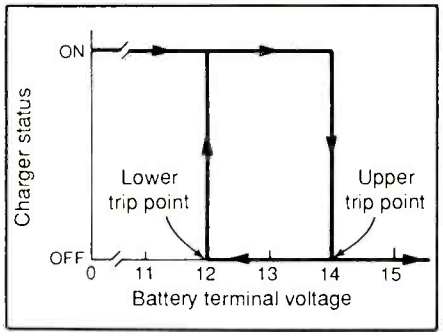


Fig. 2. Battery terminal voltage hysteresis curve.

the battery charger. When this occurs, FULL *LED1* turns on as a result of the small current flowing via *K1* and *R7* to indicate that the battery is fully charged. The setpoint again reverts to the original value of 12 volts because the comparator's output is no longer holding it at 14 volts.

When the battery's potential drops to 12 volts, the entire sequence just described will repeat, during which time *LED1* will be off, indicating that the battery is once again charging.

Construction

Since there is nothing critical about component layout for the battery-charger controller, it can be assembled using any traditional wiring method, including a printed-circuit board or a perforated board with holes on 0.1″ centers and suitable soldering or Wire Wrap hardware. Whichever wiring method you decide upon, use a socket for *IC*.

You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 3. Once the board is ready, install and solder into place the IC socket, as shown in Fig. 4. Note in Fig. 4 that most but not all of the components mount on the board. Those that mount off the board include the relay, LED and neon indicators and ac receptacle.

Install the zener and rectifier diodes, taking care to properly orient them before soldering their leads to the copper pads on the board. Properly orient the transistor, plug its leads into the appropriate board holes and solder them to the copper pads. Then install and solder into place the fixed resistors and trimmer potentiometers.

Prepare four 6″ lengths of stranded hookup wire by removing from each end ¼″ of insulation. Tightly twist together the fine wires at both ends of all four wires and lightly tin with solder. Plug one end of these wires into the holes labeled K1 COIL and LED1 and solder them into place.

Now, if you are using a separate enclosure in which to house the controller, machine it for mounting the various components and to provide

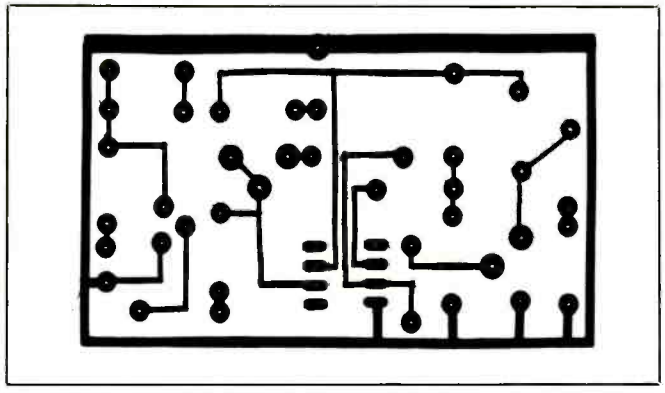


Fig. 3. Actual-size etching-and-drilling guide for home fabricating a printed-circuit board.

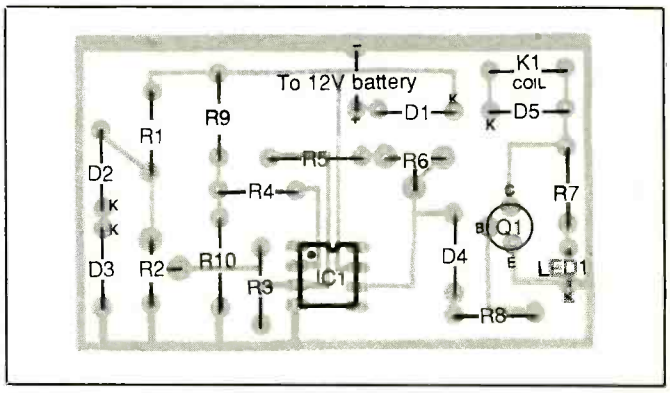
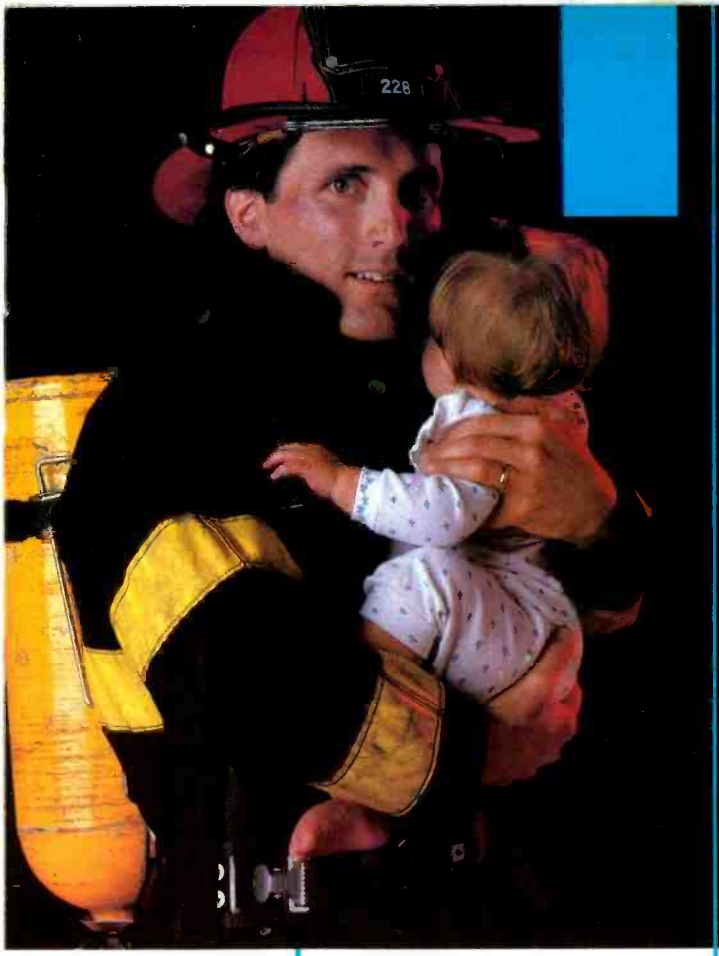


Fig. 4. Wiring guide for printed-circuit board. Use this as a guide for perforated board layout.



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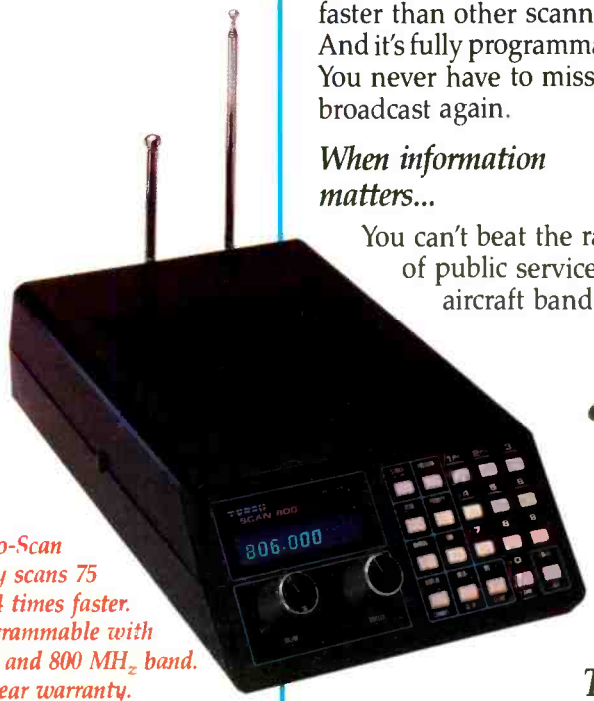

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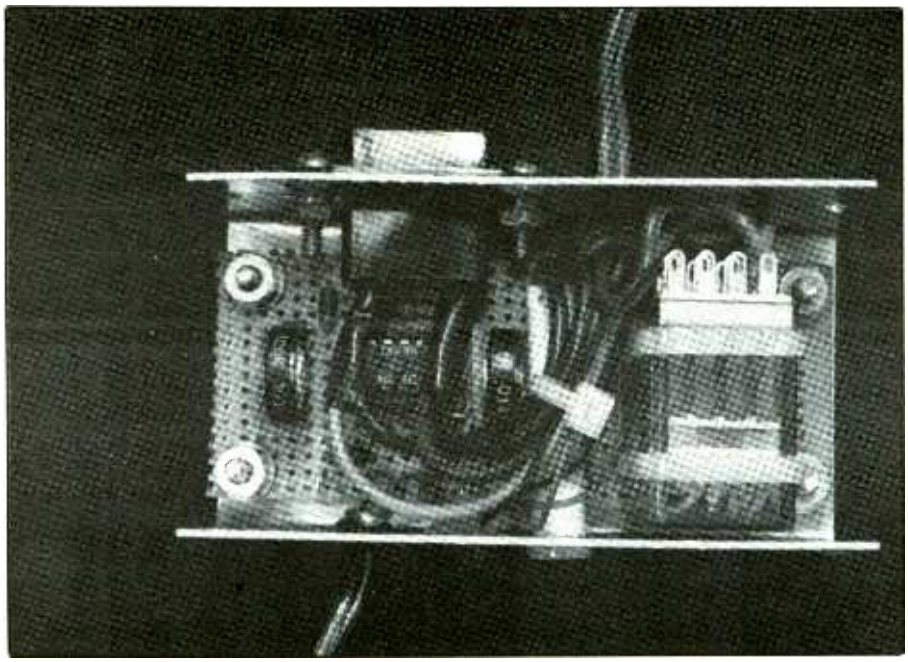


Interior view of project with circuit assembled on perforated board. Note how relay is held in place on the board with a plastic cable strap.

entry for the project's ac line cord and battery cable. When you are finished drilling mounting holes and making the cutout for the chassis-mount ac receptacle, deburr all cut and drilled edges.

Plan your layout so that the circuit-board assembly and relay mount near each other. Mount the two in their respective locations, using ½" spacers and 4-40 or 6-32 × ¾" machine screws, lockwashers and nuts for the board. Then locate the free ends of the K1 COIL wires and connect and solder them to the relay's coil lugs.

Mount the CHARGING neon-lamp assembly and FULL light-emitting diode in their respective holes. Use the mounting clip that comes with the neon-lamp assembly to hold it in place. Line the LED's hole with a small rubber grommet and force-fit it into place. Alternatively, you can mount the LED with a standard panel-mount clip or grommet or use a small daub of clear, fast-set epoxy to hold it in place.

When wiring the circuit, take particular care with the sections that carry the 117-volt ac line potential. Make sure to provide adequate insulation and make mechanically and electrically secure connections. Double check all wiring to make sure everything is okay. Wire the neon-lamp assembly directly across the *SO1* lugs. Also, use No. 18 or larger stranded wire to make the interconnection between the relay's contact and *SO1*.

Use 18-gauge two-conductor zip cord for the battery cable. Cut the cord to about 36" in length and remove ¼" of insulation from both conductors at both ends. Tightly twist together the fine wires in each conductor and lightly tin with solder. Terminate one end of this cable in color-coded (red and black) alligator clips that are large enough to provide a secure electrical/mechanical connection with the lead-acid battery's terminals.

Pass the free end of the battery cable through its grommet-lined entry hole and tie a knot in it inside the enclosure far enough from the free end to provide a bit of slack when it is connected into the circuit. Plug the conductor terminated in the black alligator clip into the board hole labeled +12V and solder into place. Then plug the other conductor into the nearby GND hole and solder it into place.

Tightly twist together the fine wires in each conductor of the line cord and sparingly tin with solder. Pass the free end of the cord through its grommet-lined hole, tie a strain-relieving knot in it as you did for the battery cable, and connect and solder the free ends to the other relay contact and appropriate side of the ac receptacle (see Fig. 1).

Calibration and Use

To calibrate the controller, you need a dc power supply and a dc voltmeter or a multimeter set to indicate at least 15 volts. The power supply's output must be adjustable from 5 to 15 volts and be capable of delivering at least 1 ampere of current.

Connect the battery cable and voltmeter to the power supply's output connectors. Do not plug the project's ac line cord into an ac receptacle. Set *R6* to maximum resistance, *R2* for maximum voltage and the power supply for an output of 12 volts. Slowly decrease the setpoint until the relay energizes.

Slowly increase the power supply's output voltage until the relay de-energizes. You should again hear a click. If the shutdown potential is less than 14 volts, decrease the power supply voltage until the relay energizes, decrease the setting of *R6* slightly and recheck the upper trip point by slowly increasing the power supply voltage until the relay de-energizes. Continue adjusting the hysteresis in this manner until the upper trip point occurs at 14 volts.

When you finish calibrating the controller, plug the line cord into an

ac receptacle and check the indicators. At this point, the CHARGING neon lamp should be on when the relay is energized and the FULL light-emitting diode should be on when the relay is energized. At no time should both indicators be on at the same time. These indications should be observed with the battery cable connected to the battery and the the power supply set to 10 volts (*I1* on) and 14 volts (*LED1* on).

Before putting the controller into service, make certain that its relay contacts can handle the current normally drawn by the charger plugged into the *SO1* receptacle. If your charger draws more that the 3-ampere rating of the contacts for the relay specified in the Parts List, replace the relay with one that has contacts that can safely handle the load.

First connect the battery charger's cable clamps to the battery. Then clip the controller project's battery cable alligator clips to the battery terminals. Observe proper polarity in both cases. Plug the battery charger's line cord into the controller's ac receptacle and plug the controller's line cord into a wall ac receptacle.

During initial operation, monitor controller operation to make certain that the charger shuts down when battery terminal potential reaches 14 volts and starts up again when the potential drops to 12 volts. Also, periodically (about once a month) check the controller for proper operation to ensure that normal charging is occurring and that the battery is kept in good condition. **ME**

Process Control With Personal Computers

(Part 3, Conclusion)

Software needs and creating simple control systems

By Dr. H. Edward Roberts

This is the third and concluding article on Process Control with personal computers. In the first article, we laid the groundwork for the series by discussing basic control principles, computer-based process control with IBM-type PCs, and examples of computer-based controllers, focusing on DataBlocks's LINK system. Last issue discussed building the LINK interface to a standard IBM personal computer or clone, which, along with Altair-II control modules from DataBlocks, Inc., form the Modern Electronics Computer Controller. Also covered were sensors such as the thermistor, photoresistor, and resolver, as well as actuators such as the stepping motor. Finally, special interfaces were examined.

In this article, we'll explore software needs and then create a simple control system for the home and a system to automate testing of an analog-to-digital converter, designing these systems around the Modern Electronics Controller.

Software Control

The PC LINK, which adds more than 2,000 addresses to the very few available on a PC, is designed to operate with any programming language to address I/O ports. This allows a system designer to use the LINK board and external A-II control blocks in a familiar programming environment. In addition, drivers written in C and BASIC exist for many of the control blocks. These drivers, collectively called the Personal Control Language, or PCL (pronounced "pickle"), were specifically developed by DataBlocks for computer control applications. They give the user a simple way to control the application blocks with a high-level language, relieving him of the need to understand hardware/soft-

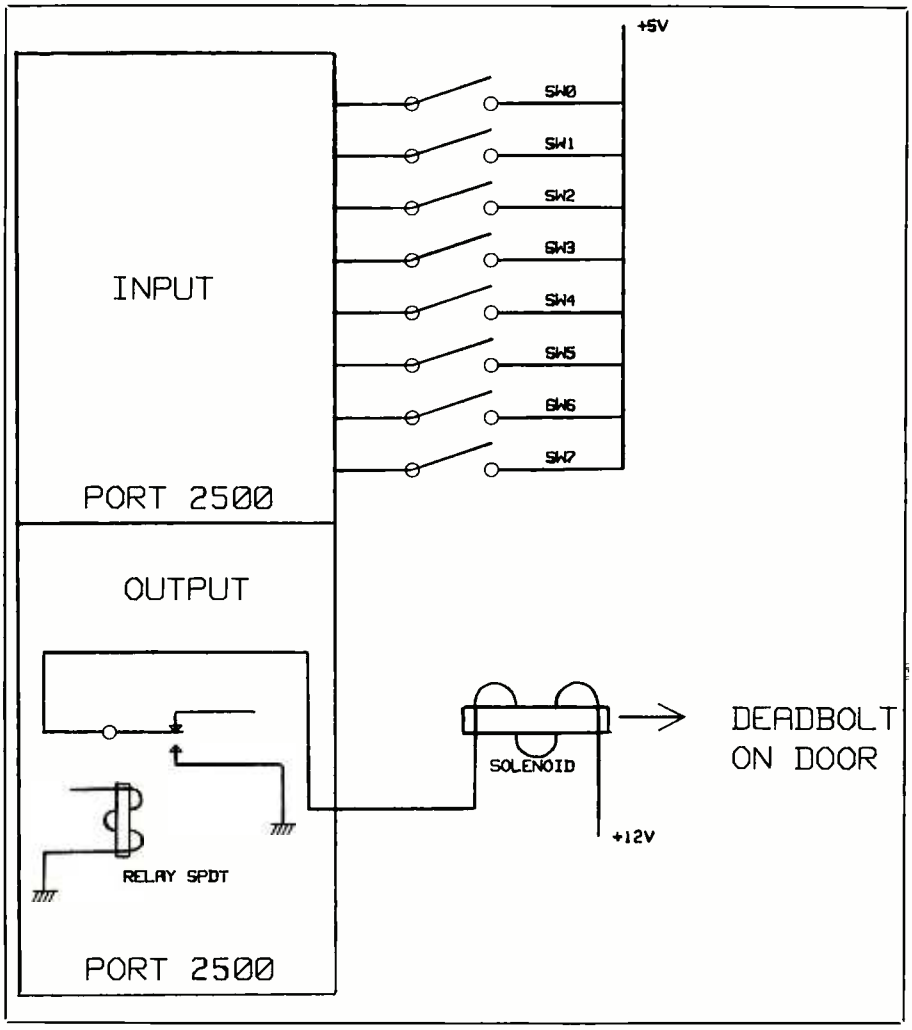


Fig. 12. Functional diagram of an electronic door lock.

ware interface details of each module. The PCL routines are contained in libraries and are accessed with simple, single line calls from the main program.

Most languages that run on a PC allow control of the input and output ports directly. For our examples, we will use standard IBM BASIC. To control a stepping motor with a dc driver block, for example, all the programmer need do is include the following line in his BASIC program:

```
10 STEP (port,steps,speed,nibble,stack)
```

where: *port* is the computer I/O port used to address the dc driver block; *steps* is the number of steps to rotate a motor, positive for clockwise motion, negative for counterclockwise; *speed* is the rate to turn the motor; *nibble* is an A or B, indicating whether the motor is connected to the upper or lower nibble of the dc driver block; and *stack* is a number between 0 and 7, denoting which of the eight possible stacks in which is contained the dc driver block.

The same line could also be included in a C program to control a stepping motor. Over 20 PCL commands exist to enable single-statement control of blocks that allow the user to control motors, read switches, monitor temperature and perform other control functions with the computer as easily as he controls his printer with the BASIC statement LPRINT.

All standard PC software is compatible with the PC LINK employed in this system series. DataBlocks also provides a real-time operating system, ARTDOS (A-II Real-Time Disk Operating System) for applications requiring real-time event processing.

To illustrate how we might control a relay block, we will write a simple BASIC program using IBM standard BASIC. The command to control an output port in BASIC is simply OUT A,D, where *A* is the address of the output port and *D* is the data to be transmitted. The following illustrates how to use this command, making the assumption that the relay block has an address of 2500. The program turns relays 0,2,4,6 on and the other relays off (relays numbered 0 through 7).

```
10 OUT 2500,&B01010101
```

That's it! The whole program is simply line 10, which is read as: Output to port 2500 the binary number 01010101. The right-most bit is 0, and it controls relay 0. The left-most bit is 7, and it corresponds to relay 7. Therefore, if bit 7 is set to a logic "0," relay 7 will be set to a logic "0" (off); similarly, a "1" will turn the relay on. For instance, the following program will turn off all relays, except relay 7:

```
10 OUT 2500,&B10000000
```

Now let's do something a little more sophisticated: make an electronic lock that will energize a solenoid-operated dead bolt on the front door of a house. For purposes of this discussion, assume that we will use toggle switches for the input. Figure 12 shows one way to wire such a circuit. A simple program to control the door lock might be:

```
10 A = INP (2500)
20 IF A = &B11000101 THEN GO
TO 50
30 OUT 2500,&B00000000
40 GOTO 10
50 OUT 2500,&B00000001
60 GOTO 10
```

In this program, we assume that both our input and output ports are at the same address, that is, 2500. Also note that the combination to the lock is 11000101. This means that switches 0,2,6,7 on the others are off. The program operates as follows:

1. First, the computer will input the setting of the switches in line 10; that is, read the switches.
2. The number read in line 10 is compared with the combination number, 11000101.
3. If the numbers match, the program will jump to line 50 and turn on relay 0. If the numbers don't match, the program turns off all relays (line 30).
4. The program will continue to cycle until stopped due to the GOTO 10 statements.

A typical PC might be able to perform the above operations several thousand times a second. This means that this routine could be "buried" in some larger program and checked occasionally, say, every 200 milliseconds. Since each check would take less than 1 millisecond, the computer will still have 99.5 percent of the second left over to do other jobs. These times are approximate, but they will give you a feel for the capability of a computer.

The lock example given above is interesting from a number of standpoints. It shows how multiple unrelated inputs (switch closures) affect an outcome. Also, by changing the number required for a match, you could make the system "adapt" to various situations.

Though number entries have been shown as binary bits, such as 11000101, the computer is just as happy to compare switch settings with decimal numbers. We could have entered 197 instead and the program would have worked exactly the same. The reason for this is that the computer ultimately compares or operates on all numbers as binary numbers. I find that in some applications it is easier to think of switch settings if I enter them in binary, but in many other applications using decimal numbers or sometimes even hexadecimal is useful. While it is not a requirement to learn binary numbers to work with control computers, anyone who wants to be really literate in computer electronics should have some familiarity with binary.

