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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

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Instrument Buying Guide

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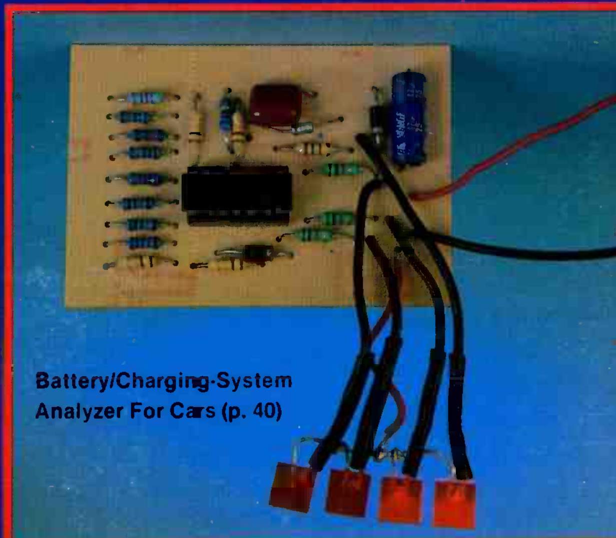
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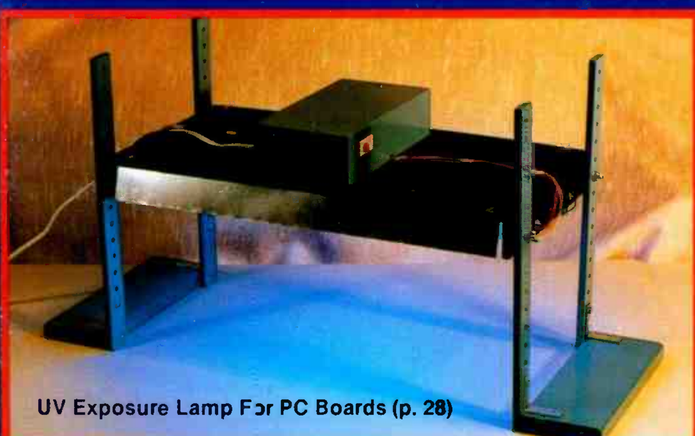
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Plus: Add Sweep & Other Functions to Basic Audio Signal Generators ● Music on the Personal Computer ● Evaluating "RightWriter" Style/Grammar Checker ● Multi-Line Home Telephones ● Electronics & Computer News ● Latest Technical Books & Literature . . . more.

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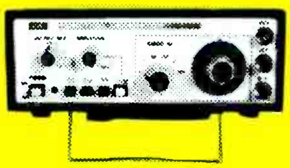

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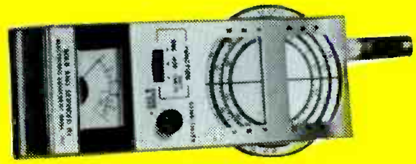

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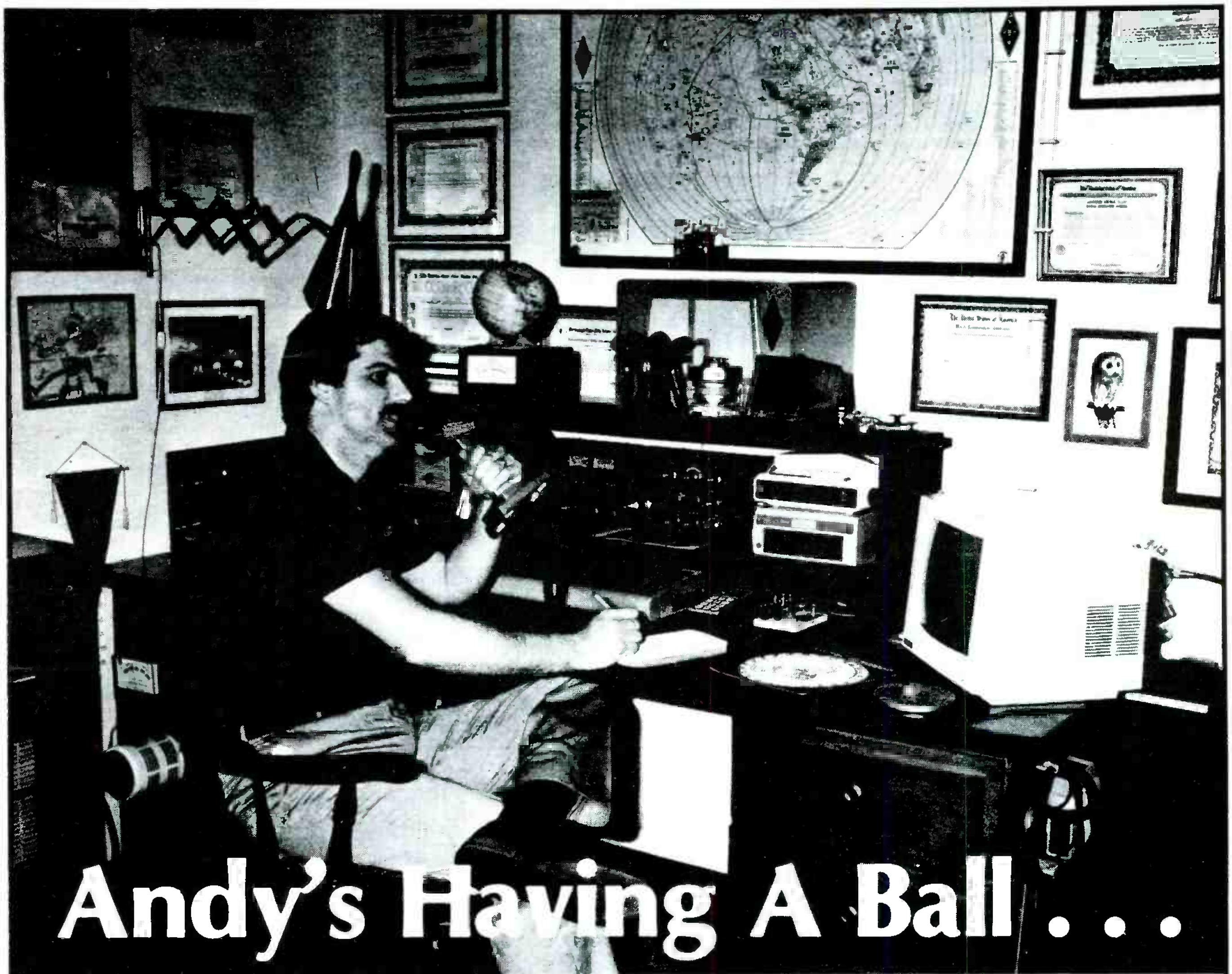

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MODERN ELECTRONICS

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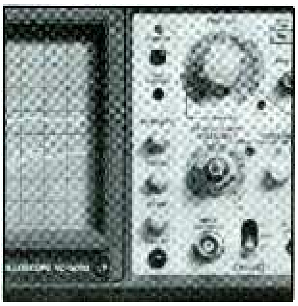

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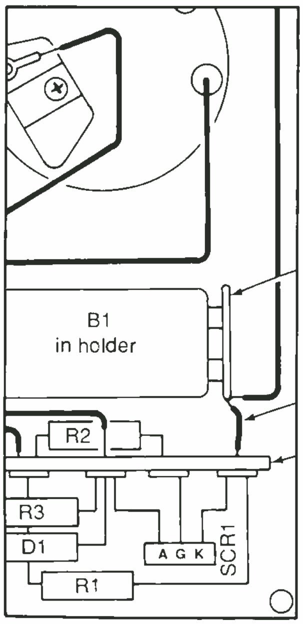

40

FEATURES

COLUMNS

DEPARTMENTS

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EDITORIAL

Yeth Thir!

Radio Shack's speech-recognition integrated circuit, discussed in *Modern Electronics'* January 1989 issue by Forrest Mims, is an experimenter's delight. Firstly, it's cheap ($9.95). Next, not much supporting circuitry is needed. And finally, you do not have to "train" it to recognize someone's speech.