Designing Systems

Using a personal computer and controller equipment makes it easy to design and install systems to provide comprehensive control of home or office security, environment, and

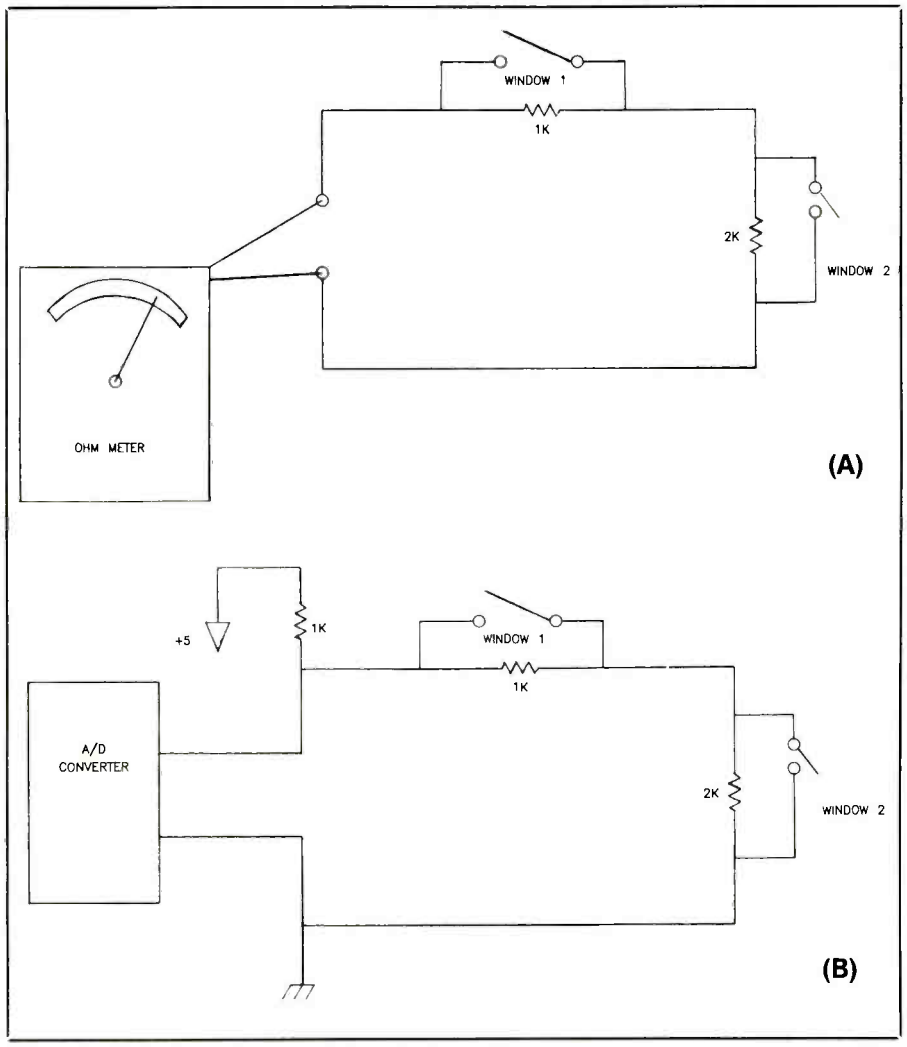


Fig. 13. Detectors for multiple windows (A) and an automated open-window detector (B).

disaster prevention. Let's discuss some approaches to doing this.

Monitoring doors and windows to detect when one is open, for example, can be as simple as wiring a resistor across a switch at each door or window to be monitored by a computer. An open-window detector's resistance can be monitored with an ohmmeter. Closing the window causes a contact switch to short out the resistor, resulting in a zero reading on the meter. Opening the window removes the short and the meter then reads the resistor's value. Let's expand this concept by wiring two windows in series, as shown in Fig. 13A. Now the meter will not only detect when one of the windows is open, it can also reveal the window's location if the value of the two resistors is different. Accordingly, if window 1 is open, the reading will be 1k, and if window 2 is open, the resistance is 2k. Of course, a 3k reading will indicate both windows open.

Extending this one step further, we can automate the system by replacing the meter with an analog-to-digital converter circuit, as shown in Fig. 13B. Here, the A/D converter reads 0V when both windows are closed since all the resistors, except *R1*, are shorted. If window 1 is open, the A/D reads 2.5 volts, while a 3.3-volt reading is detected if window 2 is open. If both windows are open, no current will flow in the circuit, and 5 volts will be measured by the converter. It is easy to see that this approach could be extended to include all windows and doors in a home or office.

The principles of environmental control are also easy. You can conserve energy simply by reducing the temperature in the house during the time of day when no one is home. This can be accomplished by placing a relay in series with the furnace thermostat control wire, as depicted in Fig. 14. A computer can be programmed to open the relay during the time of day when no one is home to allow the temperature to decrease.

It would be advisable, especially in very cold weather, to add some feedback to the system by monitoring the temperature with a thermistor circuit and an A/D converter. If the temperature decreased below a desired level, the computer would reactivate the relay and run the furnace until the temperature was again at an acceptable level. This system is also useful in the summer to reduce electricity used by an air conditioner. In addition, this simple conservation approach can be used to reduce energy wasted by an electric water heater.

Recreation and relaxation offer many opportunities for productive automation. A good example is using energy from the sun to heat the water in swimming pools and hot tubs. To have an effective solar heating system, a process control system must monitor several parameters and control several actions. For instance, the system must be able to determine if the solar isolation is high enough to increase the water temperature rather than cool it. This can be done by programming the controller to compare the water's temperature as it leaves the heater with the water's temperature in the hot tub. If the water leaving the heater is cooler than upon entering, it's time to abandon the solar heater until a sunnier day.

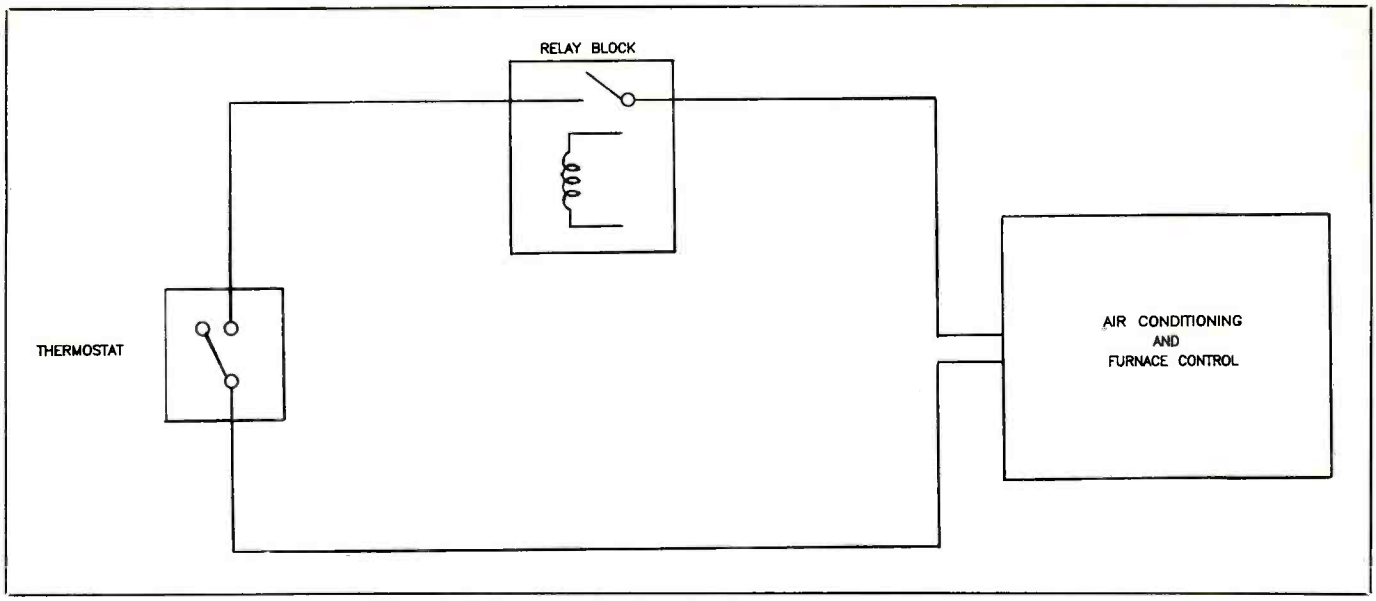


Fig. 14. Schematic details of a thermostat control system.

The water in a pool or hot tub should also be monitored to ensure that it does not become too hot. If it does, the computer must activate valves to stop the flow through the heater or activate a motor that will reorient the solar collector to reduce the amount of energy transferred from the sun to the water. The controller should also open and close valves to replenish the water lost due to evaporation and spillage. In addition, it should run the filtering systems periodically when the pool or hot tub is not in use and continuously when it is being used. These functions are easily implemented using the Controller previously described.

Monitoring indicators of impending disaster is also a very useful function that is easily performed by our controller system. For example, detecting when a smoke alarm has been triggered can be accomplished by monitoring the alarm's buzzer with the circuit shown in Fig. 15. When the alarm is activated, the voltage across *C1* increases. This increase is measured by an A/D converter, which causes the controller to dial the fire department through a computer modem. The modem circuitry informs the controller when the fire department phone has been answered, and the controller can activate a speech-synthesis block to give the fire department dispatcher information on the fire's location.

To illustrate the rudiments of designing with the controller, let's now design a system that brings together some of the home-automation ideas discussed. The first step is to define the system requirements. Let's put together a simple system, illustrated in Fig. 16, which does the following:

1. *Provides security.* (a) Monitor windows. (b) Turn on a floodlight if a window is opened (requires easy override so window can be purposely left open. (c) Make house look lived-in when occupants are gone (requires easy means to activate/deactivate).

2. *Reduces heating and cooling load during the day.* (a) Should defeat the setback on Saturday and Sunday (or any days desired). (b) Requires feedback to prevent the house from becoming too hot or cold during the setback period.

3. *Controls a solar water heating system for a solar hot tub.*

The control system we'll use consists of an IBM PC or clone, a DataBlocks LINK and a stack of the control blocks necessary to meet the control requirements. One block we need on the stack is a DataBlocks KAD-710, a 16-channel A/D converter, to monitor some open-window detector circuits such as those cited. We'll also add a Powerhouse X-10 universal interface to the controller stack to turn on a floodlight if the computer detects a window being opened. The Powerhouse X-10 system will also be used to control lights

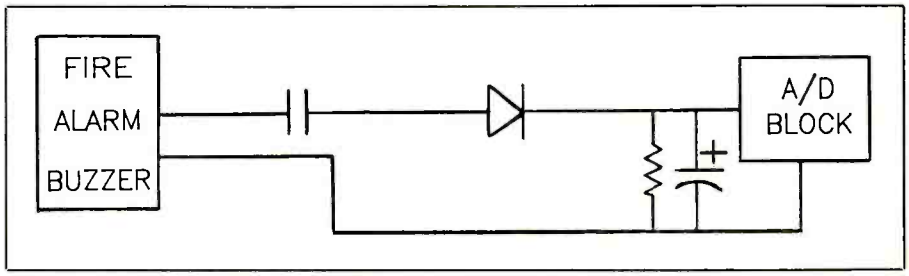


Fig. 15. A fire alarm monitor arrangement.

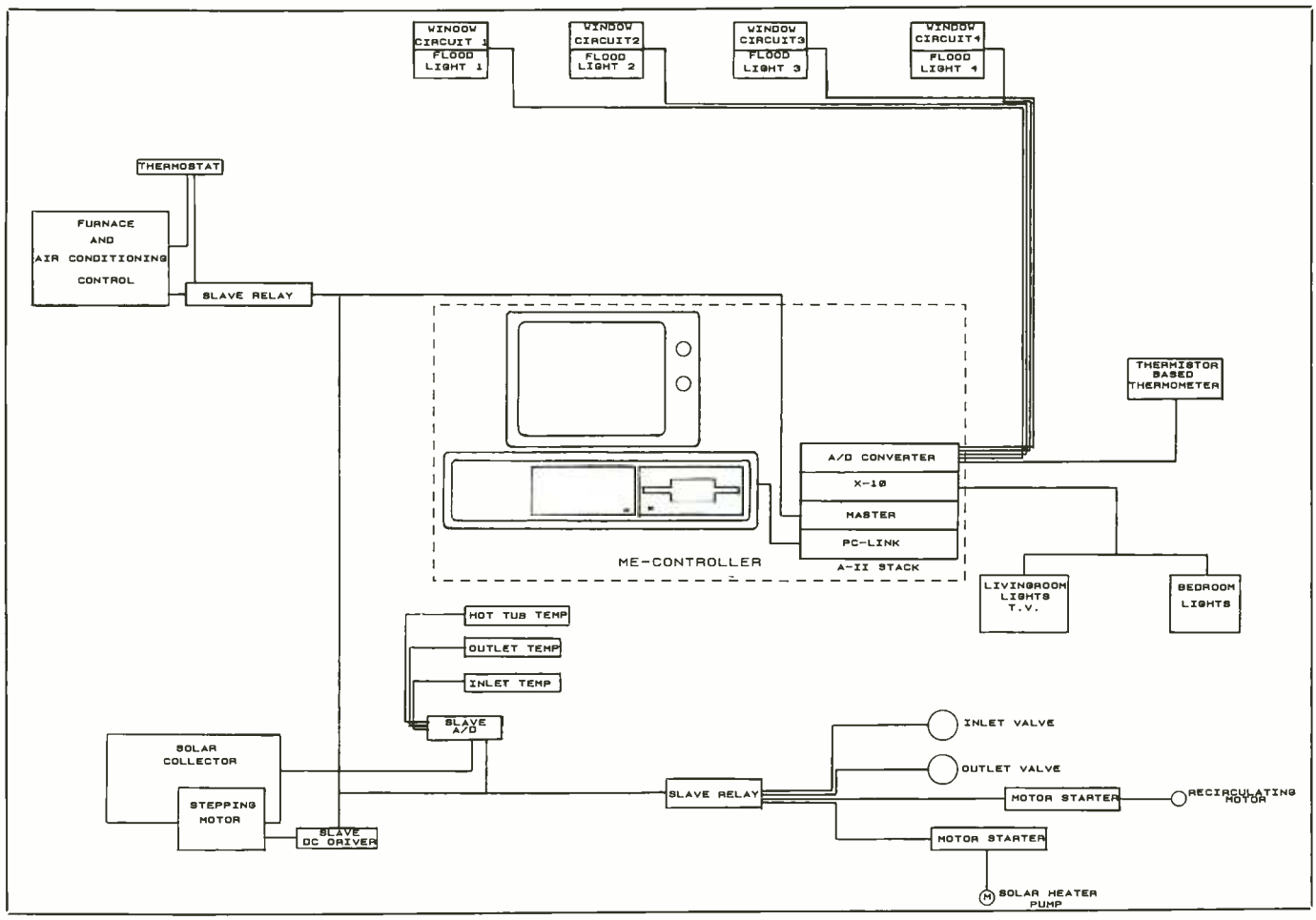


Fig. 16. A typical home automation system.

in various parts of the house to make it look lived-in when unoccupied.

A DataBlocks Master Control Block will also be included in the stack. This block will be used to send and receive data between several slave blocks needed to complete our control system. One of these is a slave relay to interrupt the thermostat and shut off the air conditioner or heater when no one is home. To prevent the house from getting excessively hot or cold when it is unoccupied, we should add some feedback to this part of the system. We'll do this by using a channel of the A/D converter already on the stack to monitor a thermistor circuit such as the one shown in Fig. 17.

You'll recall from Part 2 that a thermistor exhibits a resistance that varies with temperature. Therefore, as the temperature in the house changes, the thermistor's resistance also changes and causes the voltage across *R1* to change. When voltage across the resistor moves outside a tolerance window that represents the maximum and minimum allowable temperature, the computer sends a message through the master to the slave relay, causing the relay to close. This will allow an air conditioner or furnace to run until the temperature changes enough to cause the voltage in the thermistor circuit to again indicate that the temperature is within acceptable limits.

The solar water heating for the hot tub will also require slave blocks. Let's assume we will install a parabolic solar collector to transform the energy from the sun into heat. This type collector should always be pointed toward the sun and, therefore, we need a control circuit to rotate the collector as the sun's orientation to the collector changes during the day. As observed in last month's article, a stepping motor provides excellent rotational control without requiring explicit feedback. This makes the stepper a good choice to drive the solar collector. The stepper is driven with a dc driver block; since the motor will be located several feet away from the Controller, a slave dc driver block is the best choice.

One of the most important things to consider when using a solar water heater for a hot tub is water temperature. As in the case of monitoring temperature in a house, the thermis-

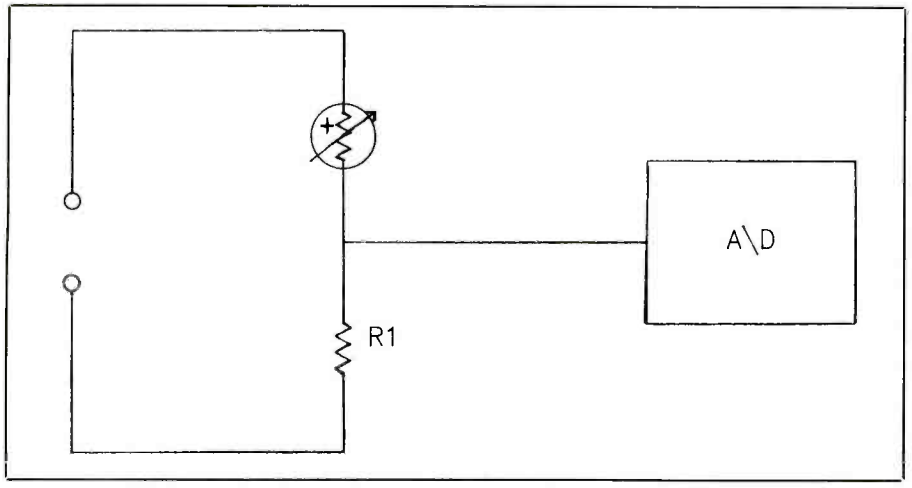


Fig. 17. A thermistor-based thermometer.

tor circuit shown in Fig. 17, monitored with an A/D converter, should work well. Since the hot tub is likely to be remotely located from the controller, we will again select a slave A/D converter. In this case, we'll use three channels of the A/D converter to monitor inlet temperature, outlet temperature and the temperature of the water in the tub.

It would also be a good idea to use a channel of the A/D converter to monitor a switch on the solar collector hardware. This switch should be mounted so that it is closed when the collector is facing about 20 degrees below the east horizon, providing a starting point from which to orient the collector. This will enable the software to re-establish the correct collector orientation if the system loses power. This is the "parked" position of the collector.

Several valves must be opened and closed, too. Also, the hot tub recirculating motor and solar collector water pump must be controlled to complete our hot tub automation project. This will best be handled with a slave relay. Current required for valves is low and, therefore, they can be controlled directly with the relay. However, depending upon the size of the recirculating motor, the current requirements, especially the starting current, may exceed the 6-ampere capacity of the relays on the relay block. It would be better, therefore, if we used a motor starter, which has lower current requirements, to switch this motor. The pump for the solar collector may not require more current than a relay can switch. In this case, it can be controlled directly by the relay. However, depending on the size of the collector, the size of the pipe to the collector, and the height to which the water must be pumped, the pump may indeed draw enough current to also require use of a motor starter.

Now that the hardware portion of the design process is done, we'll design the software part of the system. There are probably several approaches to designing software for this automation project. The easiest

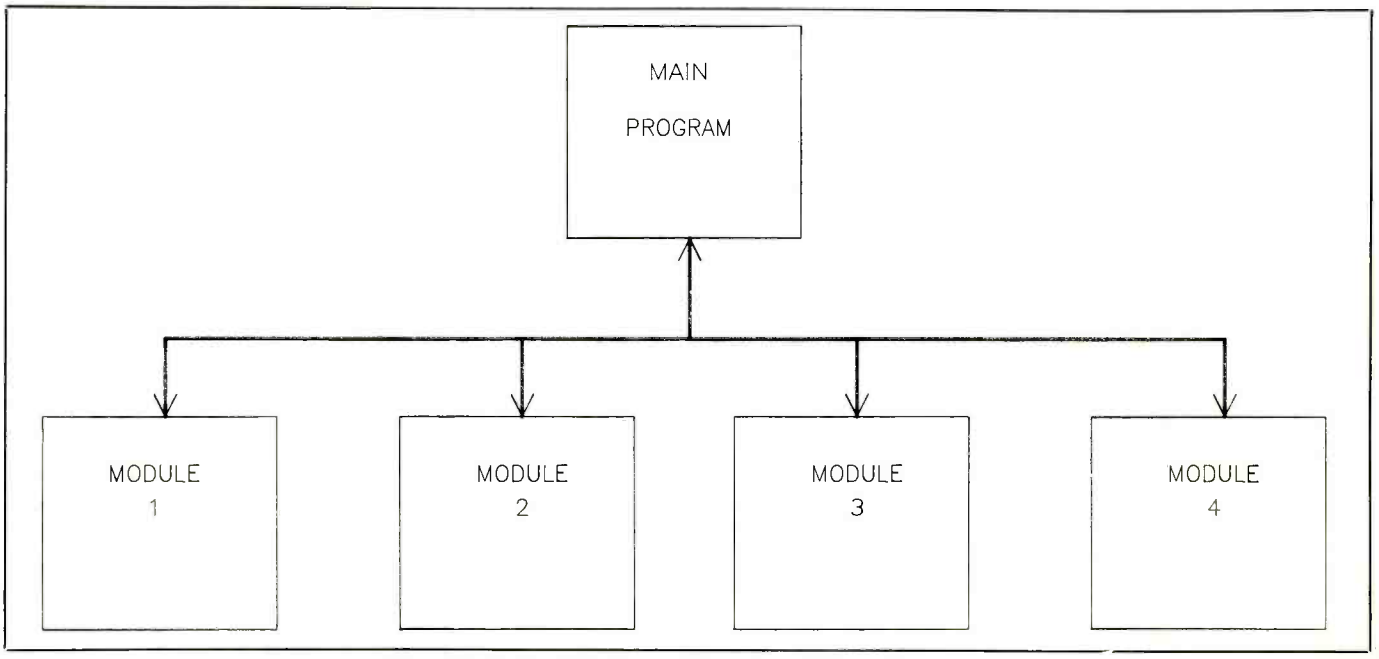


Fig. 18. Typical Software Functional Flow diagram.

to contemplate for our example is one in which the software sequentially branches to modules that perform one of the functions previously described in the system's requirements. Figure 18 depicts this as a main flow diagram and four modules.