The chip's speech-recognition prowess has its limitations, of course, which includes a design that responds to only a handful of words or phrases (nine). Nevertheless, it's practical and educational.

Voice recognition has made giant strides in the past few years. Texas Instruments, which astonished the public years ago with its high-selling "Speak & Spell" game, has embarked on another educational toy/game that employs speech—this time, voice recognition. Called "Voyager," it also is a speaker-independent system. It's a $65 interactive headset that's designed to exchange talk in response to any child's voice. It uses TI's TSP50C40 speech-recognition/speech synthesizer IC. Prerecorded cassette story tapes plug into the headset so that there's an exchange between machine and user relating to what's on the educational-oriented tape.

A child's answer in response to Voyager's question can determine what the next question is, operating in a typical artificial intelligence manner. With small children, though, there are voice-recognition obstacles that are significantly different than when words are spoken by adults. TI's development team discovered this on their way to creating the first real voice-recognition educational electronic toy.

"Yes" is not easily recognized by an electronic voice-recognition system when the speaker is a child with a few front teeth missing. So TI engineers had to circumvent this by creating algorithms that would accept the word, "Yeth" as "Yes," as well as recognizing a casual "Yeh" or "Naw" (for "No").

Speech-recognition-circuit response precision can be seriously undermined by ambient noise, as Forrest was quick to point out in his "Electronics Notebook" discussion in January's issue. He suggested that the microphone of his speech-recognition system be held close to your mouth when speaking to get best results. No such directions are needed with TI's Voyager because the headset has a boom microphone attached to it so that the distance between the mike and the child's mouth is more or less a fixed length.

The beginning-of-year annual Toy Fair in New York is a hot bed of new toys and games. Products that contain electronics represent the fastest-growing part of the business, we're told, just about doubling the 5% rate of the industry's annual growth.

Interestingly, one of our readers called last week to thank us for Forrest Mim's column about Radio Shack's VCP200 voice-recognition chip. He told me that he's an electronics toy designer and discussed the Toy Fair show coming up (now past) as a very worthwhile one.

He also asked if Forrest made an error on the name or address of the VCP200's manufacturer, listed as Voice Control Products, Inc. in his column, because the telephone information operator said that there is no such company listed. I promised to check it out and let him know it.

The first thing I did was dial "information" and investigate this myself because Forrest hardly ever makes a mistake, bless him. The operator confirmed that no such company exists at that address. Having once had a similar experience many years ago when an operator insisted that there was no RCA in New York, I then asked if there is a VCP company there. The response was disappointingly the same.

As I was about to hang up, the operator said, "There is a VCPI listed, though." That's "I" for Incorporated, of course. And that's how an electronics toy designer got a voice-recognition-chip supplier's phone number.

Art Salsberg

Author Feedback

• Readers who build my "Automatic Hold Device" (February 1989) using perforated board should make sure to ground pins 8 and 9 of CD4001 *IC1* to assure stable operation of the project. These pins are not shown grounded in the schematic diagram. Readers who use the published etching-and-drilling guide to make a printed-circuit board or a board purchased from me need not be concerned about this because the trace to pins 8 and 9 of the IC goes to the ground trace in the pattern.

Anthony J. Caristi
Waldwick, NJ

• The SK3950 silicon-controlled rectifier specified for *SCR1* in my "Personal Intrusion Detector" (January 1989) is very sensitive. It requires 0.8 milliampere of current to turn on, which makes the device sensitive to surge currents when power is switched on and may falsely trigger even when gate switch *S1* is open. Any reader who experiences this problem can can solve it by bridging the anode and cathode leads of the SCR with a 0.05-microfarad capacitor. The capacitor then absorbs the surge current.

Charles Shoemaker, Ph.D.

Setting the Record Straight

• After reading "Making Printed-Circuit Boards the Old-Fashioned Way" (December 1988), I thought I would set the record straight by pointing out the advantages of using positive resist in place of negative resist. Making pc boards the way the author describes entails more work than is necessary. By using positive resist, one can progress from positive artwork (which is what one gets with the usual tapes and patterns used for making master pc artwork—Ed.) directly to exposing the sensitized board without having to go through the intermediate step of reversing the artwork master to make an exposure mask. The master artwork itself is the exposure mask. The entire procedure for making pc boards this way was detailed in an article I authored that appeared in a 1976 issue of *Popular Electronics*. Also, anyone who does not wish to sensitize his own pc blanks can purchase presensitized blanks from a number of sources.

Another benefit of the positive photoresist route is that it entails use of less expensive and non-volatile solvents, which is not the case with negative resists.

Mr. Caristi's article states that ferric chloride is a much faster etchant than ammonium persulfate, which is a fallacy. In fact, ammonium persulfate is an exceptionally fast etchant when properly prepared. This has been substantiated by R.H. Clark, an authority on pcb manufacturing in his book *Handbook of Printed Circuit Manufacturing* (Van Nostrand, 1985).

William T. (Ted) Roubal, Ph.D.
Seattle, WA

• I've discovered a small error on the pc-board wiring diagram for the "Low-Cost Function Generator" in the January 1988 issue. The component designations associated with input pin 2 and output pin 1 of IC4 should be as follows: transpose R15 and R16; transpose J1 and R14.

Mark E. McDowell
Patrick AFB, FL

COMPUTER SECURITY. Denying unauthorized persons access to computer data is a fertile area for imaginative developers. The industry has gone way beyond requiring common passwords to be used. A new security product in this area, a software package named Electronic Signature Lock, is an interesting new alternative to other user identification methods. It identifies users by analyzing their typing patterns. It's claimed that the probability of gaining unauthorized access with this program is less than one in one-million, while granting quick access to authorized users. No additional hardware is required. The program is said to be compatible with all popular operating systems, and can be used on microcomputers, mainframes, LANs, and major networks. For more information, contact John Garcia at 503-937-3437, in Fall Creek, OR.

"A Generous Collection of Public Domain Software and Shareware for the Macintosh CD-ROM Reader" by Quantum Leap Technologies (Coral Gables, FL) contains an impressive 350 megabytes of program files. It was accompanied by a note requesting we destroy a recently received Volume 1 of the same because a [computer] virus was discovered on seven of its programs. Called a MEGA-ROM, the 3-1/2" disc also includes virus utilities, so users can double-check the virus' eradication.

INDUSTRY FIRSTS. Industry "firsts" abound. But they're often interesting since some initiatives are copied by many competitors. Among interesting ones announced recently was Sharp Electronics Corp.'s use of a powerful 12:1 variable-speed power zoom lens in two new camcorders....Radio Shack, too, announced a recent first with the introduction of the first Small Computer System Interface (SCSI) adapter board ($299.95) for AT-class personal computers. The 16-bit adapter board comes with a 10-MHz DMA chip. At the same time,. the company introduced an SCSI-compatible 80 Mb internal half-height hard drive ($1,799).

POCKET ELECTRONIC BIBLE. Another "first" is Selectronics' world's first pocket-size electronic Bible, measuring only 4 15/16" x 6 1/8" x 9/16", and weighing just six ounces. Using advanced text compression technology provided by Microlytics, Inc. (with algorithms licensed from Xerox Palo Alto Research Center), it features a typewriter-style keyboard to select Bible passages and a 160-character, four-line dot-matrix display.

The basic unit contains all the Old Testament books, while optional cartridges smaller than a credit card will be offered that contain several versions of the New Testament as well as other reference works. It'll retail for under $200.

DAT'S DAT. Digital audio tape (DAT) machines have been voluntarily held back for sale in the U.S. by their Japanese manufacturers owing to resistance by recording companies and artists who believe its recording ability will damage compact disc sales. They're being sold in Japan and West Germany, however. But though DAT is not here for audio purposes, it will soon make the U.S. scene in the form of a digital data storage device called DDS. The technical standards for this application have been drawn up by the collaboration of Hewlett-Packard Ltd. in England and Sony Corp. in Tokyo, while other companies have agreed to the new standard. Using 4-mm audio tape, each cassette can store 1.3 gigabytes of data contrasted to 150 megabytes of standard cassette tape.