Such a modular approach is useful for several reasons. First, it allows very complicated software to be decomposed into simple components to facilitate development. Although our example is not particularly complicated, the modular approach makes it even easier. Second, a modular approach allows additional modules to be added without significant software rewrite. Finally, it makes the software much easier to test and debug.

Once in a module, the software compares the current time with preset start and stop times for the various functions. The preset times, along with other fixed parameters, are called the data base and should be stored in a file on disk and read into the program as necessary. This makes it easy to change the parameters as requirements change. It also permits access to several sets of parameters to accommodate different circumstances, such as seasons of the year and vacation schedules. The files could easily be made and stored with a utility program written for that purpose.

Figure 19 illustrates the software control flow. The initialization routines are executed first. They establish the operating environment for the program by reading a parameter file from disk and storing the data in data-base memory so that it can be used by the rest of the program.

You may choose to store the data in separate variables, or you can group data functionally and store it in arrays. Included in the parameter file are such things as start and stop times for each function, maximum and minimum temperatures, and X-10 addresses and control codes. Depending upon your approach and

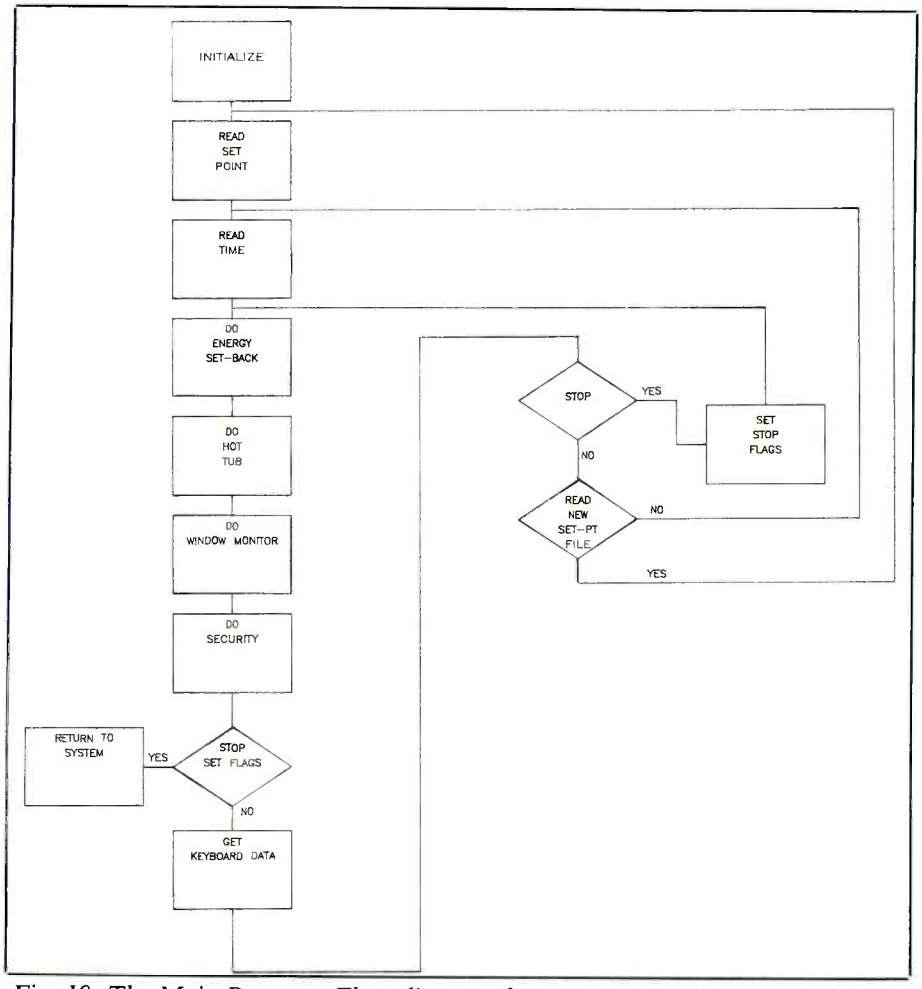


Fig. 19. The Main Program Flow diagram for the system described in the text.

the system enhancements you wish to include, you can add to or subtract from this list when you develop your software. In addition to data-base initialization, the initialization routines may contain other software pertinent to getting the system ready to control your home or office. For example, you might wish to devise a test to ensure that each of the hardware blocks is working when the system is powered on. The software to perform these tests will be included in the initialization routines.

After initialization, the main program sequentially transfers to each of the service modules. The first service module is the one that controls the energy setback relay on the furnace and air conditioner relay. Figure 20 shows the thermostat's logical program flow through this module. Upon entry into this module, the software checks a flag to determine if the routine has been activated. That is, whether the start-time criteria for this activity, defined in the data base, has been met on a previous pass through the module. If not, it tests the current time against the start criteria to see if it is time to activate the energy setback function. Until the start time is reached, the software simply returns to the main routine to continue servicing the other modules.

When the start time is reached, the active flag is set and the software executes the rest of the code in the module. The first step is to see if it is time to stop. Of course, on the initial time through the routine, it will not be time to set the stop; but we do need to

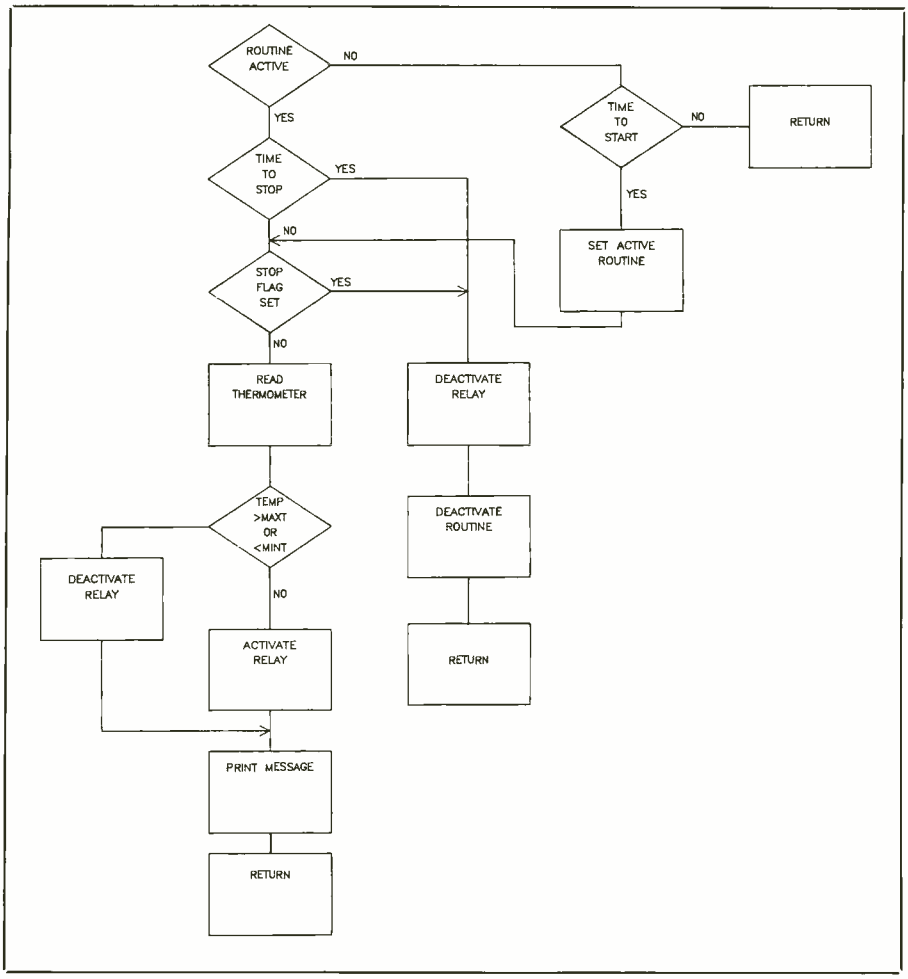


Fig. 20. A Thermostat Set Back Flow diagram.

make this check later. Moreover, the programming logic is simpler if we check each time through.

The next step in the flow diagram is to check if a stop flag has been set. This flag is the one that is set from the keyboard to interrupt the normal flow of events. For example, if you come home from work early and the energy setback routine is in operation, you need an easy way to deactivate the module and make the house more comfortable. Setting the stop flag from the keyboard will initiate an orderly shutdown and allow you to do this. If the stop flag is set or it is time to stop, the software deactivates the relay controlling the setback, deactivates the screen and returns to the main program.

If neither of the two conditions that cause the software to exit the module are true, the program reads the thermometer. The temperature is compared with two data-base values, MAXT, the maximum temperature you are willing to let the house attain, and MINT, the minimum temperature you want.

If the temperature in the house is determined to be greater than MAXT or less than MINT, the program deactivates the setback relay, allowing an air conditioner or furnace to run until the temperature is again between maximum and minimum. If the thermometer reading indicates that the temperature is between extremes, the software activates the setback relay to to conserve energy and then returns to the main routine. At this point, you might question turning on a relay that may already be on. Since there is no mechanical reaction, it makes no difference. You could test to see if the relay had previously been turned on, but this complicates the software unnecessarily.

The second module our software will service is the hot tub. As illustrated in Fig. 21, the software in this module reads the tub's temperature as soon as the start time has been reached. The temperature is compared with MAX, a data-base value that you set to establish the hottest temperature you want the hot tub to reach. If the temperature is equal to or greater than MAX, the recirculating pump is turned off, the solar collector is pointed away from the sun, the water pump is turned off, and control returns to the main program. If the temperature in the tub is less than MAX, the recirculating motor and water pump are started, and the collector is pointed at the sun.

A word about controlling the collector is in order here. Temperatures in a parabolic solar collector on a sunny day can become very hot. Therefore, in our application it is important that the collector be pointed away from the sun when water is not circulating through it. This will prevent water that is extremely hot from entering the hot tub when the water pump is first started. Recall that we made provisions for a park position for the solar collector by monitoring a switch closure with the slave A/D converter. Turning the collector to the parked position when the water pump is off will prevent the water from becoming overheated.

Let's also examine how we'll keep the controller pointed toward the sun when we have the water pump on. We could install a sensor that signals the computer when the collector is pointing toward the sun. Remember, however, that the rotational position of the stepping motor can be determined by keeping track of the number of steps sent to it. We also know

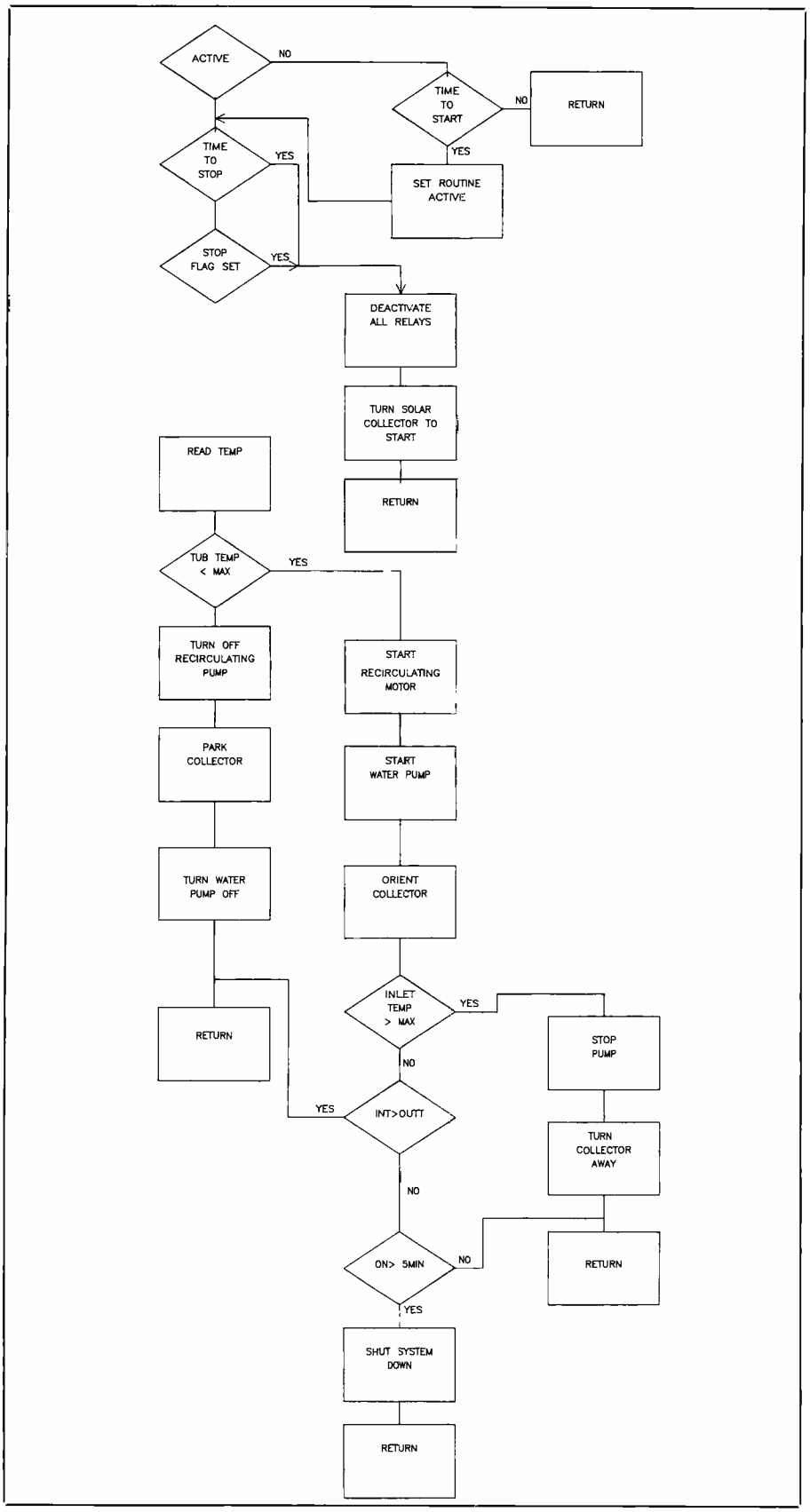


Fig. 21. A Hot Tub Software diagram.

that the location of the sun is very predictable if we know the day of the year, time of day and our location. It simplifies our design, therefore, if we compute how much collector rotation is needed to point toward the sun and the number of steps we need to send to the stepping motor to turn the collector that amount.

Once the collector is oriented, check the inlet temperature to make sure the incoming water will not burn anyone in the tub. If the water is equal to or greater than the data-base value MAX, we immediately stop the water pump, turn the collector away from the sun and return to the main program. If the inlet temperature is less than MAX, we check to make sure it is greater than the outlet temperature. If it is, the system is heating as it should and we return to the main program. If it isn't the software checks to make sure the system has been on long enough (5 minutes) to get the cold water out of the pipes and allow the collector to become heated. If enough time has passed, the software starts a wait timer for, say, 10 minutes to prevent the turn-on sequence from being executed every few seconds. Then the system is shut down to wait for a sunnier time. Otherwise, we return to the main routine to service the next module and give the heating system a chance to warm up.

The next module scheduled for the main routine is the window monitor routine. The software flow for this module is shown in Fig. 22, the Window Monitor Software Flow Diagram. Once it is time to activate this routine, each of the four channels of the A/D converter in the controller is read. If the voltage indicates any open windows, a flag is set to identify the circuit and window that is open. The software then checks to see if a security flag is set. This flag indicates to the software whether you wish to activate the flood lights and sound the alarm when the window is open or whether you only

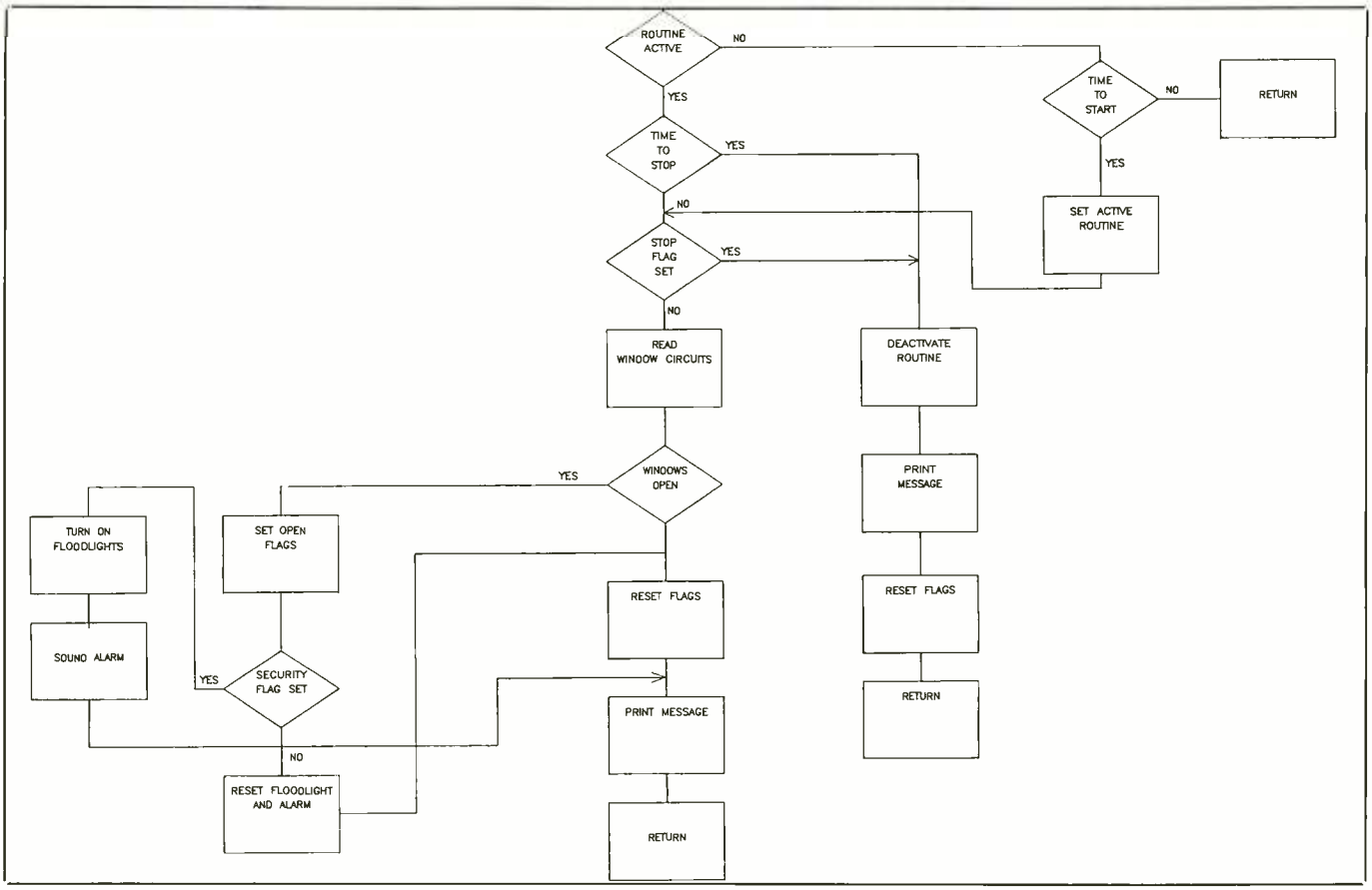


Fig. 22. The Window Monitor Software Flow diagram.

want to display a message on a video monitor. You will probably want to activate this flag based upon time of day, with the capability to change it from the keyboard. This will give your system the flexibility to provide protection during periods of non-scheduled absence from a house.

If the flag is set, the floodlights and alarm are turned on, a message that the window is open is displayed, and the software returns to the main routine. If the flag is not set, the software turns off the floodlights and alarm, displays an open window message and returns. The alarm for this circuit can be selected from a variety of devices. You might choose to turn on a radio or a stereo system, flash lights off and on, or install a loud buzzer.

The last software module serviced by our home control system is the one that makes the home looked lived-in when it is unoccupied. The key to successful implementation of this portion of the system is how natural the pattern of lights, TV, stereo, etc., is to an external observer. For example, if a bed room light flashes on and off too rapidly or always comes on at exactly 2:37 a.m., it will be obvious to an observer that the lights are not operating according to normal living patterns. Establishing appropriate timing patterns, then, will require some planning and testing to accomplish successfully. Making the start and stop times available to the software is probably best done by forming an array containing a table of start times, stop times and the appropriate address of the device or devices to control.

Referring to Fig. 23, the Occupant Activity Software Flow Diagram, each time software enters this routine it checks to see if it's active. If it isn't, it checks to see if it is time to activate it. If not, the software returns to the main program. Otherwise, the software searches the table of start and stop times to determine which devices need to be turned on and which need to be turned off. It then outputs the appropriate X-10 commands for each device in the table and returns to the main program.

The main program has now serviced all the modules instantly, as far as humans are concerned, and is ready to begin over again. Before it does, however, it determines whether the stop flag was set on the previous pass, If it was, this control program stops executing and control passes to the Controller's operating system. If the stop flag has not been set, the program determines if there

has been keyboard activity during the previous pass.

Our software discussion has been generic in that we have not made any assumptions that favor or preclude any programming language. One of the attractive features of the Controller being used here is that it is based upon familiar computer hardware running familiar software. As a result, you can use the programming language that is most comfortable to you. The only thing you might want to consider when you choose your programming language is the ease with which the language supports manipulation of the I/O ports. Obvious good candidates are BASIC, C and Pascal.

Testing Environment

So far, we've confined our discussion to control systems around the home or office. The Control system's versatility, however, makes it equally capable of control work in a laboratory or test environment, as follows.

Assume we need to perform a functional check of A/D converter blocks as they come off a production line. The requirements of the test are:

1. Test the conversion accuracy over a 0- to +5-volt range.
2. Verify operation of all 16 input channels.
3. Test operation and accuracy of the programmable gain amplifier.
4. Test that conversion time is within specification.

Further, we need to store the data acquired during the test and produce a hard-copy report when the test is concluded. Figure 24, an A/D Test Configuration, shows the hardware used to perform the tests. In addition to the PC and the LINK, the Controller is configured with a line-printer block, an IEEE-488 block, timer/counter block and a dual D/A converter. A digital multimeter with an IEEE-488 interface, a line printer and a magnetic tape recorder are also part of the test configuration. The A/D block under test is included on the Controller stack.