DDS and DAT aren't precisely the same, though they share plenty. Both use the helical-scan method, but error-correction methods are more stringent for DDS, not surprisingly. But it's really a DAT when you get right down to it.

RURAL SMARTS. Nineteen rural electric cooperatives in 12 states have begun to introduce new "smart home" technology. Developed by Access Corp. of Nashville, TN, the system's initial function is to automate electric meter readings from consumers' homes. Furthermore, the cooperatives can monitor daily electric usage to improve preparations for peak consumption periods, and remotely disconnect or turn on electric service in residences when people move in or out in place of a representative traveling to and fro. The system is also designed to add security and fire alarms, and pay-per-view TV without special rewiring or retrofitting in the consumers' homes.

NO-CODE HAM RADIO. There's serious talk again about instituting a no-code amateur radio license class. Real serious! In spite of steps that were taken to stimulate ham-radio growth, it seems that beginners applying for their novice license are still on the decline. Moreover, the average age of a ham is increasing.

VIDEO GAME LOCK-OUT. Atari Games Corp. is suing Nintendo for damages due to their making video games and cartridges that essentially eliminate the possibility of competition. Atari charges that this is done through coded master/slave integrated circuitry, and requiring that authors of Nintendo-compatible cartridges have their devices made by Nintendo Co. Ltd. of Japan. According to Atari Games, this has resulted in Nintendo revenues of over $1-billion dollars per year.

COMPUTER BRAND OWNERSHIP. A recent study of brand ownership of desktop personal computers by Venture Development Corp. (Natick, MA) shows Tandy leading the pack with 17.2% of owners, and IBM and Apple neck and neck with 15.6% each. This is followed by Commodore's 9.1% share; Leading Edge with 5.4%; Epson, 3.8%; NEC and Amstrad with 2.2% each; and a fat 28.9% of owners who reported they own other brands names.

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

Pocket Telephone Dialer

The TI-3100 Pocket Dialer™ telephone dialer from Texas Instruments stores up to 125 names and telephone numbers and dials each with the touch of a button. Designed for single-hand use, the new dialer performs five functions, as follows:

In Telephone Directory mode, two-line entries can contain a name, address and several telephone numbers with up to 36 letters and numbers in the upper and up to 35 numerals in the lower lines. Longer than

12-character listings are displayed by left/right scrolling. Entries automatically store in alphabetical order and are retrieved by scrolling up or down, keying in the first letter and scrolling, or typing the first word and scrolling. Any sensitive entry can be protected by a password.

In Dialing mode, the unit is designed for use with Touch Tone phones and lines. It is held against the telephone receiver and the button for dialing the desired number is pressed. Functions include one-button dialing and redialing, pause, slow dialing and local dialing (eliminates area code from directory entries).

In Appointment Schedule mode, you can store information about appointments and meetings by date in chronological order, as well as set the alarm to alert you to the appointment on any date in the future.

In Clock/Alarm mode, a 24-hour clock displays hours, minutes, seconds, day and date. You can set an hourly chime, same-day chime, or both.

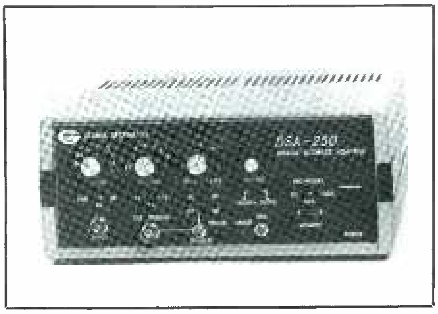
In Calculator mode, you can add, subtract, multiply and divide numbers, calculate percentage and access three-memory functions. Results are given in the 10-digit display.

An automatic power-down feature extends the life of the included replaceable lithium battery. When replacing the battery, the Pocket Dialer saves all memory contents for a few minutes to avoid data loss. The 5.2″ × 2.9″ × 0.6″ unit weighs just 5 ozs. $65.