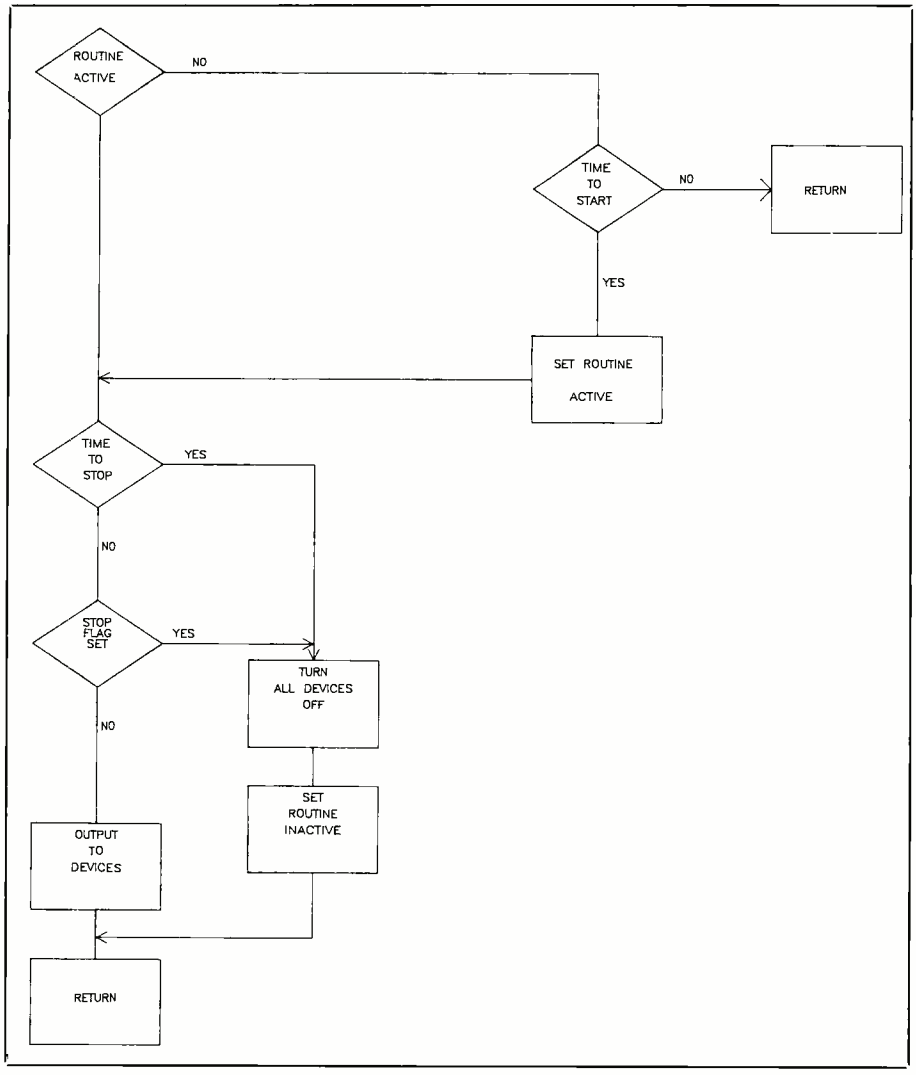


Fig. 23. The Occupant Activity Software Flow diagram.

The dual D/A block is used to produce a programmable voltage that is fed to the A/D input channels. This voltage will be changed by the Controller during the test to determine if the A/D converter under examination can digitize across the range of 0 to +5 volts. This range is important because it generally repeats minimum and maximum signal strengths sent to and from I/O ports.

Input signals to a computer are as-

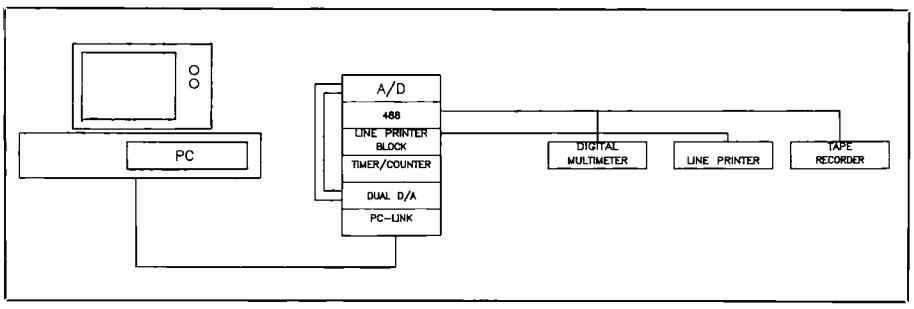


Fig. 24. An A/D converter test configuration.

sumed to be a "1" if they are greater than approximately 3 volts and assumed to be a "0" if they are less than 1 volt. If you remember this rule, it is relatively easy to interface to a computer from a signal standpoint. But there is one more detail since all the devices in the system use the same eight lines to transmit and receive data. We simply cannot connect our input signal directly to the data bus. If we did, we would lock up the bus. What must happen is that the input controller places a switch between the incoming signals and the bus. This switch is kept open until the correct conditions are met; that is, right address or IOR. Simple!

If input signals to the computer are greater than the allowed amount, you may have to use a voltage divider to lower them to acceptable levels. Also, if there is a chance of a high-voltage spike occurring on the line, an opto-isolator is probably a good device to use. In some cases where the polarity is wrong or the signal is noisy, more complex signal conditioning may be required. Another good point to remember is that input signals should be off prior to turning on the computer. Unfortunately, it is not always possible to ensure that the inputs will be off prior to power-up. In those cases, serial resistors and clamping diodes should be used.

The IEEE-488 block controls the digital multimeter functions and acquires data from the multimeter. This data serves as a control on the test results by providing a redundant measurement of the input to the A/D converters. In addition, this block controls the tape recorder, providing a permanent archive of test results.

The timer counter block is used to determine the conversion time of the test A/D converter. One of the counters in this block is present to start a count when the A/D is given a convert command. The accumulated count is then read at the end of the conversion process to determine conversion time.

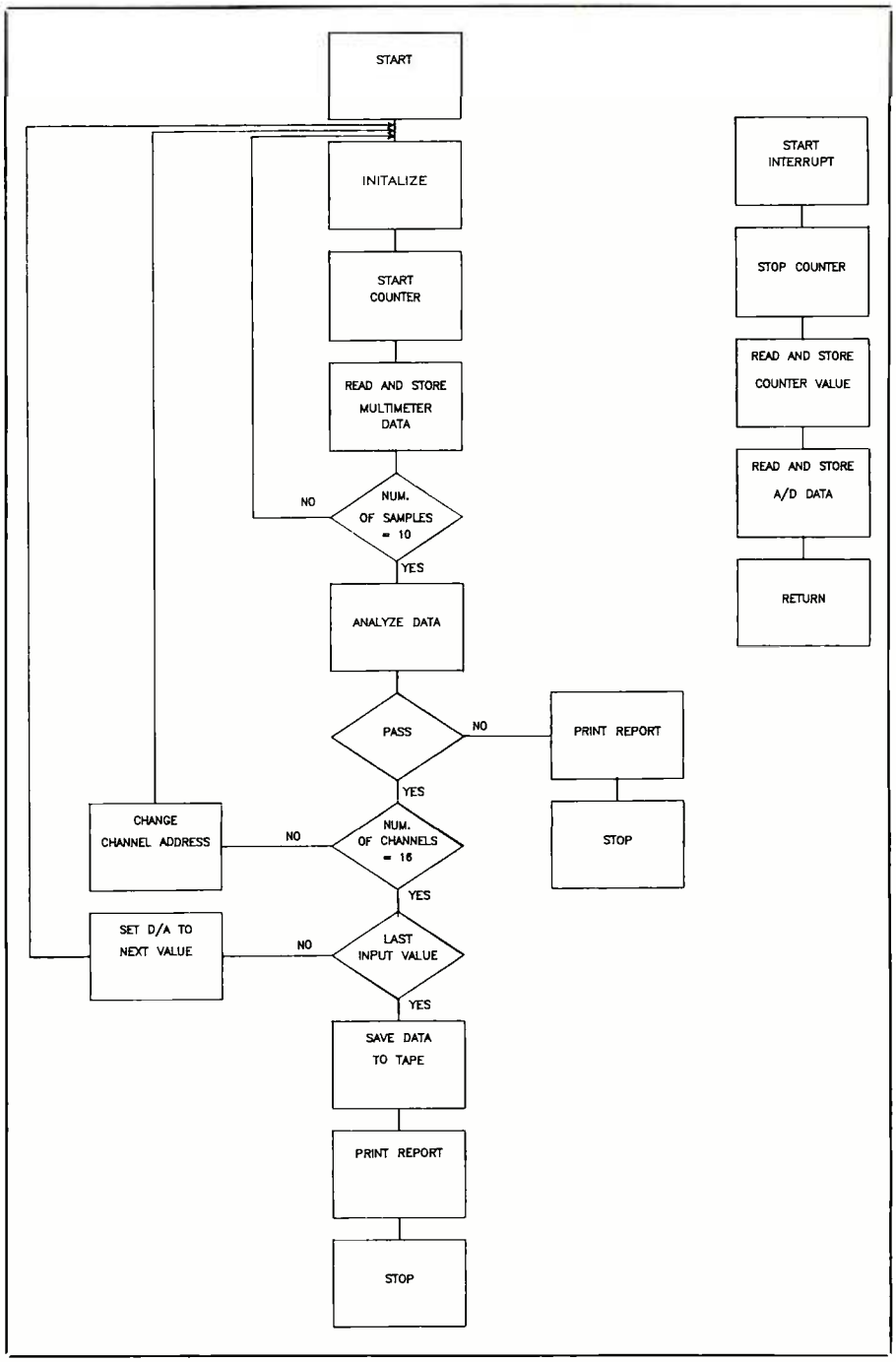


Fig. 25. The Test Set Software Flow diagram.

Software for this control example has to be designed somewhat differently from that of the house-control example by taking advantage of the Controller's interrupt capability. This means that instead of continuously sequencing through software to determine if certain events have happened, we will let the device inform us when they are happening by signaling the controller through the interrupt system.

The flow diagram for the test software is shown in Fig. 25. The software begins by performing the necessary system initialization. This will

include running any desired self-test routines, sending initialization sequences to the IEEE-488 and line-printer blocks, setting up the interrupt system and establishing a data base of constants to be used by other parts of the software as needed. Once initialization is completed, the software proceeds to the A/D converter test.

The D/A output is set to the first test value in the data base. The timer in the clock circuit is started and the A/D is commanded to digitize the voltage on the first input channel. When it has completed the conversion, the A/D block signals the computer through the interrupt system. This causes the Controller to stop the counter, input the data from the A/D, and store it in memory. When it has finished, the Controller sends a command to the digital multimeter, causing it to measure the A/D input voltage. The voltmeter measurement and the time from the counter are placed in the Controller's memory. This sequence is repeated 10 times for the first input channel. At the end of the tenth sample, the analog input channel address is incremented to the second channel: the 10 measurements from the A/D converter, counter and digital multimeter are then repeated. This process continues until all 16 channels are tested at the current input voltage.

The Controller now sets a new value into the D/A converter and the 16 input channels are commanded to measure the new input voltages 10 times each. This process continues until all the data-base values between 0 and +5 volts have been measured by all 16 channels on the A/D 20 times. This completes requirements 1, 2 and 4 of our test program.

The last requirement to be tested is the programmable input amplifier. There are three values of gain for this amplifier: 1, 10 and 100. Since the gain was set at 1 for the previous set of tests, this part of the gain test is already complete. The software now programs the amplifier for a gain of 10 and sets the voltage from the D/A converter to 0.4 volt. A sequence of 10 measurements from the A/D converter and from the DMM are taken and stored in memory. After the measurement sequence is completed, the data in each sequence is averaged, and the average of the A/D converter is divided by the average from the meter. The result should be 10. If it is (within some tolerably accepted error), the A/D converter gain is programmed to 100 and the input from the D/A converter is set to 0.04 volt. The average of 10 samples from the D/A converter is divided by the average of 10 samples from the meter, and the result is compared with 100. If it is 100 (again with an acceptable error), the A/D converter passes the amplifier gain test.

During each sequence in the test, data acquired from the A/D converter, the digital multimeter and the counter are analyzed as desired to ensure that the A/D converter is functional. At the end of each sequence, the analyzed data is transmitted over the IEEE-488 interface and stored on disk or tape. In addition, a short pass/fail report for the unit is printed on the line printer, concluding the A/D test.

Conclusion

This series illustrated how computers can be used for a variety of control applications. Whether you want to generate a control signal based on input signals or collect real-time data for process control, quality control, research, etc., computer technology makes it easier and speedier.

Using an IBM PC or compatible computer, DataBlocks' LINK system of interface and application-specific, encased modules, a host of tasks can be simplified, as we've shown. This methodology invites you to push a PC's performance and utility far beyond its typical uses at moderate cost. For more LINK system info, call toll-free: 800-652-1336.

Airline Headphone Substitutes

This device takes the discomfort out of listening to music or in-flight movies by substituting electrically operated headphones for the air-driven ones you rent

By Paul M. Danzer

Anyone who has ever worn the earphones that airlines rent to passengers to listen to canned music or in-flight movies knows how uncomfortable they are. The earpieces of these rental phones dig into your ears. Moreover, if you try to shift them, even slightly, for greater comfort, the audio volume tends to vary. Fortunately, it's relatively easy to convert the conductive air from the rental headphone's plastic tubes into electrical signals, amplify the signals and listen to them in comfort with "real" phones. All you need is the simple conversion system described here.

In use, you plug one end of a pair of hollow tubes into the jack at your passenger seat and the other end into your converter. Inside the converter, a pair of miniature microphones translate the air-conducted sounds into electrical signals that are fed to a pair of single-chip integrated-circuit audio amplifiers. The amplifiers, in turn, drive standard lightweight earphones like those used with Walkman-type personal stereos that not only give excellent sound but are very comfortable to wear. You also have a dual control that allows you to vary the level of the sound in both ears simultaneously.

About the Circuit

Shown in Fig. 1 is a simplified block diagram of the converter system. The complete schematic diagram of the circuitry is shown in Fig. 2. As you can see, the circuit consists of two identical audio channels built around separate left- and right-channel miniature electret microphone elements *MIC1* and *MIC2*, integrated-circuit audio amplifiers*IC1* and *IC2* and earphones. A ganged dual volume control, *R1* provides the means for varying the level of the sound heard from the miniature phones.

Air-conducted sound from the airplane seat's earphones jack are coupled through short lengths of plastic tubes to *MIC1* and *MIC2*. In turn, the microphone elements convert the sounds into electrical signals that are

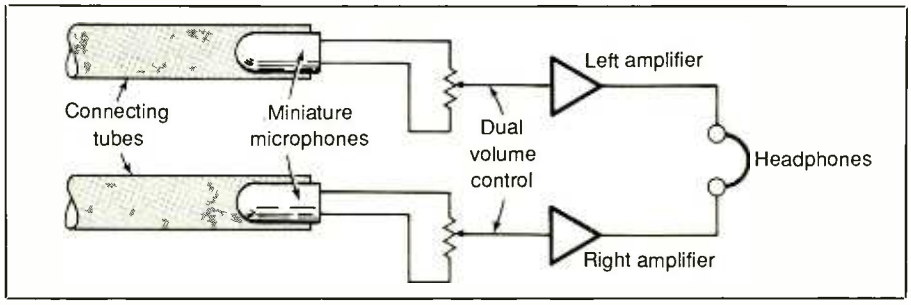


Fig. 1. Simplified block diagram of converter system.

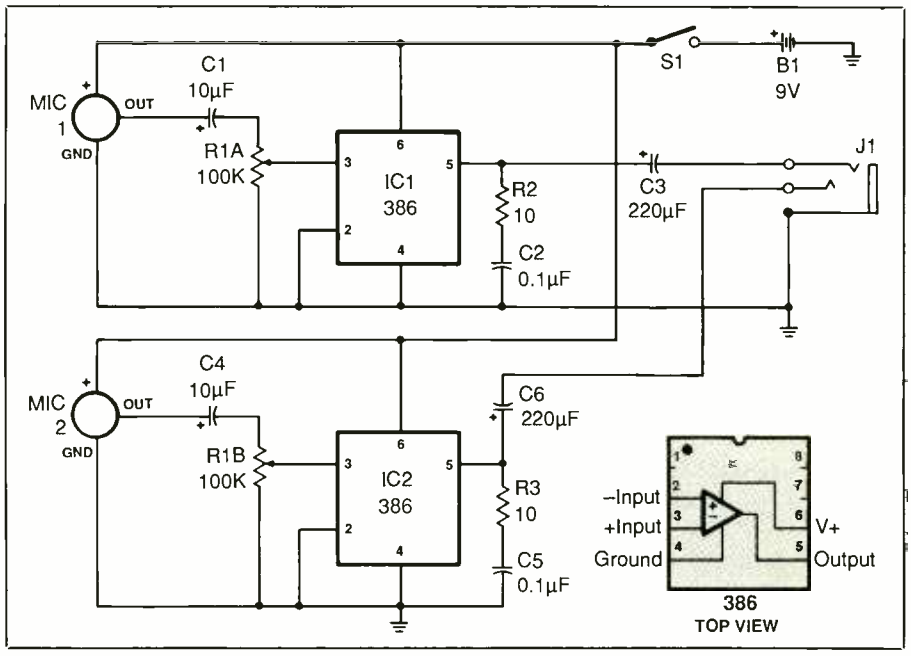


Fig. 2. Complete schematic diagram of the converter.

PARTS LIST

Semiconductors

IC1,IC2—LM386 IC audio amplifier (Radio Shack Cat. No. 276-1731 or similar)

Capacitors

C1,C4—10-μF tantalum

C2,C5—0.1-μF, 50-volt disc

C3,C6—220-μF, 35-volt electrolytic

Resistors

R1—100,000-ohm dual potentiometer (Radio Shack Cat. No. 271-1732B or similar)

R2,R3—10-ohm, ¼-watt, 10% tolerance

Miscellaneous

B1—9-volt transistor battery

MIC1,MIC2—Electret microphone element (Radio Shack Cat. No. 270-0928 or similar)

J1—Miniature stereo phone jack

S1—Miniature spst toggle switch

Circuit board (see text); suitable enclosure (see text); 8-pin DIP IC sockets (2); plastic electrical tape; plastic tubing (see text); heat-shrinkable tubing; hookup wire; solder; etc.

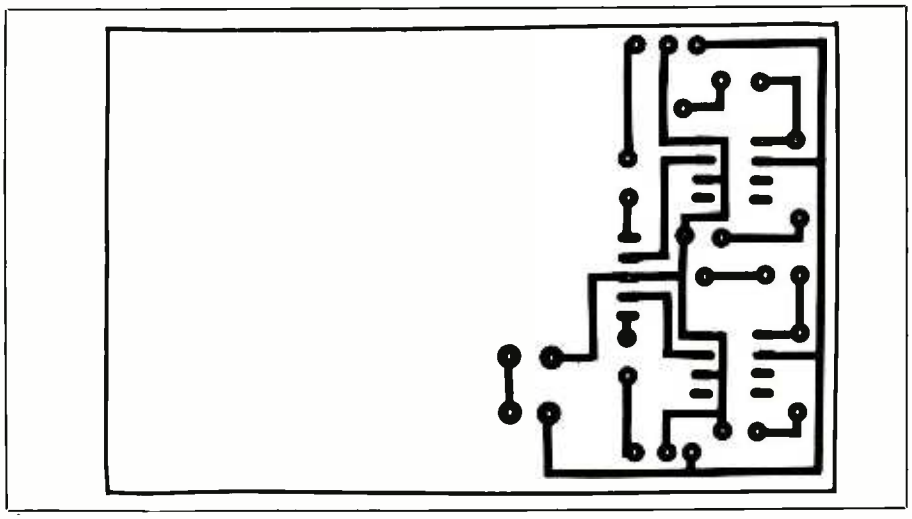


Fig. 3. Actual-size etching-and-drilling guide for home fabrication of printed-circuit board.

then coupled through capacitors *C1* and *C4* and the *R1* volume control into the inputs of *IC1* and *IC2*. The integrated-circuit audio amplifiers boost the electrical input signals to levels sufficient to separately drive the left and right electrical earphones plugged into miniature stereo phone jack *J1* to listenable levels.

Greater gain from the system can be obtained by connecting the positive and negative leads of a 10-microfarad capacitor between pins 1 and 8, respectively, of the IC amplifiers in each channel. This gain normally isn't needed; the circuit as shown will provide plenty of gain to drive the earphones.

Amplified signals from the pin 5 outputs of *IC1* and *IC2* are capacitively coupled via *C3* and *C6* to the output jack. The capacitors readily pass audio signals but block any dc.

Power for the converter circuit is provided by a conventional 9-volt transistor battery (*B1*). Switch *S1* provides the means for switching on and off the circuit as needed.

Construction

There is nothing critical about circuit layout, as long as you keep the inputs and outputs physically separated from each other. Therefore, you can use any traditional means for wiring the board. I built the prototype of the project on one-half of a Radio Shack Cat. No. 276-159 dual IC board. If you wish, you can use a home-fabricated printed-circuit board, made with the actual-size etching-and-drilling guide shown in Fig. 3 instead. A third alternative would be to wire the circuit on a perforated board with holes on 0.1-inch centers, using suitable Wire Wrap or soldering hardware. Whichever way you wire the circuit, use separate 8-pin DIP sockets for *IC1* and *IC2*.