CIRCLE 38 ON FREE INFORMATION CARD

Digital Scope Adapter

Global Specialties' Model DSA-250 storage adapter inexpensively converts an analog oscilloscope into a digital storage instrument. The adapter gives the user the ability to acquire and display very slow phe-



nomena and to view a stored waveform for extended periods of time. It is also said to be capable of capturing information that cannot be obtained and easily viewed with a conventional scope. A pre-trigger feature permits viewing of events that occur prior to the trigger point.

Technical specifications: eight bits of resolution; 1 megasample/second digitizing rate; selectable 0, 50 and 100 percent pre-triggering; and 1,024-word display capacity. $399.

CIRCLE 39 ON FREE INFORMATION CARD

2,400-BPS Modems

Okidata is offering new Okitel Hayes-compatible external and internal 2,400-bit-per-second (bps) modems. The external Model 2400 Plus and internal Model 2400B Plus feature Microcom Networking Protocol class 5 for error correction and 2:1 data compression to provide a throughput of up to 4,800 bps. Both models provide essentially identical operating characteristics and both

comply with CCITT V.22 BIS requirements as well as Bell 212A and 103J standards for asynchronous data transmission at 1,200 or 300 bps. Each model operates in either full- or simulated half-duplex mode.

Common features include automatic dialing and answering capabilities and memory storage for up to four telephone numbers. Additionally, a call progress detection feature enables the modems to detect line activity generated at the telephone company's central office and feed this information back to the software user for presentation. Transmission speed of incoming calls is automatically determined and compensated for.

The modems work with either Touch Tone or pulse-dial instruments and store the last number dialed for

High-End Audio Line

Heath Co. has a new line of high-end stereo component kits and factory-assembled products, including a CD player, cassette deck, power amplifier, AM/FM stereo tuner, preamplifier and two speaker systems. Except for the speakers, component packaging shares a common appearance (all are black) and size (all measure 17½" wide, though differences in height and depth exist). The power amplifier, preamp and tuner come in both kit and assembled forms, the other items only assembled.

The Model ADW-2530 CD player features a discrete analog output section and three-beam laser optical head. It comes with a 10-function wireless remote controller and 36-track programmable memory (3¾"H × 10"D). $349.

Designed by Harmon Kardon, the Model ACW-2540 cassette deck features the Dolby HX Professional headroom-extension system; 7-segment LED "meter"; 20-Hz to 20-kHz ±3 dB frequency response with any tape formulation; record mute; MPX filter; metal tape capability; and solenoid-operated transport (4¾"H × 10¼"D). $349.

Delivering 100 watts per channel output, the Model AA-2500 kit (AAW-2500 assembled) stereo power amplifier is said to provide more headroom to handle digital recordings. Technical specifications: 10-Hz to 70-kHz power bandwidth at half rated output power into 8 ohms; 0.1-Hz to 170-kHz +0/−3 dB frequency response; 98-dB S/N; and 1-volt/22K-ohm input sensitivity (5¾"H × 14½"D). $449 kit, $499 assembled.

Utilizing a digitally synthesized, quartz-locked tuning system, the Model AJ-2520 AM/FM tuner kit (AJW-2520 assembled) is said to virtually eliminate drifting and mistuning. Features include: 16 FM or AM station presets; muting; 3-segment LED signal-strength meter; and manual up/down tuning (2¾"H × 14¼"D). $229 kit, $249 assembled.

The Model AP-2510 kit (APW-2510 assembled) preamplifier has a rated frequency range of 0.1 Hz to 180 kHz, THD level of 0.006%, S/N of 83/80/92/92 dB MM phono/MC phono/AUX/tape, and output level of 1 volt, 10 volts maximum (4"H × 13¾"D). $349 kit, $399 assembled.