If you use a pc board or perforated board, refer to Fig. 4 for component locations and orientations. For the pc board, wire the circuit exactly as shown, installing first the IC sockets,

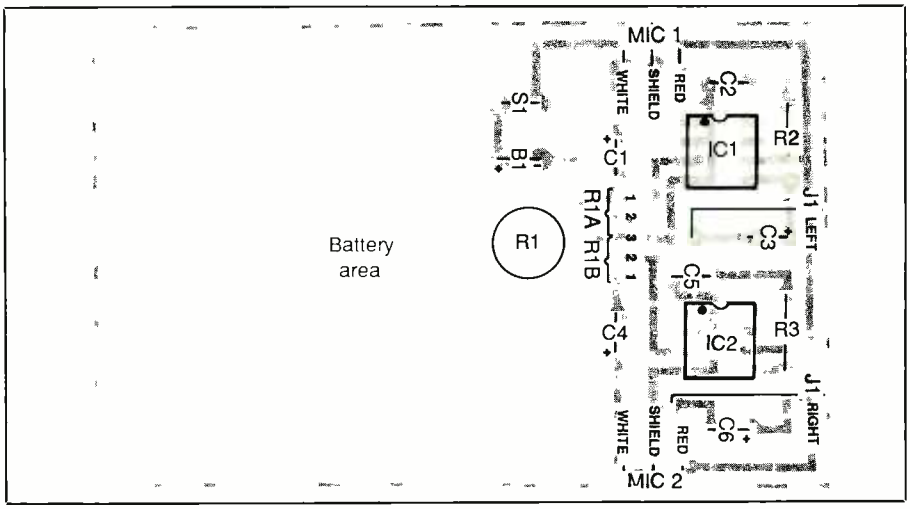


Fig. 4. The wiring guide for the pc board. Use this arrangement for perforated-board layout as well.

then the resistors and finally the capacitors. Make sure you properly orient the polarized capacitors before soldering their leads to the copper pads on the bottom of the board. Do *not* wire the microphone elements to the board just yet, nor install the ICs in their sockets.

This project was designed to easily fit inside a standard audio cassette case to make a very compact assembly that easily fits into a jacket pocket along with the earphones with which it will be used. You can use whatever other type of box (even a defunct personal stereo tape player or radio case) you prefer as an enclosure for the project, of course. If you use the cassette case, the power switch, volume control and output jack should be mounted in holes drilled through the large flat side of the case. The short plastic tubes used for the input microphones enter the case through holes drilled through one end wall of the cassette case. Cut the top of the cassette case to allow the 9-volt battery to protrude so that it can be replaced without having to open the case.

For the tubes that join the microphones to the airline seat jacks, you should ideally use the bottom 6 inches cut from an old set of airline earphones. If these aren't available, you can use any plastic tubing that has an outer diameter of approximately ¼". As shown in Fig. 5, butt-join the tubes and microphones, building up the diameter of either to match the other's diameter with as many layers of plastic electrical tape as are needed. Use an additional layer or two of tape to hold the joints together as you gently shrink heat-shrinkable tubing over the joints to hold the assemblies together. Make the heat-shrinkable tubing long enough to cover the entire microphone elements and extend about 1" up the tubes and shrink into place.

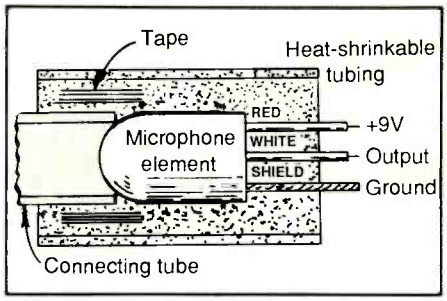


Fig. 5. Details of plastic tube-to-microphone element assembly.

Checkout and Use

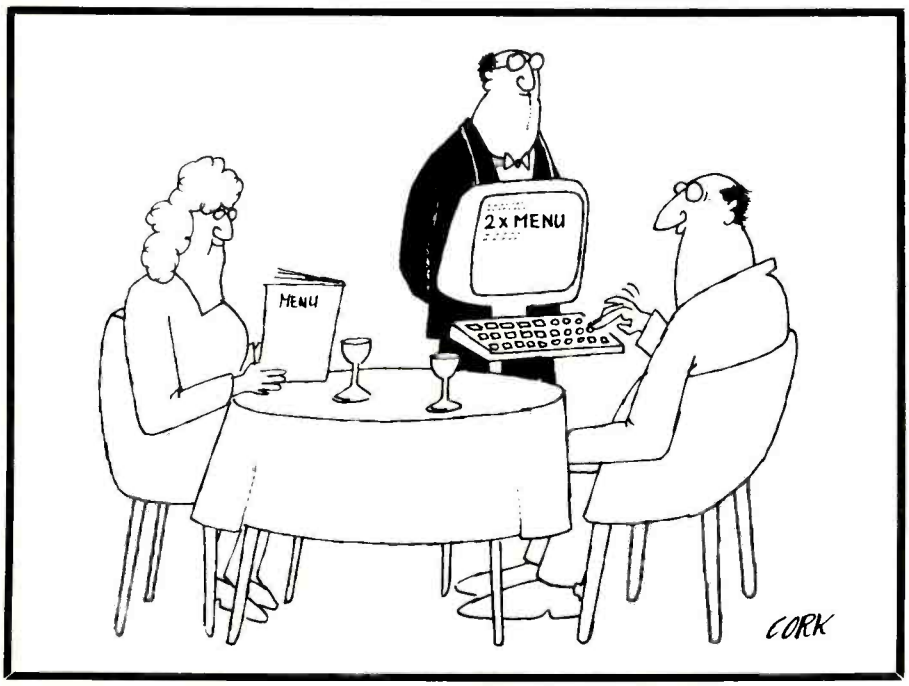
Before plugging the ICs into the sockets or connecting the microphones and battery into the circuit, use an ohmmeter to check that all points shown going to ground and to the positive bus are properly connected. If everything appears to be okay, wire the microphone elements into the circuit as detailed in Fig 4. Make sure you observe the wiring arrangement shown.

Snap a 9-volt transistor battery into its connector and flip the power switch to on. Measure the voltage from the negative side of the battery to pin 6 of both IC sockets. You should obtain a reading of approximately +9 volts dc if you wired the board properly. Similarly, take a voltage reading at pins 5 and 7 of both sockets. If the reading this time is not 0 volt in all cases, recheck your wiring and especially your soldering for short-circuiting solder bridges.

When you're sure your wiring is correct, flip the power switch to off and carefully install the ICs in the sockets. Make sure the ICs are properly oriented and that no pins overhang the sockets or fold under between IC body and socket as you push each home.

Plug into the output jack a pair of lightweight earphones. Turn on the power to the project, set the volume control to the middle of its range and alternately cover one air tube and then the other as you talk into the open ends of the tubes. You should hear your voice in first one and then the other earphone. Speaking into both tubes, you should hear your voice in both earphones.

When you use the converter in an airplane, set both volume controls in the seat arm to the middles of their ranges. Plug your two air tubes into the sockets provided and turn on the project's power. Set the project's volume control for a comfortable listening level. Then sit back and, for a change, enjoy the movie.



BOOKS

Digital Circuits by Kenneth Muchow, Anthony Zeppa & Bill Deem. (Prentice-Hall. Hard cover. 390 pages. $34.95.)

With digital techniques dominating modern technology, even in areas heretofore considered to be strictly analog, it is of vital importance that anyone involved in electronics be familiar with digital circuitry and practices. This book offers a practical avenue to in-depth learning of digital circuits and techniques. Leading off with a short chapter that surveys digital computers, it gets down to cases with number systems and codes, binary arithmetic, and logic functions and Boolean algebra, which set the foundation for the remaining chapters that deal with the digital "hardware." A chapter titled "Gates," for example, discusses the major logic families commonly used in digital circuitry and their characteristics. After this comes a chapter on implementation of logic functions. Most subsequent chapters deal with specific logic elements and their related function blocks (flip-flops, registers, encoders/decoders/ converters and counters). Timing, the arithmetic logic unit and memory (both solid-state and magnetic media) are each covered in separate chapters. The final chapter deals with interfacing.

Traditional "textbook" style presentation—including end-of-chapter review questions with answers to odd-numbered ones at the back of the book—make this a formal classroom book. Its unusually lucid text and lavish use of tables, schematics and other illustrations make it suitable for self-study as well.

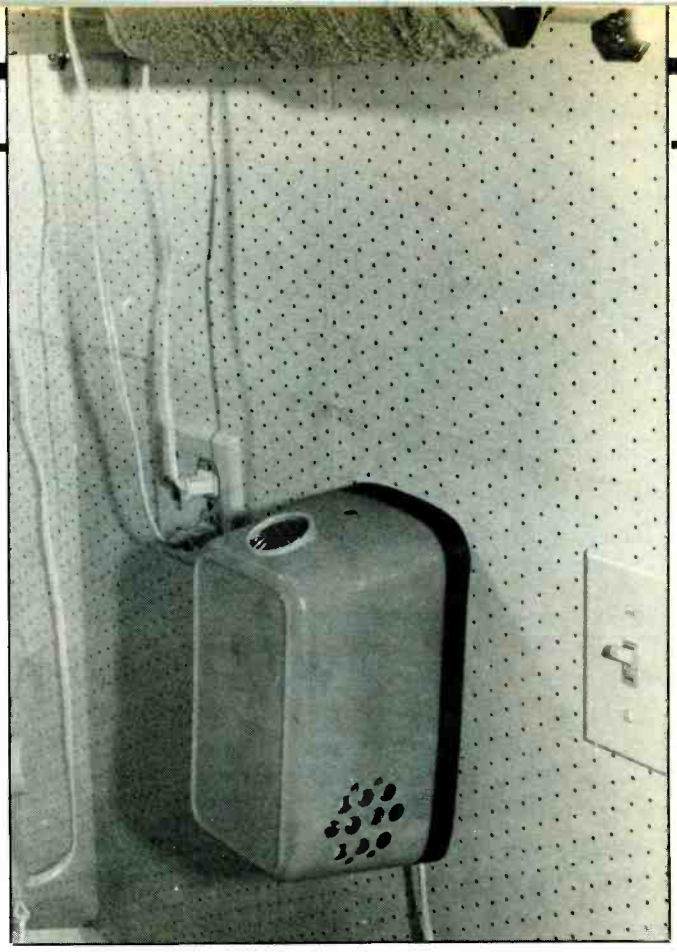
NEW LITERATURE

Electronic Components Catalog. American Design Components' illustrated 16-page 1987 Christmas Catalog of electronic, electromechanical and computer-related parts and components lists items specially selected for the hobbyist, tinkerer, teacher, scientist and design engineer. It lists thousands of items, including: ICs, other semiconductors, fans, blowers, ac, dc and fractional-horsepower motors, and a full range of other components ready for immediate off-the-shelf delivery. For a free copy, write to: American Design Components, 62 Joseph St., Dept. ME, Moonachie, NJ 07074.

Software Catalog For Scientists & Engineers. "The Scientific & Engineering Software Guide" from Lifeboat is said to be the first reference catalog to include more than 100 application and development software packages designed especially for the science and engineering community. The software listed covers statistical data analysis, circuit design, data acquisition and signal analysis, solving complex equations, three-dimensional CAD/CAM design, graphics, technical word processing and more. Complete descriptions include a run-down of features and benefits of each listed software package, compatibility and system requirements, and indicates where a demo disk is available. For a copy, write to: Lifeboat Associates, Inc., 55 S. Broadway, Tarrytown, NY 10591.

An Electric Hand Dryer

Convert an inexpensive hair blow dryer into a sanitary, automatic or semiautomatic hot-air hand dryer



By Joseph O'Connell

A hot-air hand dryer like those used in public restrooms can be a very practical appliance in your home bath room. It saves on wear and tear of towels and can be a lot more sanitary than towels. Hot-air hand dryers used in public restrooms are quite expensive, though. However, you can *build* a home version of this appliance from an inexpensive "pistol" type hair blow dryer, which you can pick up in many department and discount stores for as little as $5, a simple controller circuit and a home-fabricated housing.

In this article, we'll tell you how to convert a common hair blow dryer into either of two different activation versions of a hand dryer. The simpler and less expensive version is a semiautomatic pushbutton-start, timed-off dryer that works much like the great majority of those found in public restrooms. You push the button and the hot air flows for a predetermined amount of time and then automatically shuts off. The other version uses a motion sensor to achieve fully automatic operation. When you place your hands near the dryer's hot-air nozzle, the system turns on and remains on as long as your hands are in sensing range. Pull your hands away, and the dryer shuts off immediately.

Controller Choices

It's quite easy to activate a hand dryer with a pushbutton switch and time-delay circuit, as is done in most commercial hot-air hand dryers. This delay circuit keeps the dryer on for a predetermined number of seconds after a start button is pressed.

Activation by a proximity detector is more high-tech and offers better operating convenience, not to mention more sanitary. In this type of arrangement, the dryer stays on for only as long as you heed hot air to dry your hands.

● *Time-Delay Version.* In this version controller, the basic timing element is a popular 555 timer, shown as *IC1* in Fig. 1. Power transformer *T1*, rectifier diodes *D1* through *D4* and filter capacitor *C4* make up a common full-wave bridge-rectified power supply that converts ac line power to dc to power the controller circuit. (The 555 timer can operate over a 9-to-16-volt range; so the values of the power-supply components aren't critical.)

Together with potentiometer *R3* and capacitor *C1*, *IC1* makes up an adjustable time-delay circuit. When this circuit is triggered by momentarily pressing and releasing START pushbutton switch *S1*, the output of *IC1* at pin 3 goes high for a period of time that can be varied from about 5 seconds to more than 60 seconds, depending on the setting of *R3*.

Current-limiting resistor *R1* couples *IC1*'s pin 3 output into optical triac driver *IC2* to turn on the internal light-emitting diode. When this internal LED comes on, it triggers the internal triac into conduction to bias on external triac *Q1*. When *Q1* conducts, it delivers ac line power to the fan and heating elements of the blow dryer.

When *IC1*'s timing cycle has run its course, the output at pin 3 drops to near 0 volt (ground) and turns off *IC2*'s internal LED. This causes *IC2*'s internal triac to shut down and, in turn, shut down the external triac to shut off the dryer.

For safety, the timing elements of the controller circuit are fully isolated from the ac line. Hence, you could use a remote pushbutton switch—located perhaps near your bath room sink—to turn on the hand dryer so that by the time you get to it the air will already be warm.

Electrical noise is kept from *Q1* by bypass capacitors *C2* and *C3*.

● *Motion-Detector Version*. Despite the fact that most commercial hot-air hand-drying machines use them, a pushbutton-start controlled isn't the best way to let your hand dryer know when you want it to turn on. For one thing, your hands are usually wet and clean after you've washed them, while the pushbutton on the switch probably carries germs. For another, the timing interval of the time-delay controller is rarely correct. It usually turns off the dryer before your hands are dry or keeps it on after you're done. This wastes energy.

Perhaps the best way to activate a hand dryer is to just put your hands in the vicinity of the nozzle to turn on the hot air flow and keep it on only for as long as you need it. This is accomplished with a controller that senses when hands are placed near it and pulled away to turn on and off the hot air flow. Achieving this method of control would be a complicated and costly task were it not for a fairly new IC designed for use in intruder alarms. The motion detector IC used in this version of the project is a 14-pin DIP IC, shown as *IC1* in Fig. 2. Only a few external components are needed to adapt the motion-detector IC to our purpose and to interface it with the blow dryer's heating elements and fan.

Use of a motion-detector chip isn't without its disadvantages, however. Because the chip is very sensitive (it must be to assure positive, reliable detection in an intruder-alert system for which it was designed), turning on a nearby light or walking past the chip's field of view can trigger on the dryer for a few seconds even when it's not being called upon to dry

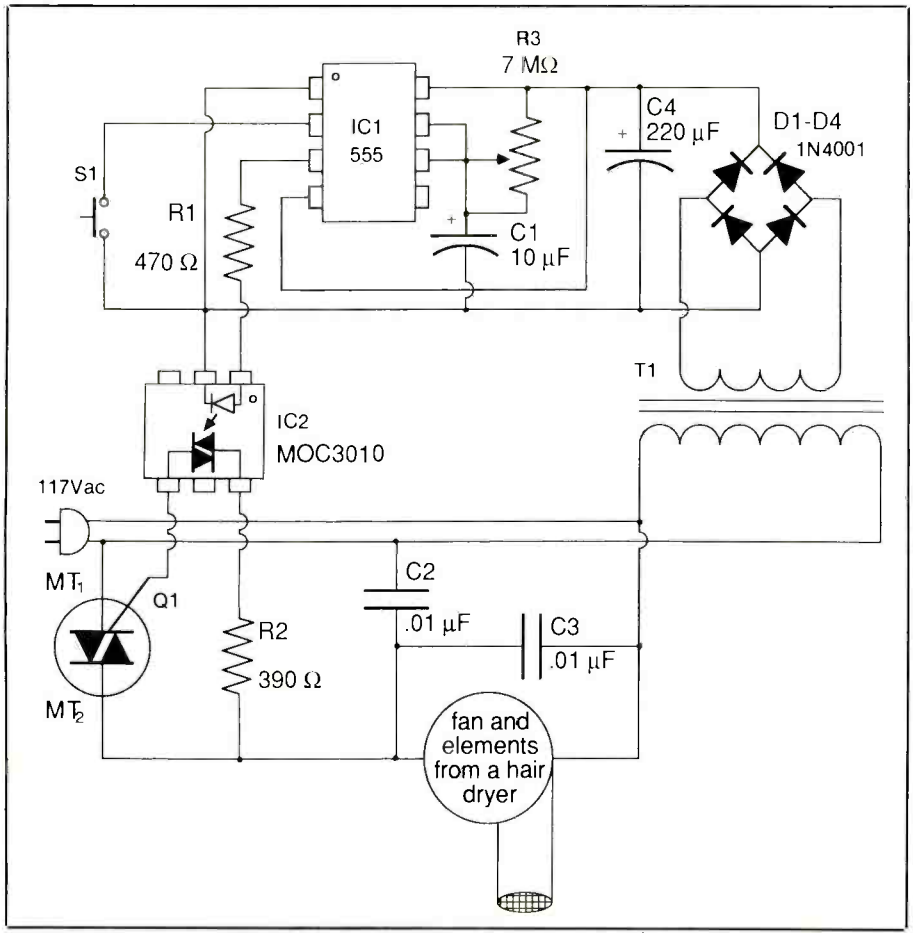


Fig. 1. Schematic diagram of semiautomatic pushbutton-operated, timed-on hand dryer.

PARTS LIST (Timed Version)

Semiconductors

D1 thru D4—200-volt, 1-ampere or greater bridge rectifier or individual rectifier diodes

IC1—555 timer

IC2—MOC3010 or similar triac-driver optical isolator

Q1—200-volt, 16-ampere or greater triac

Capacitors

C1—10-µF, 16-volt electrolytic

C2,C3—0.01-µF, 200-volt disc

C4—220-µF, 16-volt electrolytic

Resistors (¼-watt, 10% tolerance)

R1—470 ohms

R2—390 ohms

R3—7-megohm linear-taper potentiometer (see text)

Miscellaneous

S1—Normally open, momentary-action pushbutton switch

T1—9-volt ac transformer

Printed-circuit board or perforated board and suitable soldering or Wire Wrap hardware (see text); low-cost hair blow dryer (see text); suitable cover for project (see text); TO-220 heat sink and mounting hardware; cap for pushbutton switch; lumber for base and dryer support; machine hardware; ac line cord with plug and hookup wire; solder; etc.

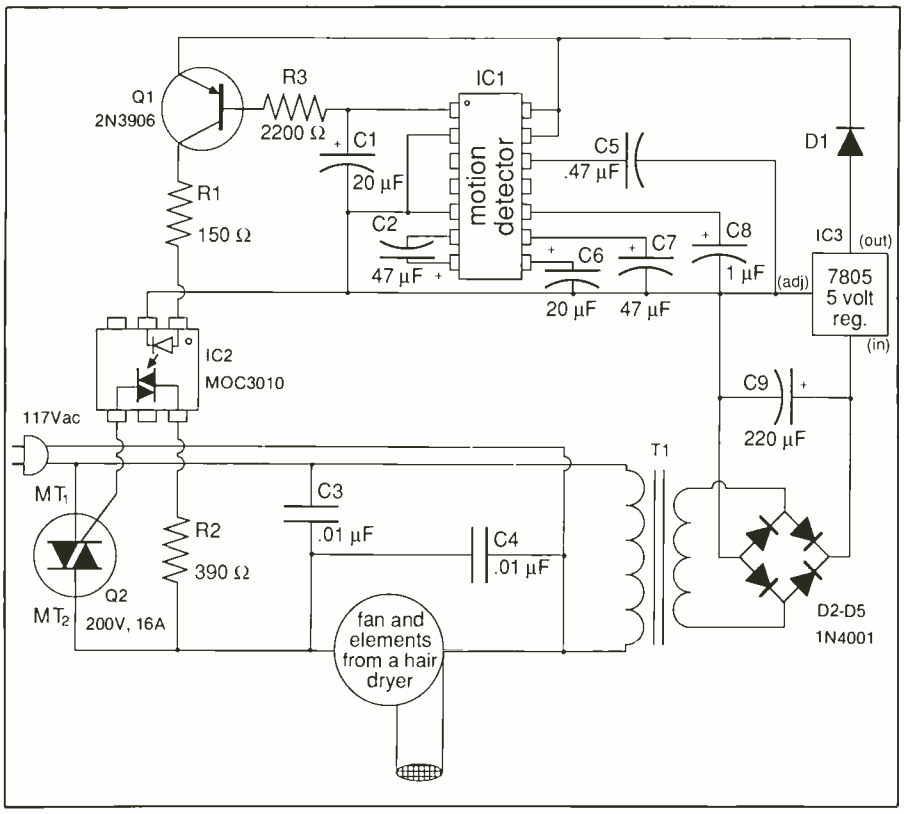


Fig. 2. Schematic diagram of fully automatic motion-sensing hand dryer.

PARTS LIST

(Motion-Detector Version)

Semiconductors

D1—1N4001 or similar silicon diode

D2 thru D5—200-volt, 1-ampere bridge rectifier

IC1—Motion detector (see Note below)

IC2—MOC3010 or similar triac-driver optical isolator

IC3—7805 or equivalent + 5-volt regulator

Q1—2N3906 or similar general-purpose pnp transistor

Q2—200-volt, 16-ampere or greater triac

Capacitors

C1,C6—20-µF, 6-volt electrolytic

C2,C7—47-µF, 6-volt electrolytic

C3,C4—0.01-µF, 200-volt disc

C5—0.47-µF, 6-volt tantalum

C8—1-µF, 6-volt tantalum

C9—220-µF, 6-volt electrolytic

Resistors (¼-watt, 10% tolerance)

R1—150 ohms

R2—390 ohms

R3—2,200 ohms

Miscellaneous

T1—4- to 12-volt power transformer

Printed-circuit board or perforated board and suitable soldering or Wire Wrap hardware (see text); low-cost hair blow dryer (see text); suitable cover for project (see text); TO-220 heat sink and mounting hardware; cap for pushbutton switch; lumber for base and dryer support; machine hardware; ac line cord with plug and hookup wire; solder; etc.

Note: The motion detector IC used in this project is salvaged from circuit board assembly Part No. SMD-01 ($7.95 including P&H) from I.P.C. Sales, P.O. Box 1540, Haverhill, MA 01830.

hands. So, depending on the number of false starts you're willing to put up with and how annoying you think they'll be, the time-delay controller described above might be your better choice.

Figure 2 shows the complete schematic diagram of the motion-sensing controller circuit. A 2.5-to-4.5-volt dc power supply is required to operate motion detector *IC1*. Though an ordinary 7805 + 5-volt regulator (*IC3*) is used in the power supply, silicon diode *D1* provides a 0.7-volt drop to bring the supply potential down to an almost ideal 4.3 volts. (If the regulator you buy outputs slightly greater than 5 volts, you may have to add a second silicon diode in series with *D1* to maintain a supply voltage that is within the safe operating range for *IC1*.)

Capacitors connected to *IC1* set the motion sensor's operating parameters. The interval *IC1* waits after sensing motion before resampling light is set by *C8*. You might have to experiment with the value of this capacitor to fine-tune the dryer to a particular installation. Capacitor *C6* lowers the IC's sensitivity to high-frequency light changes, as would occur under fluorescent lighting conditions. Capacitor *C5* determines the pitch of the "alarm" output at pin 1 of *IC1* and isn't very important in this application. Capacitors *C2* and *C7* have uses that are internal to the IC and, thus, need no explanation here.

When *IC1* senses motion, the output signal at pin 1 turns on transistor *Q1* through resistor *R3*. This turns on the LED inside optical triac driver *IC2*. From here on, operation of the controller circuit is identical to the same section of circuitry in Fig. 1. (Indeed, from *IC2* onward, the circuit itself is identical.)

Turn-off of the dryer is virtually instantaneous when hands are removed from detection range of *IC1*, though the fan will continue to blow out hot air until it winds down to a stop. As soon as *IC1* senses that no hands are in its vicinity, its output at pin 1 ceases and cuts off base drive to the transistor. In turn, the cutoff condition of the transistor turns off the LED inside *IC2* and shuts down the dryer.

Construction

For this project, you need the com-

mon pistol-type hair blow dryer that has a centrifugal, rather than axial, type of fan (blower). The number of speed settings doesn't matter, since you'll be wiring the heating elements and fan into the project's controller in the highest-power setting.

Decide on the enclosure in which to house the dryer before cutting away any of the blow dryer's housing. A good way to go is to build the dryer and its control circuit on a wood base and equip it with a detachable plastic cover, as was done for the prototype of this project shown in the photos. The removable plastic cover could be the bottom of a wastepaper basket (see lead photo), or it could be a large food storage container. Use at least ⅜"-thick lumber for the wood base. After cutting the wood base to size and shape, smooth its edges with a file and/or sandpaper and check to make sure it makes a snug fit with the cover.

Open the blow dryer and study the switch arrangement prior to removing the switches to determine how to wire the heating elements and fan for maximum heat/speed. Make a note of the required wiring on a sheet of paper. While you're at it, examine the baffle that encloses the fan and make a note of which parts can be removed without cutting into the airtight section of the blow dryer's housing. When you remove them, save the ac line cord for use in this project and discard the switches or save them for another project.

Now carefully cut away the handle and excess plastic from the blow dryer. Remove all the plastic housing except the part that encloses the heating elements and fan. This will be easier to do if you trim with a saw the excess from each half of the dryer's housing separately.

As you trim away plastic from the blow dryer's housing, keep in mind how the assembly you want to use will fit into the project's housing. Mounting will be easier to accomplish if you cut so that there's a flat surface on the dryer assembly that can rest on the wood base. Also, it's a good idea to arrange things so that the nozzle, when mounted, will angle slightly away from the wall on which the project is to be mounted.

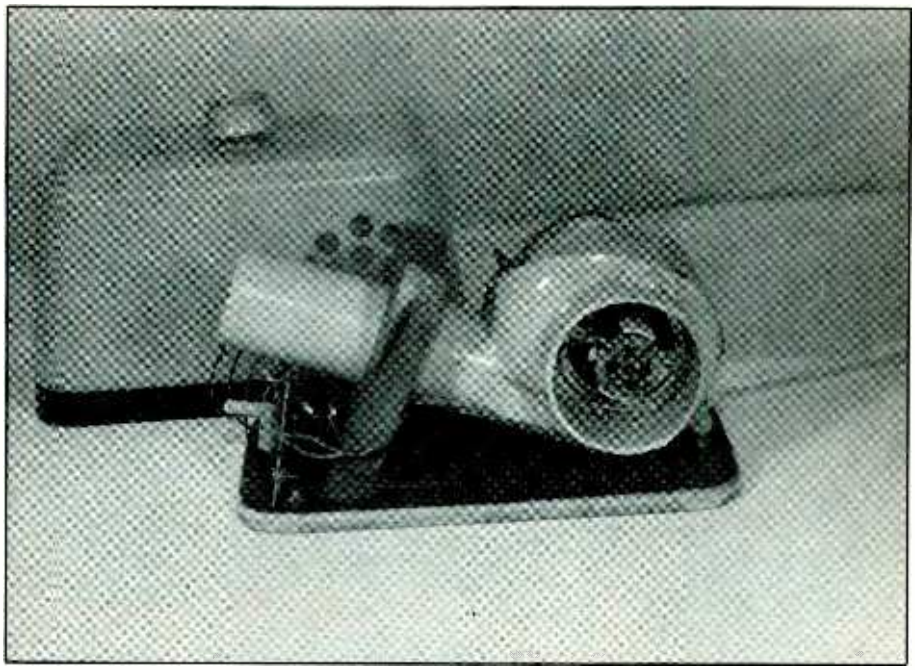


Fig. 3. Mounting details for blow dryer's heating-element/fan assembly. Note upward angle of nozzle and controller board mounted below nozzle.

When you've reduced the blow dryer's plastic housing to a minimum, what's left should look like that shown in Fig. 3. That is, only the fan and tube with the heating elements inside should remain. Wrap duct tape around the fan baffle to seal out any leaks, but avoid taping over the air inlets.

Whichever controller you decide to use can be built on perforated board with holes on 0.1" centers. Use suitable soldering or Wire Wrap hardware, including sockets for the DIP ICs. If you prefer, you can design and fabricate a printed-circuit board instead of using perforated board on which to mount the components for the circuit of your choice, using sockets for the ICs here as well.

In both cases, mount the power transformer and heating-element/fan assembly off the board on the wood base with woodscrews. In Fig. 1 the pushbutton switch and potentiometer also mount off the board, the switch on the cover of the project and the pot on an aluminum L bracket secured to the wood base. (You can, if you wish, mount the potentiometer in a hole drilled in the circuit board, as shown in the last photo in this article.)

Wire your choice of circuits exactly as shown in Fig. 1 for the pushbutton-start/time-delay version and Fig. 2 for the motion-sensing version. Be sure when wiring the electrolytic capacitors and diodes into the circuit that they're properly polarized. Similarly, when wiring the transistor, triac and voltage regulator, be sure their basings are correct before soldering any leads into place.

Because the triac must handle a lot of current and, thus, must dissipate a lot of heat, it's a good idea to mount the power triac on a separate piece of perforated board and run heavy-duty stranded wires to it from the main circuitry. This way, the triac can be mounted where its heat will be

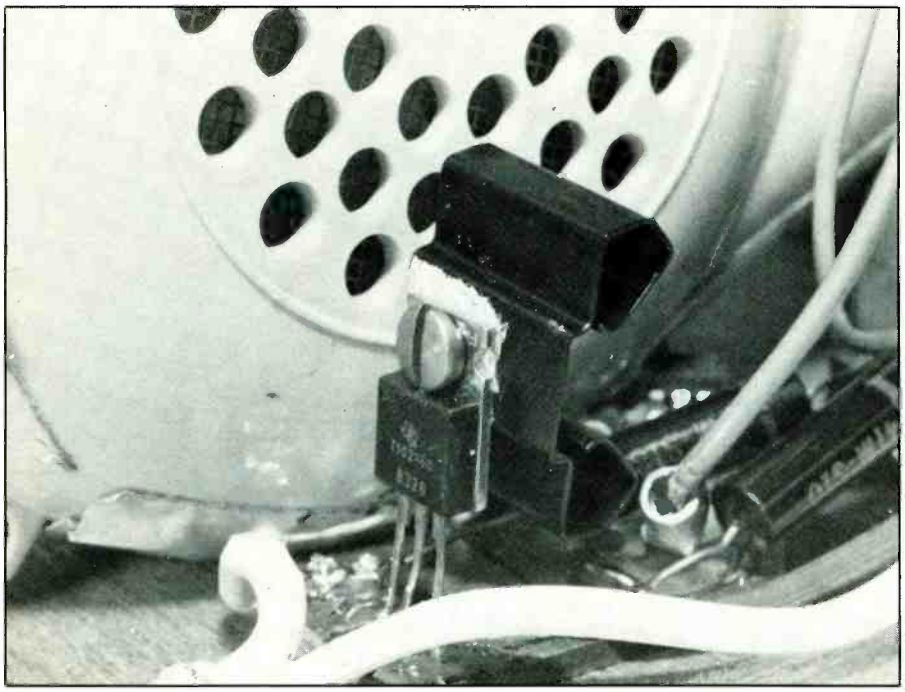


Fig. 4. Triac requires bolt-on heat sink. Mount triac/capacitor subassembly so that drawn-in cool air will carry off heat generated by triac.

drawn off by the cool air drawn into the enclosure by the fan.

To connect the ac line cord into the circuit, you can provide terminals on the circuit-board assembly for it. Alternatively, you can use a two-lug (neither lug connected to the mounting tab) terminal strip mounted via one of the screws that hold down the transformer to which to wire the cord and transformer's primary.

Cut a bracket out of lumber to hold the blow dryer assembly securely in place as shown in Fig. 3. A friction fit around the heating-element tube should be sufficient, but secure the rear end of the dryer housing to the wood base with a small L bracket and screws.

Use small L brackets to mount the controller circuit board on the wood base just ahead and under the dryer's nozzle. For the timed version, connect and solder wires into the circuit at the appropriate points for the potentiometer and switch. The lengths of the wires for the switch should be adequate to allow the plastic cover on which the switch is mounted to be removed without straining. Use a switch that has very little behind the panel depth. A good choice here is a computer keyboard or calculator keypad switch.

With the motion-detecting controller, mount *IC1* so that it can "look" down through a hole in the project's cover to "see" the area under the dryer's nozzle. The lead photo shows a small peephole in the cover through which this IC looks.

Cut a hole in one end of the project's plastic cover through which the dryer's nozzle can protrude slightly. Then cut or drill a pattern of holes to allow outside air to be drawn by the fan into and through the dryer assembly to exit heated through the nozzle. Leaving about 1" of clearance above the dryer, trim the plastic cover to a uniform height and test for fit over the base with the nozzle protruding through its hole.

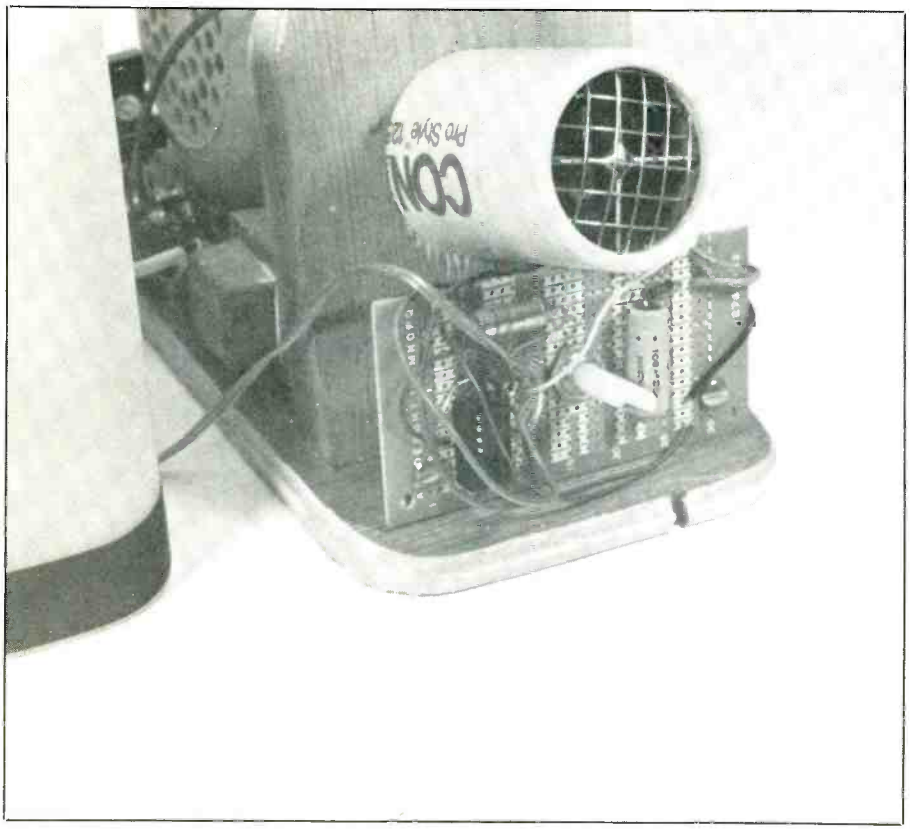
Drill or punch a pattern of holes through the walls on both sides of the plastic cover to provide the means through which cool air can be drawn in by the fan. Also drill or punch the viewing hole for the motion-detecting IC for the Fig. 2 version of the controller. Mount a small heat sink on the triac (see Fig. 4) and then mount the triac assembly on the wood base where it will be directly in the stream of air drawn through the holes.

Checkout and Use

Before plugging the triac driver into its socket (or if you've already installed it, remove it from the socket), check out your hand dryer for proper operation with an ordinary visible-light light-emitting diode. Plug the anode and cathode leads of this LED into the triac driver's socket at pins 1 and 2, respectively. Make sure the LED is positioned so that none of its light can fall on the sensitive surface of the motion-detecting IC in the Fig. 2 circuit.

Plug the project's line cord into an ac receptacle and press and release the pushbutton switch on the timed version. The LED should now light and remain on for a period of time determined by the setting of the potentiometer. It should automatically extinguish when the timing cycle runs out. For the motion-detector version, bring your hands into detection range and note that the LED lights and remains on for as long as you keep your hands under the nozzle. It should immediately extinguish when you pull your hands away. Perform this test several times to make sure whichever controller you've built is working properly and reliably.

If you obtained the proper results from this test, pull the project's line cord from the ac receptacle, remove the LED from the socket and replace it with the triac driver IC. If you didn't obtain the proper results, recheck all wiring for wrong connections, poor soldering and short-circuiting solder bridges. Also check the orientations of the electrolytic



Nozzle-end view of assembled timed-on project. Time-setting potentiometer can be mounted with its shaft protruding from top of controller board as shown or on a separate aluminum L bracket.

capacitors and diodes and the basings of the transistors, triacs and ICs. Rectify any problems before attempting to put the electric hand-dryer project into service.

Mount your hot-air hand dryer in a convenient location in your bath room where it will be conveniently accessible but won't interfere with other items in the room. If you built the timed version, set the potentiometer to about the middle of its range. Wet your hands and shake off excess water. Then press and release the start switch on the cover and place your hands in the air flow coming from the nozzle. Rub and turn your hands in the air flow. If the dryer shuts off before your hands are dry or keeps going after they are dry, adjust the setting of the potentiometer for a longer or a shorter on period. Wet your hands again and dry them with the dryer. Repeat as necessary until the time-on period has been optimized.

Punch or drill a number of small holes through the cover about 3/16" from the cut edge all around the perimeter. Mount the cover to the wood base with small woodscrews.

Always keep foremost in mind that your hot-air hand dryer is an intermittent-duty appliance. It should never be run continuously for longer than a couple of minutes at a time and should be allowed to cool off between uses.

Use this project to dry hands only —*not* wet or damp washcloths or towels or any other item that requires a long drying time. When you do use the dryer, always shake off excess water before turning it on and rub and turn your hands in the air flow to speed drying time. **ME**

Laser Eavesdropping

By Forrest M. Mims III

Intercepting conversations inside a closed room by detecting and demodulating a laser beam reflected from a window pane is not just a spy novel gimmick or a motion-picture special effect. Under certain conditions, this technique can be made to work.

Whenever the press rediscovers laser eavesdropping every few years, it often describes it as a "new" tool of the high-tech spy. In fact, the technique has been reported on in the open literature since about 1970. And though a laser is claimed to be necessary, the technique can be implemented with reflected sunlight or an infrared spotlight. Indeed, the basic principles of optoelectronic eavesdropping were invented by Alexander Graham Bell and Sumner Tainter in 1880, when they built the first photophone lightwave communicator.

One rumor has it that nearly a century after Professor Bell demonstrated his photophone in Washington, D.C., KGB agents from the Soviet Union attempted to use a laser on the roof of the Department of Commerce building to intercept conversations inside the oval office of the White House.

In 1974, Victor Marchetti and John Marks wrote in *The CIA and the Cult of Intelligence* (Alfred A. Knopf) that the CIA had developed ". . . a laser beam which could be aimed at a closed window outside and used to pick up the vibrations of the sound waves caused by the conversation inside. This system was successfully tested in the field—in West Africa—but it never seemed to function properly elsewhere, except in the United States."

In 1976, laser eavesdropping was mentioned in a study of state-of-the-art electronic surveillance methods prepared by the National Wiretap Commission. The report concluded that ". . . the laser is not a cost-effective device and no evidence or verification of the existence of a laser eavesdropping system was found." Apparently, the Commission was denied access to the classified work in this field performed by government intelligence agencies and their contractors. Nor was it aware that an electronic writer in New Mexico was then building inexpensive laser bugs that used both visible light and near-infrared lasers.

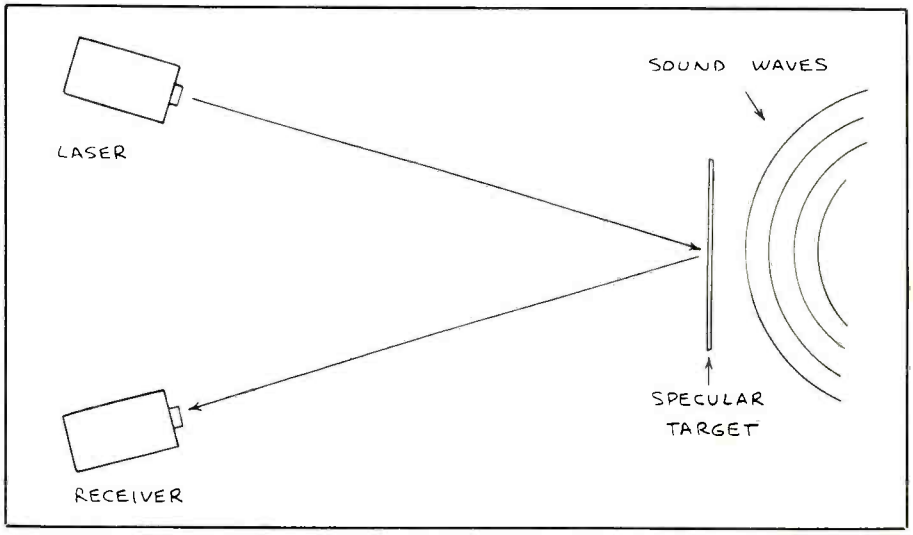


Fig. 1. Laser eavesdropping arrangement in which positional modulation is used.

During the past few years, numerous revelations about espionage have received widespread media coverage. A spinoff of this media attention has been the publication of several articles that give detailed construction plans for laser eavesdropping devices. These articles may encourage students and adults who should know better to build and attempt to use a laser bug. This is unfortunate, since the articles I have seen fail to address either the legal or the safety aspects of laser eavesdropping.

It's only natural for electronics experimenters and engineers to be curious about the latest electronic eavesdropping devices and techniques. Learning about the design and operation of such devices, however, is quite different from actually building and using them.

Before going further, I must confess to not having had a spotless record in this field. I'm the electronics writer mentioned above, and I was building laser bugs back in the '70s. I have written

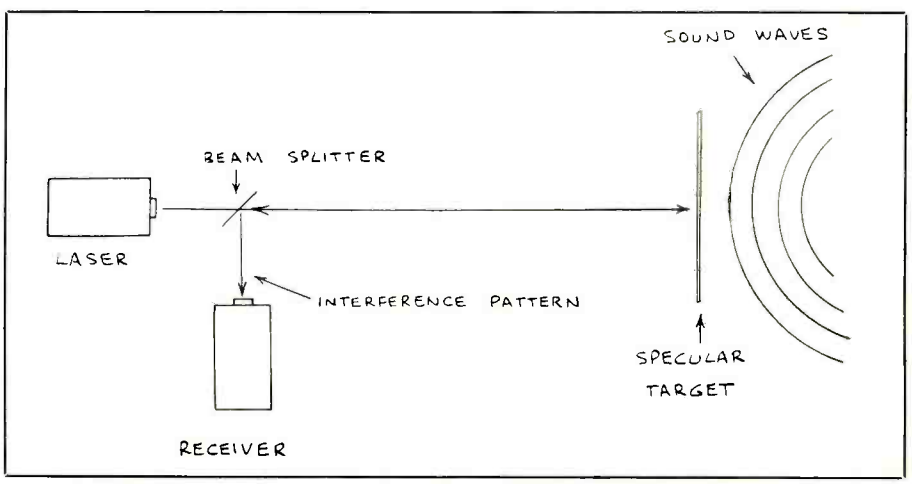


Fig. 2. Laser eavesdropping using the interferometric approach.

about some of this work in books and articles and have spoken about countermeasures for laser eavesdropping at an annual meeting of the Laser Institute of America. I've also prepared a report for the Senate Select Committee on Intelligence on the potential threat to national security posed by laser eavesdropping.

Nevertheless, I've heretofore purposely not written about the subject for an experimenter magazine. In view of the articles that have recently appeared, however, there is a need for an article that discusses the technical, legal and safety aspects of the subject.

There is yet another reason for a complete discussion of this topic. Recently, the media has reported that the new Soviet embassy in Washington has a clear line of sight to many important government offices in the nation's capital. William Safire and other journalists have reported that Soviet agents have attempted to use laser eavesdropping gear installed in their new embassy or the nearby housing quarters against some of these government facilities.

Buzzers, speakers and other vibration-inducing devices have been installed on or near the exterior windows of some government offices in an effort to jam would-be laser eavesdroppers. From my own experiments in developing countermeasures for laser eavesdropping, I know that these techniques can be very effective. Unfortunately, they do not necessarily solve the problem, since it might be possible to aim a laser bug at a glass or plastic picture frame, clock face and similar reflective surfaces *inside* to room being targeted. Therefore, while laser eavesdropping can be very difficult to implement in the real world, government officials should remain concerned about the possible threat.

Laser Eavesdropping Basics

A normal conversation has a sound level intensity of only around 60 dB, or a microwatt per square meter. While this figure is quite small, it is often enough to force a window pane into synchronous vibration with the impinging sound waves. A light beam reflected from such a window will be positionally or amplitude modulated by movement of the window. A suitable receiver can detect and demodulate the reflected beam.

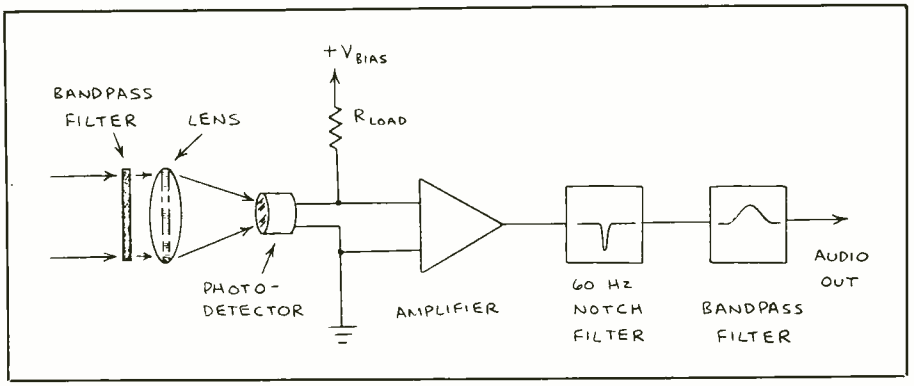


Fig. 3. A block diagram of a typical laser eavesdropping receiver.

Several methods can be used to surreptitiously monitor conversations by reflecting a laser beam from a window pane. The most straightforward method is to project a highly collimated laser beam at a window and detect the reflected laser beam with a sensitive receiver, as shown in Fig. 1. In this method, the laser and receiver can be widely separated, as long as the reflected beam is accessible.

Another method is to place the laser normal to the plane of the window pane so that the reflected beam returns along the path of the transmitted beam. As shown in Fig. 2, this forms a Fabry Perot interferometer. A beam splitter is used to reflect a portion of the interfering beams to a detector. Though this method is exceptionally sensitive, in practice, it's extremely difficult to implement.

While the basic principles of laser eavesdropping are quite simple, successfully intercepting a conversation is not. For best results, the light beam must be highly collimated and have a very low noise level. If covert operation is desired, a near-infrared laser must be used to avoid detection. But this greatly complicates aligning the system without attracting attention.

The laser eavesdropping construction projects described in various magazines and journals use helium-neon (He-Ne) lasers. While this type of laser can be used with reasonably good results, it's inherently not a low-noise source. Continuous-wave (CW) laser-diode collimators can provide a lower noise source, but they, too, aren't noise-free.

Undesirable effects of noise from the illuminator can be reduced by incorporating a filter stage in the receiver. Another significant noise source is light from the sun, as is artificial light, particularly when inside the room being monitored. A 60- or 120-Hz notch filter can reduce the effect of artificial lighting. An optical bandpass filter tuned to the wavelength of the laser source can reduce the adverse effects of both sunlight and artificial light. An audio equalizer is helpful in this respect, since it can both subdue unwanted noise and help compensate for the poor frequency response of most window panes. A block diagram for a receiver that incorporates these noise-reduction principles is shown in Fig. 3.

Placement of the receiver's detector in the reflected laser beam is crucial to the performance of the system. In a straightforward application against a glass pane, the reflected beam will probably be positionally modulated. In other words, the reflected beam will sweep across a very small angle in direct proportion to the incident wound waves. The reflected beam will generally consist of an interference pattern caused by the reflections from the front and rear surfaces of the glass. For best results, the sensitive surface of the detector should be placed at the edge of one of the bars of light in the reflected pattern. If a lens is used to achieve greater detection range, other techniques can be used to enhance the sensitivity of the receiver.

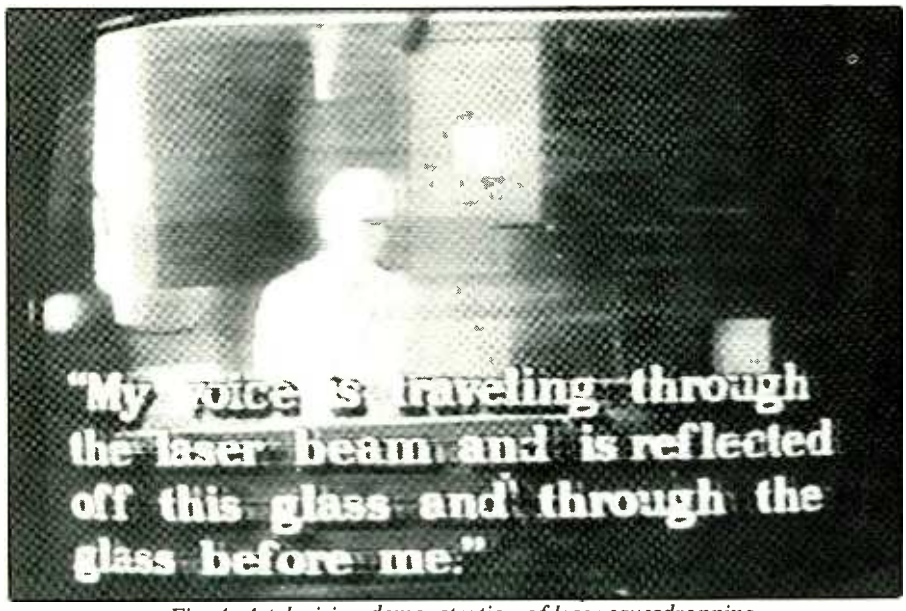


Fig. 4. A television demonstration of laser eavesdropping.

Even when noise and interference reduction techniques are employed, the voice quality of conversations intercepted by a laser is generally less than good. Often, the amplitude of the voice is not much above the noise level, and the voice sounds as if the person speaking is inside a box. External interference from temperature fluctuations in the atmosphere, blowing dust and flying insects can add to the problem.

"Siliconnections"

Earlier, I confessed to having experimented with laser eavesdropping gear. Later, the legal implications of some of that work and electronics eavesdropping in general were discussed. First, here is the background.

Siliconnections: Coming of Age in the Electronic Era (McGraw-Hill, 1986) is a memoir about my experiences as an electronics writer and tinkerer. This book includes several chapters about the development of the Altair 8800, the microcomputer generally credited with having initiated the personal computer industry. Since I was a co-founder of MITS, the publisher and I assumed the Altair story would be the book's main selling point.

Siliconnections also includes chapters about the annual Consumer Electronics Show, the electronics press and an Air Force laser laboratory. There's also a chapter about the time the *National Enquirer* hired me to monitor the conversations of Howard Hughes by reflecting a laser beam against the window of his hotel in the Bahamas.

Most print reviewers of *Siliconnections* emphasized the Altair connection. But when I toured the country to promote the book on radio and television, the emphasis was almost entirely on the laser eavesdropping chapter. During every interview, I was asked to explain and, if the interview was televised, display laser bugging devices. TV stations in Los Angeles and Houston were so intrigued by the technology that they spent considerable time taping demonstrations I conducted for them. A production company even flew me to New York to demonstrate the technique for a documentary that was later telecast on HBO ("Surveillance: No Place to Hide").

Figure 4 is a screen photograph of Cliff Morrison of KCBS in Los Angeles participating in one of the demonstrations. Morrison is inside a soundproof booth fronted by two thick panes of glass, and the laser eavesdropping system is pointed toward a glass picture frame inside the booth. Superimposed on the screen are Morrison's words as intercepted by the laser receiver.

I agreed to conduct these televised demonstrations only after first contacting the Senate Select Committee on Intelligence, the FBI and two other government intelligence agencies. I had learned that my equipment, which could be used for laser eavesdropping, was considerably cheaper and apparently much smaller than equipment developed by the government. Also, I learned that the new developments in inexpensive, pocket-size semiconductor laser transmitters had been overlooked by some government officials.

A staffer for the Senate committee suggested several officials to contact, including an Oliver North on the staff of the National Security Agency. Lt. Col. North was not in when I called, but I did manage to reach several other officials. Eventually, my offer to conduct a confidential demonstration of laser eavesdropping for the FBI and two other agencies was accepted by representatives of each organization. Later, however, an FBI official warned me that he couldn't guarantee that I wouldn't be arrested if I transported the equipment to Washington. That's when I decided that the only way to inform the government about the potential threat of miniaturized laser eavesdropping devices was to accept the invitations to demonstrate the equipment on television.

These demonstrations resulted in some strange telephone calls. A man claiming to represent a middle eastern government called and asked to buy six laser bugs. Several private detectives called to ask me to sell them laser bugs. And then there was the elegant woman who saw a televised demonstration of my equipment in Los Angeles. She then visited the computer show where I was exhibiting an Altair computer to ask how she could prove to the police that her former boyfriend was bugging her house with a laser.

In view of the laws that govern electronic eavesdropping devices, it's important to note here that the apparatus I demonstrated on television was originally

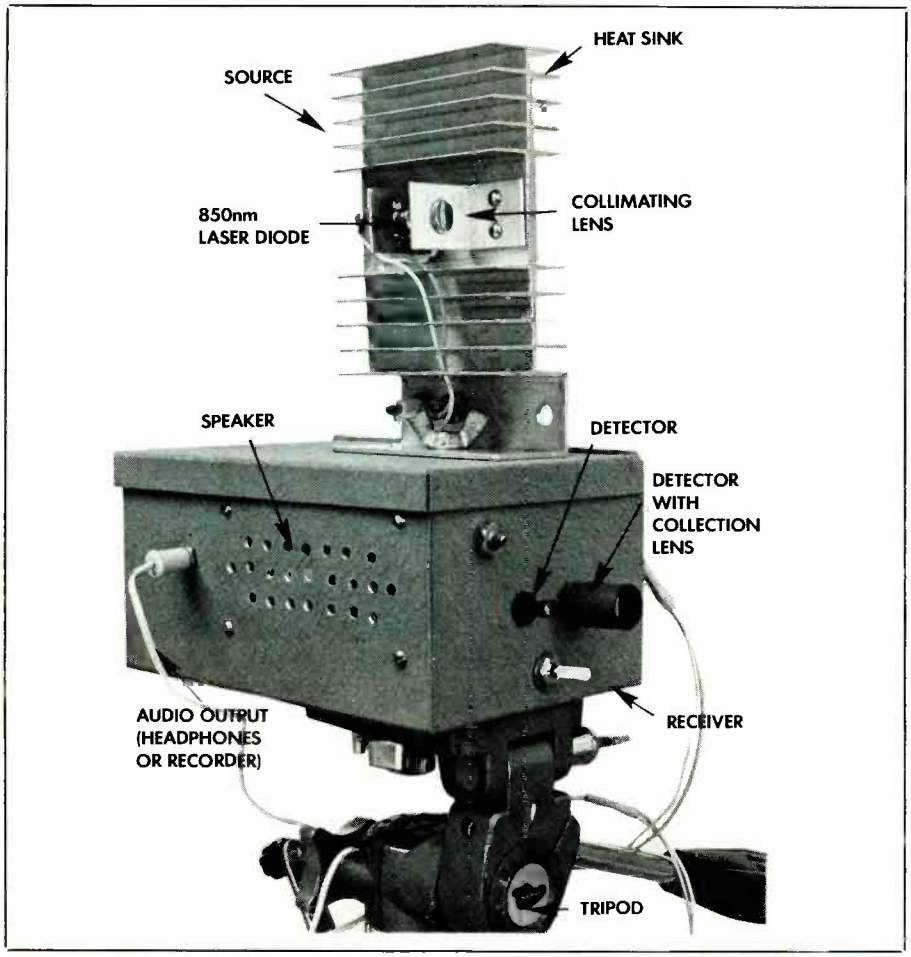


Fig. 5. A laser eavesdropping system built by the author in 1976.

built for other purposes. It was a highly sensitive optical fiber vibration sensing device. When the fiber was removed and some optics were added, the system formed a pocket-size laser eavesdropping device. Had I built this system specifically for laser eavesdropping purposes or maintained it as such a system, it might well have violated some of the laws that are discussed below.

On the other hand, the systems I built for the Howard Hughes project in 1976 were intended specifically for surveillance and, as I later learned, would have violated the law had they been used without the knowledge of the person whose conversation was being intercepted. The legal aspects of laser eavesdropping will be covered later. First, here's a highly condensed account of the *National Enquirer's* Howard Hughes project described in *Siliconnections.*

Confessions of a Laser Spy

In 1975, an editor at the *National Enquirer* called to assign a series of articles on advances in laser technology. During our discussion, he asked me if I was familiar with press reports about laser bugging technology. When I mentioned that a laser bugging system could be assembled from parts in my workshop, the editor suddenly lost interest in the laser articles. Instead, he informed me about the paper's interest in intercepting the conversations of Howard Hughes at the Xanadu Princess Hotel in the Bahamas. The objective of this plan, he claimed, was to uncover questionable dealings of significance. He then asked if I would be willing

ELECTRONICS NOTEBOOK...

to build a suitable laser eavesdropping system.

Intrigued by the possibility of helping to develop a major news story and being unaware of the legal aspects of electronic eavesdropping, I agreed to the assignment. Over a six month period, I designed and tested two basic kinds of laser eavesdropping systems. The first used a 3-milliwatt He-Ne laser with a collimating telescope to provide a beam divergence of only 0.1 milliradian. The second, shown in Fig. 5, used a then state-of-the-art CW semiconductor laser fitted with a collimating lens.

After tests revealed that both these systems could surreptitiously intercept conversations inside my house from some distance outdoors, I became concerned about the legality of the project. The editor from the *Enquirer* assured me that the project was entirely legal. (More about that later.) And since I had once worked with highly classified military programs, I became concerned that the U.S. government should be made aware of the technology. Therefore, I suggested that the *Enquirer* exchange the Howard Hughes project for a demonstration before government officials in Washington, D.C. One of the editors liked the idea and said it might be possible to enlist the help of former Senator Barry Goldwater.

After the two test systems were perfected, the *Enquirer* flew me to their headquarters in Lantana, Florida to demonstrate the devices. The project was considered so secret that only two editors and the paper's owner knew why I was there. Therefore, our tests outside the building raised a good deal of curiosity on the part of the *Enquirer*'s staff.

The hurricane-proof windows installed in the paper's modern offices were much too thick to vibrate in response to sound. Therefore, I reflected the laser beams off the glass panels atop some of the office dividers, with moderate success. I also used, with excellent results, a passive optical bug I had previously installed in an *Enquirer* office. Though the two editors searched the room, they were unable to find the bug.

During the tests, the *Enquirer*'s editors showed much more interest in the Howard Hughes project than in my alternative proposal for a demonstration before government officials. They even produced ground and aerial photos of Hughes's hotel and asked if I was prepared to fly to the Bahamas. Fortunately, Hughes himself intervened when he was flown to Acupulco while I was still in Lantana.

Miniature semiconductor laser eavesdropping equipment.

Two weeks later, one of the *Enquirer*'s editors called me to ask how soon I could be in Acupulco with my equipment. With better judgment than I had theretofore exercised, I declined the assignment. Hughes died a few days later while being flown to Houston.

Laser Eavesdropping and the Law

Shortly before the *Enquirer* asked me to follow Hughes to Mexico, I saw Art Salsberg, then Editor of *Popular Electronics* and now Editor-in-Chief of *Modern Electronics*, at an electronic convention. Art, who had once edited a magazine for attorneys, thought the entire project was potentially illegal and completely insane. Following his advice, I visited a law library to research the relevant laws and soon learned that Art was correct.

Recent laser eavesdropping projects published in the *American Journal of Physics* and an electronics magazine omitted any mention whatsoever of the severe legal sanctions that can be imposed for unauthorized use of laser eavesdropping gear in all 50 states. What follows is a very brief summary of legislation governing electronics eavesdropping.

It's important to observe that laser eavesdropping is governed by the same laws that control any other form of electronic eavesdropping. These laws also regulate manufacture, sale, possession and advertising of devices whose primary purpose is the unauthorized interception of wire or oral communications.

The federal statute is given in Title 18, Chapter 119 of the U.S. Code. This statute prohibits the manufacture, assembly, possession, sale and transport across state lines of oral interception devices. Also prohibited is advertisement of such devices in publications sent through the mail or across state lines. Individuals who willfully violate this statute can be fined up to $10,000 and imprisoned for up to five years.

Excluded from the federal statute is "... an officer, agent, or employee of a person under contract to the United States, a state or a political subdivision thereof . . ." in the normal course of activities of these governmental bodies.

Also excluded is the interception of wire or oral communication where the interceptor "...is a party to the communication or where one of the parties to the communication has given prior consent to such interception...." Incidentally, this exclusion poses an interesting contradiction, in that the law that prohibits possession of a device permits the same device to be sometimes used.

In addition to these restrictions, various local, state and federal regulations and statutes govern the use of lasers. Moreover, persons whose conversations are intercepted might have grounds for civil action against the eavesdropper. In short, a would-be laser eavesdropper might find himself charged with a list of criminal acts including use, possession and transportation of electronic eavesdropping equipment and unsafe use of lasers.

These legal sanctions bring us back to the magazines that have published construction details for laser bugs without warning their readers of the potential consequences resulting from their use.. One can only wonder if these publications are prepared to provide legal defense for any of their readers who build and use such devices.

Going Further

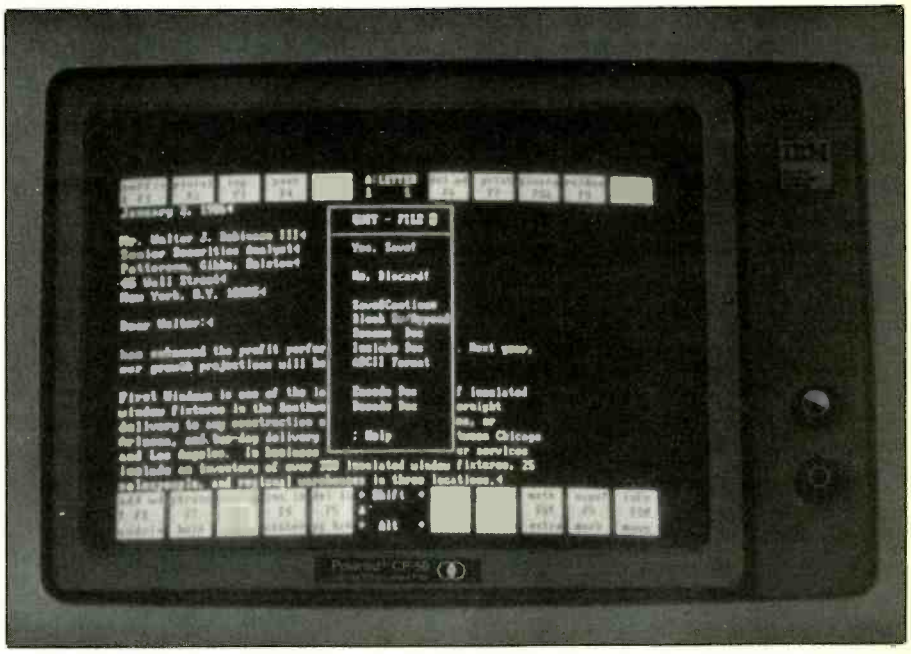
Eavesdropping with a laser is a highly specialized surveillance technique. It's difficult to implement in the field, and the quality of the intercepted communication is often poor. Its only legitimate use is in government intelligence-gathering operations in which direct access to a room to be monitored is not possible.

Experimenters interested in intercepting conversations with lasers would be well advised to build lightwave communication systems. So long as any relevant regulations concerning the use of lasers are followed, lightwave communications are legal and do not require a license from the Federal Communications Commission. Moreover, they can provide excellent voice quality.

Experimenters interested in building one of the recently published laser eavesdropping systems should first carefully review the relevant laws. If they still plan to proceed, they might then inquire of the magazine that published the plans if it will guarantee any legal expenses that might be incurred. **ME**

An Artificial Intelligence Word Processor: "MindReader"

By Art Salsberg



MindReader with on-screen function-key aids and pop-up menu.

If you're not a reasonably proficient typist, MindReader from Businesssoft, Inc. (Annapolis, MD) may be just the word processing software you've been looking for. It requires an IBM PC, XT, AT or true compatible, 256K system memory and DOS 2.0 or higher. Price is only $65, which is easy enough to take. The program is copy protected, but allows two backup copies to be made.

MindReader is certainly an unusual sort of program. It uses artificial intelligence (AI) to guess what word you intend to write upon typing the first few letters. Up to five "choices" are listed in a window that opens up, with each possible word preceded by a number. (The program's choice of the most likely word in the pop-up window is preceded by a semicolon instead of a number.) Pressing the semicolon or number key of the correct word causes the word you partially typed to be completed for you before your eyes.

The window can be turned completely off by the user, too. Or it can be put into a standby mode for call-up when you press a semicolon key. Furthermore, AI doesn't stop at a static list. It's a "living" list that moves word choices toward the head of the group (actually the bottom of the list since the list scheme starts there with the most likely one and works its way up with less likely choices) as the program continually analyzes the word you use most frequently.

Function keys are used to add "ing," to a word, make a word plural, create the past tense or add a suffix to a word. When the computer finishes typing a word or punctuation mark, it automatically spaces correctly. Text is word wrapped so that sentences automatically continue to the next line without pressing the Enter key. Using Alt and a function key simultaneously sets boldface, underline, centering and page break.

MindReader's dictionary consists of about 2,500 of the most commonly used words for business and memo writing. Even with this limited number of words, you'll be pleasantly surprised at the high number of hits it makes. Further, words and whole phrases can be easily added to the dictionary. You can also delete a word or phrase.

A host of functions expected with any word processor worth its salt is here for the using, such as erasing a character, a word, and an entire line. There's also an "oops" key to restore a last word or line mistakenly erased. You can also search and replace a word, with a pop-up window aiding you with option choices such as global and wildcard choices. Moving text blocks, too, is in the province of MindReader, as is flush-right text selection, paragraph indentation, tabs, and word, phrase or line insertion, etc.

In addition to the foregoing, macros can be created for use with a function key and the control key; there's a built in spelling checker; a four-banger calculator with a percent function; a password code word choice for security; a conversion function to ASCII format; and a name and address file that hold up to 150 records. With the latter, you can have an address block automatically typed in a document. Additionally, MindReader has a monthly calendar and a 60-day diary for scheduling appointments.

The word processor comes installed for a monochrome video monitor, but it can be changed to limited color with a blue or black background and writing in white, yellow, blue or green.

Hands-On Performance

MindReader loads kind of slowly on floppy drives (it can be used with a hard disk drive, too, which is considerably faster). As with any program, one has to learn what each function key does and how to use the shift and alt keys to be used for a specific action. The icon boxes (ten across the top and two rows of ten along the bottom of the screen) simplify this learning process. Pop-up menus complement it all.

The unusual word processor is easy to use and, though it doesn't have some of the bells and whistles of professional packages, it offers some that they don't have, such as desktop management. One of the files here, the Rolodex, even has a chart of state abbreviations, as well as being able to sort entries by zip code or alphabetically. Files are saved automatically every 20 minutes, which is nice. Additionally, your typing speed and current file size are noted.

You don't get footnoting provisions, a fat synonym finder, line spacing selec-

tion beyond double space, and some other features. But you do enjoy pressing a key for printing and away you go, a split screen option (horizontal), and all the basics such as cut and paste. Search and replace operation was surprisingly fast, too, while spelling check moved along at a fair pace.

This program would not be a personal choice for *me* for two reasons: I'm a proficient typist and I often work with long manuscripts. However, for someone who cannot type well and works mostly with letters and reports, it will probably be a Godsend. Having a machine automatically type out most of a word for you has got to be a great relief for someone who struggles to find the correct key. And if you ever need a work break, MR has a word game, Word Jumble, to entertain you. I like the remarkably low price as well. In all, MindReader is a fine program for nontypists; better than any other I've ever come across.

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A Sampling of Fall 1987 English-Language International Shortwave Broadcasts

By Gerry L. Dexter

Time	Country/Station	Frequencies
0000	Radio Canada Int'l.	5960, 9755
	HCJB Ecuador (30)	11910
	Kol Israel	7410, 7480, 9435
	WCSN, USA	7365
	VOA, USA	5995, 9650, 9775, 9815, 11580, 11695, 11740, 15205
	REE, Spain	6125, 9630, 11880
	Vatican Radio (50)	9605,11780
	Radio Norway (Mon)	9580, 9605
	R. Sofia, Bulgaria	6070, 11720
	R. Beijing, China	15445
	RBI E. Germany	6080, 9730
	Air India	9912, 11715, 15110
	R. Korea	15575
	R. Luxembourg	6090
	Voice of Nicaragua	6015
	R. Havana Cuba	6090, 9740
	R. Thailand	9655, 11905
	R. Portugal (30)	9680
	BBC England	5975, 6120, 6175, 7325, 9590
	R. Moscow	6000, 7150, 7185, 7290, 9600, 9640, 9685, 9765
0100	DW, W. Germany	6040, 6085, 6145, 9545, 9565, 11785
	V. of Israel	7420, 7465, 7480
	RAI Italy	9575, 11800
	V. of Greece (30)	7430
	R. Prague, Czech.	5930, 7345, 9740, 11990
	RFI France	5950, 9715
	R. Budapest, Hungary	6025, 6110, 9520, 9585, 9835, 11910
	R. Austria Int'l. (30)	9550
	R. Baghdad, Iraq	11705
	RBI East Germany (15)	6080, 9730
0200	HCJB, Ecuador	6230
	R. Havana, Cuba	6090, 6120, 6140, 9740
	R. Polonia, Poland	6095, 7145, 9525, 11815, 15120
	WCSN, USA	9745
	Radiobras, Brazil	11745
	RAE Argentina	9690, 11710
	R. Cairo, Egypt	9475, 9675
	TGNA Guatemala	3300
	R. Budapest, Hungary	6025, 6110, 9520, 9585, 9835, 11910
	R. Netherlands (30)	6020, 6165, 9590, 9895
	SRI Switzerland	6135, 9725, 9885, 12035
	R. Korea	15575
	R. Sweden Int'l. (30)	9695
	R. RSA, So. Africa	6010, 9615, 9695
	R. Kiev, Ukraine SSR	7260, 9640, 9800, 11790, 11875, 13645
	R. Bucharest, Romania	5990, 6155, 9510, 9570, 11810, 11940
0300	DW, W. Germany	5965, 6010, 6045, 9545, 9565
	MBC, Malawi	3380
	V. of Turkey	9560
	V. of Greece (40)	7430
	R. Prague, Czech.	5930, 7345, 9740, 11990
	RFI, France (30)	6055, 9800
	HRVC Honduras	4820
	R. Japan	5960, 15280, 17810, 17825
	R. New Zealand (45)	9630, 11780
	TWR Bonaire	9535
	R. Beijing, China	11970, 15180, 15280, 15445
	RBI (30)	9560, 9620
	UAE Radio, U.A.E. (30)	9640, 11940, 15435, 17890
	P. Polonia, Poland	6095, 6135, 7145, 7270, 9525, 11815, 15120
0400	WCSN, USA	9465
	R. Botswana	4820, 7255
	R. Norway (Mon)	9650, 11735
	SRI Switzerland	6135, 9725, 9885, 12035
	R. Austria Int'l.	9550, 11805
	R. Beijing, China	15180, 15280
	R. Bucharest, Romania	5990, 6155, 9510, 9570, 11810, 11940
	RAE Argentina	9690, 11710
	R. Havana Cuba	5965, 6035, 6090, 6120, 6140, 9740
	BBC England	5975, 9510, 9640
	R. Moscow	7175, 7270, 7315, 7345, 9580, 9685, 9755
0500	HCJB Ecuador	6230, 11910
	DW, W. Germany	5960, 6120, 6130, 9635
	Kol Israel	7465, 9435, 9815, 9855, 11585, 11960
	VOA, USA	6035, 7280, 9540, 9670
	Vatican Radio	6185
	V. of Nigeria	7255
	R. Japan	11705, 15235, 15280, 17810
	R. Netherlands (30)	6165, 9715
	R. Dublin Int'l, Ireland	6910
	R. Doluala, Cameroon	4770

Times are in UTC. Numbers in parentheses are starting times for English that many minutes past the hour.

Time	Country/Station	Frequencies
0600	WCSN, USA	9465
	R. Korea	6060, 9570
	R. Cook Islands	11760
	R. Austria Int'l (30)	5945, 6155, 9635
	SRI Switzerland (30)	12030, 15430
	GBC Ghana	3366, 4915
	R. Havana Cuba	9525
	TWR Monaco (25)	7105
0700	HCJB Ecuador	6130, 9745, 9860, 11975
	R. Japan	11705, 11875, 15195, 15230, 15280, 17810
	SIBC Solomon Islands	5020, 9545
	R. Korea (15)	9570
0800	BRT Belgium	9880, 15515
	KNLS Alaska	5960
	WCSN, USA	9465
	R. Australia	9580
	NBC Papua New Guinea	4890
	R. Austria Int'l (30)	6155, 9620, 11915
	AFRTS	6030, 9530, 15265, 15430
0900	R. Moscow	9600, 11850, 11950, 13755, 15225
	KTWR (30)	11840
	R. Beijing, China	9700, 11755
	R. Ulan Bator, Mongolia (15)	9615, 12015
	R. Afghanistan	4450, 15255
	R. Australia	6060, 9580, 11720
1000	WCSN, USA	17640
	R. Australia	9580, 11720
	V. of Vietnam	9755, 9840, 12020, 12035
	R. New Zealand (30)	6100, 9630
	R. Norway (Sun)	11870, 15175, 15230
	SLBC Sri Lanka	11835, 15120
1100	Kol Israel	11665, 11700, 12080, 13725, 15640, 15650, 17630, 17685
	VOA	7230, 9760, 15160, 15425
	RFI France (15)	9790, 11670, 11690, 11700, 15365
	VOIRI Iran (15)	11790
	R. Japan	5990, 6120, 17810
	TWR Bonaire (10)	11815
	R. Beijing, China	15606, 17660
	R. Singapore	5052, 11940
	R. Finland	11945, 15400
	R. Pyongyang, N. Korea	7300, 9977

Time	Country/Station	Frequencies
1200	HCJB Ecuador	6075, 11740, 15115, 17890
	R. Australia	9580, 11720
	R. Bangladesh (30)	12030, 15525
	R. Austria Int'l. (30)	15320
	R. Beijing, China	9535, 11650
	R. Pyongyang, N. Korea	9600, 9715
	R. Tashkent, Uzbeck SSR	7325, 9600, 9715, 11785, 15460
	VOPK Kampuchea	9693, 11938
	R. Finland	11945, 15400
	TWR Bonaire	11815
	RCI Canada	9625, 11955, 17820
	AIR India	11620, 15120
1300	R. Beijing, China	9550, 9730
	BRT Belgium (30)	15515, 15595
	V. of Vietnam (30)	9755, 9840, 12020, 12035
	R. Norway (Sun)	6040, 9590, 15310
	AIR India (30)	9545, 11810, 15335
	AFRTS	15265, 15330, 15430
	BBC England	6195, 9510, 11775
	R. Finland	11945, 15400
	R. Korea	9750, 15575
	FEBC Philippines	11850
1400	R. Japan	5950, 9695, 11870
	KTWR Guam (30)	9840
	R. Norway (Sun)	15250, 15300, 15310
	R. Korea	15575
	R. Sweden Int'l.	11785, 15345
	R. Finland	15185, 15400
1500	HCJB	6075, 11740, 15115, 17890
	VORE Ethiopia	9560
	HKBS Jordan (30)	9560
	WRNO	11965
	V. of Nigeria	11770
	R. Japan	5950
	V. of Indonesia	11790, 15150
	Vatican Radio (10)	9645, 11740
	V. of Greece (40)	11645, 15630, 17565
1600	RFI France	11705, 15300, 15315 17620, 17795
	KNLS Alaska (30)	7355
	WCSN, USA	15270
	VOA, USA	11920, 15410, 15445 15580, 15600, 17855 17800, 17870
	V. of Vietnam	9755, 9840, 12020, 12035
	R. Norway (Sun)	11925, 15180, 17840
	BSKSA Saudi Arabia	9705, 9720

COMMUNICATIONS

Time	Country/Station	Frequencies
	R. Pakistan	9465, 11615, 11625, 15605
	UAE R. UAE	9640, 11730, 11955, 15320
	V. of Nigeria	15120
1700	R. Japan	5990, 9695
	R. Norway (Sun)	9655, 11925, 15310
	WRNO	15420
	RAE Argentina (30)	15345
	AFRTS	9700, 15330, 15430
	BBC England	11775, 15260
	R. Moscow	9600, 9765, 11840, 11860, 12050, 13605
	R. Africa, Eq. Guinea	9553
	V. of Nigeria	11770
1800	WCSN, USA	15230
	R. Jamahairya, Libya	15450
	Radiobras, Brazil	15265
	R. Discovery, Dom. Rep.	15045
	R. Kuwait	11675
	RCI Canada	15260, 17820
	V. of Nigeria	15120

Time	Country/Station	Frequencies
1900	HCJB Ecuador	11740, 15270, 17890
	VOIRI Iran (30)	9022
	R. Norway (Sun)	11925, 15310
	R. Afghanistan	9635, 9665, 11755
	Kol Israel	11610, 11655, 13725, 15585
	R. Algiers, Algeria	9509, 9640, 15215, 17745
2000	Kol Israel	9020, 9435, 9815, 9885, 11700, 11960
	WSCN, USA	15265
	R. Damascus, Syria (05)	9950, 12085
	R. Norway, (Sun)	9590, 11865, 15310
	R. Kuwait	11675
	RCI Canada	5995, 9555, 11945, 15325, 17820, 17875
	V. of Nigeria	11770
	R. Baghdad, Iraq	9875
	RBI East Germany (45)	5965, 6125
2100	BRT Belgium	5910, 9675
	R. Sofia, Bulgaria (30)	6070, 7115, 9700
	WRNO	11705
	Kol Israel (30)	9010, 9435, 11610, 11700, 13725, 15485, 15585
	RCI Canada	11945, 15150, 17820
	R. Yugoslavia (15)	6100, 7240, 9620
2200	BRT Belgium	9925
	Kol Israel (30)	7410, 7465, 9020, 9815, 11960, 12025
	WCSN, USA	15300
	VOA	6130, 15290, 17740, 17820
	Vatican Radio	11830
	R. Jamahiriya, Libya (50)	11815
	R. Norway (Sun)	9605, 11930, 15165
	R. Sofia, Bulgaria	6070, 11720
	V. of Turkey	9560
	RBI East Germany	6125, 6175, 11750
	R. Vilnius, Latvian SSR	7260, 9640, 11790, 11875, 13645
	RCI Canada	5960, 9755
	RAE Argentina	9690, 11710
2300	RBI East Germany	6080, 9730
	R. New Zealand (45)	11780, 15150
	R. Sweden Int'l.	9695, 11705
	R. Kiev, Ukraine SSR (30)	7260, 9640, 9800, 11790, 11875, 13645, 13775
	R. Baghdad, Iraq	11705
	Kol Israel	9435, 9885, 11610
	R. Pyongyang, N. Korea	11735, 13650
	R. Japan	15300
	R. Korea	15575
	R. Sofia, Bulgaria	9700, 11720
	RCI Canada	5960, 9755

ME

nector and whatever instrument you are using it with to the newly installed CONDITIONED BNC connector. If you selected DIVIDED, you also have to set the DIVISION SELECT switch to the appropriate position.

With the ICs still not plugged into the sockets on the conditioner/divider board, set the POWER switch to on (if you are using a separate battery to power this board, snap one into its connector before turning on the power.) Connect a dc voltmeter's common lead to the ground lug of one of the BNC connectors. Then measure the voltage at pin 7 of *U1*, pin 14 of *U2* and pin 16 of *U3*. The measured potential in all three cases should be +9 volts.

Calibration

Due to the 9400CJ's linear/proportional operation, its output voltage can be read directly without post-scaling. This means that an input frequency of 1,345 Hz will be displayed on a voltmeter as 1.345 volts, providing that the F/V converter is set to the appropriate range. To perform calibration, you need an accurate frequency source of 500 Hz, 5 kHz and 50 kHz—the center points for the basic converter's three ranges.

Before calibrating the F/V converter, you must adjust the offset null. To do this, power up the instrument with your DMM (set to read low dc volts) across the OUTPUT terminals in the proper polarity and measure the output voltage with nothing connected to the INPUT. Slowly adjust *R6* until the output voltage reads as near to zero as possible. This done, connect a function generator to the INPUT jack and begin calibrating each of the three ranges as follows:

To calibrate RANGE 1 (1 Hz to 1 kHz full-scale), you can use a 6-volt rms power transformer directly at the converter's INPUT BNC connector. Adjust *R1* for an indicated output of 0.6 volt, which, in this case, corresponds directly to 60 Hz.

Calibration of RANGE 2 (10 Hz to 10 kHz full-scale) and RANGE 3 (100 Hz to 100 kHz full-scale) is identical except for a change in input signal frequency. Set the switch to RANGE 2 and inject a 5-kHz signal into the INPUT connector and adjust *R2* for an indicated 0.5 volt. This done, switch to RANGE 3, inject a 50-kHz signal into the INPUT and adjust *R3* for an indicated 0.5 volt. This completes calibration of the F/V module. The conditioner/divider module needs no calibration.

Your DMM can now double as an accurate portable frequency counter that can be used in audio through ultrasonic work and, with the optional conditioner/divider, can even be used in low-frequency r-f work. Though the converter/DMM combination is not truly a "counter," its accuracy and linearity rivals the real thing. **ME**

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CIRCLE 57 ON FREE INFORMATION CARD

NEW PRODUCTS . . . *(from page 14)*

Computer Printer Stand

The Vertistack Printer Stand from Vector (San Jose, CA) supports an 80-column printer and its paper without taking up any desk space of its own. It can be mounted to a wall, much as wall-bracket shelves are, on the side of a desk, or hanging from a wall partition. The stand accommodates all popular types of 80-column printers and has slots in the shelves and base for routing fan-fold printer paper, power cords and data cables. $75.

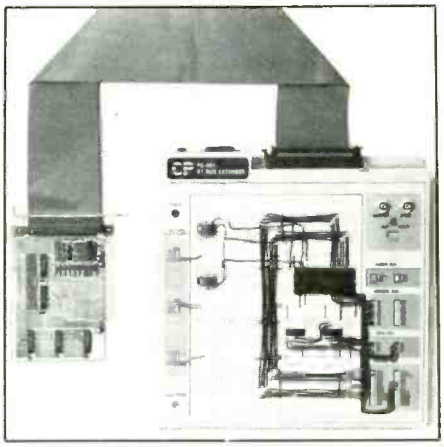
CIRCLE 72 ON FREE INFORMATION CARD

Computer Breadboarding Lab

A bus extender and breadboarding lab, the Model PC-601, for use with IBM PC/XT and compatible computers, has been announced by Chenesko Products, Inc. (Centereach, NY). The bus extender is a ½-size buffer expansion card that plugs into any slot in the computer, where it picks up the bus signals, buffers them and sends them via a 24" ribbon cable to the external breadboarding lab portion of the system.

ADVERTISERS' INDEX

NEW PRODUCTS . . .



The bus signals are readily available on the breadboarding assembly's front panel. These signals are clearly labeled and shown on the lower-right side of the board.

A large size standard solderless breadboarding socket work area with 3,060 tie points make up the prototyping area. Connections to the solderless socket points and bus are made with standard 22-gauge solid hookup wire.

Included on the front panel are independent 117- and 220-volt ac power supplies that output +5 volts at 3 amperes, −5 volts at 0.5 ampere, +12 volts at 1 ampere and −12 volts at 0.5 ampere. All supply lines are short-circuit protected and are provided in addition to the computer-bus-supplied supply lines. A 4:1 TTL multiplexer enables viewing of four logic signals simultaneously on a single-channel oscilloscope. Each channel's signal is alternately dc-level displaced or chopped by front-panel switch selection. A "sync" output is available for oscilloscope triggering, and a 60-pin bus output connector located on the front end of the lab permits daisy chaining of more than one PC-601 for more complex circuits. $369.95.

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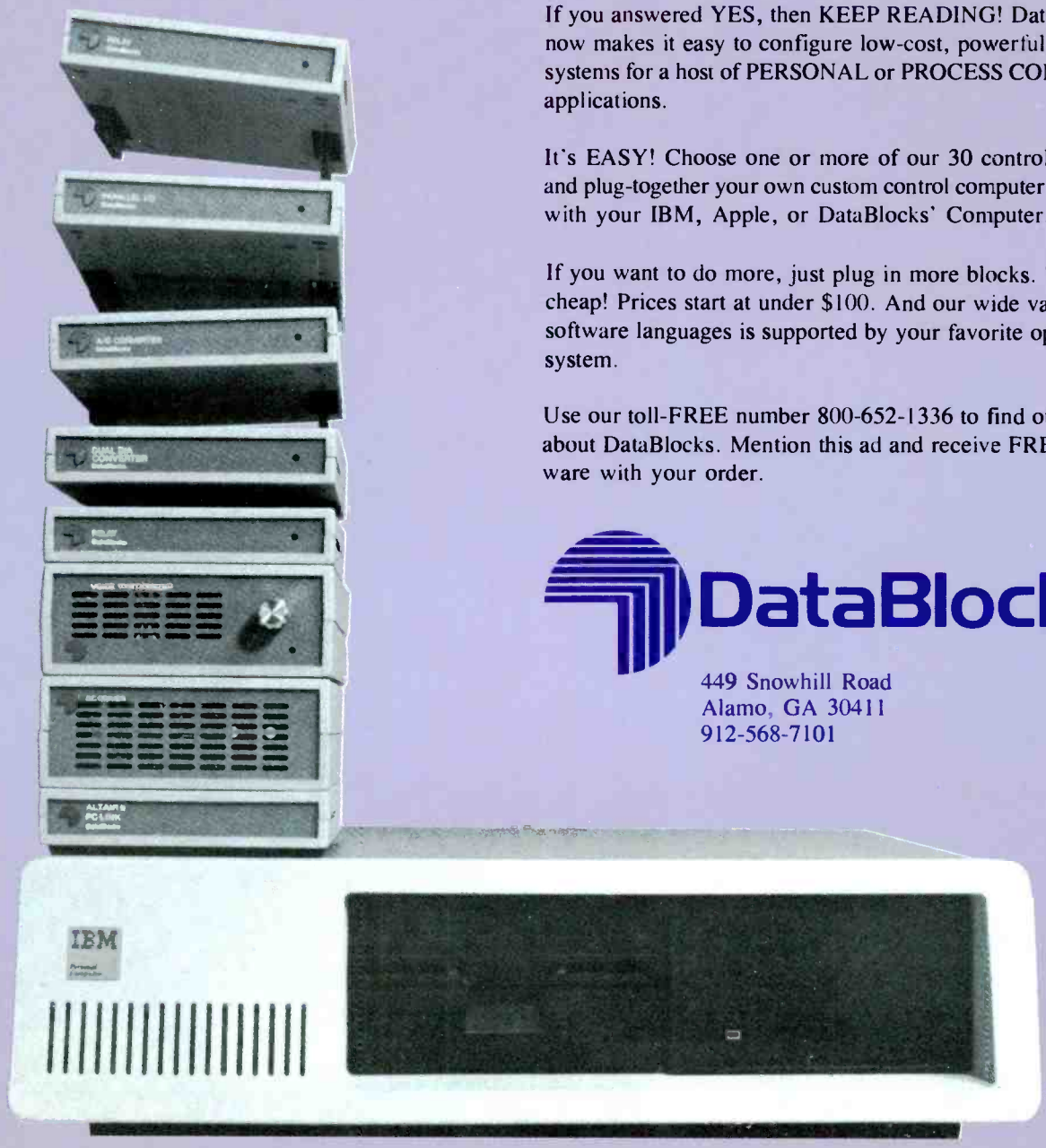

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