One of the two 8-ohm speaker systems that complete the line is the Model ASW-1230 3-way, floor-standing unit with ported enclosure from JBL that handles 10 to 200 watts of input power and has an input sensitivity of 91 dB SPL. Rated frequency response is 60 Hz to 20 kHz −3 dB, and crossovers are at 800 Hz and 4 kHz. The system features a 12" woofer, 5" midrange driver and 1" tweeter and measures 40"H × 14"W × 10½"D. $349 each. Finally, the Model AS-1082 2-way bookshelf speaker system with ported enclosure, also from JBL, handles 10 to 100 watts of input power and has an input sensitivity of 90 dB SPL. It offers a frequency response of 80 Hz to 20 kHz −3 dB, crosses over at 4 kHz, features an 8" woofer and 1" tweeter, and measures 23"H × 13¼"W × 8"D. $129.95 each.

CIRCLE 94 ON FREE INFORMATION CARD

automatic redialing. A built-in speaker monitors the calling process and alerts the user to wrong numbers, recordings and busy signals.

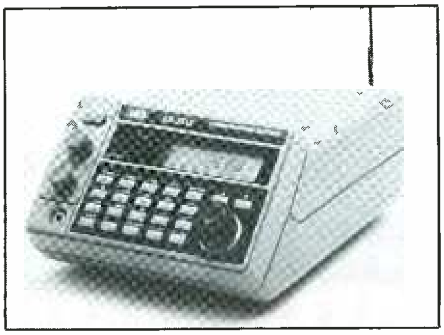
Two standard modular telephone jacks are provided, and low power consumption is attained through use of custom Okidata VLSI circuitry. The Okitel 2400B Plus is a full-card modem for use in IBM PC and compatible and IBM PS/2 Models 25 and 30 computers. Both modems come bundled with Okitel II communications software that is claimed to provide every feature needed for error-free communication. $549 for Okitel 2400 Plus, $499 for Okitel 2400B Plus.

CIRCLE 40 ON FREE INFORMATION CARD

NEW PRODUCTS . . .

Scanning Receiver

A new Model AR2515 scanning monitor radio from Ace Communications (Indianapolis, IN) features a 2,000-channel capacity and high-speed scanning rate. It also has a built-in interface to permit connection to the serial RS-232 port of a computer for programming, unattended control and frequency activity logging. The new radio can be placed on a tabletop or shelf or be mounted under the dashboard of a motor vehicle.



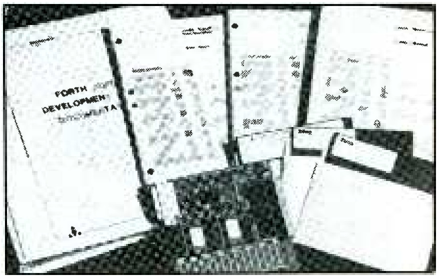
This receiver is capable of scanning 62 banks of 32 frequencies each for a total of 1984 scanned frequencies. An additional 16 memory locations are set aside for beginning and ending search limit frequency pairs. Bank 1 can be designated to allow the user to give up to 32 frequencies a higher priority. The scan rate of 36 channels or search increments per second automatically slows to compensate to tuning lags if adjacent frequencies are more than 30 MHz apart.

Sensitivity of the receiver is rated at better than 0.35 microvolts at 12 dB SINAD in narrow-band FM from 10 MHz to 1.5 GHz. AM sensitivity in the 10-MHz to 1.0-Ghz range is rated at better than 1.2 microvolts for 10 dB S/N. Tuning increments are 5 kHz, 10 kHz, 12.5 kHz and 25 kHz and are user-selectable. The compact radio measures 7⅞"D × 5½"W × 3⅛"H and weighs 2 lbs. 10 ozs. $695. Owners of Ace's Model AR2002 can upgrade to AR2515 operating status for $250.

CIRCLE 42 ON FREE INFORMATION CARD

Computer Development Lab

The Super8 Development Lab from Inner Access (Belmont, CA) is a hardware and software package for IBM PC and compatible computers that allows an engineer to develop



new products that incorporate Zilog's 28-MHz Super8 single-chip microcomputer fast and interactively. The Super8 Development Board, the hardware, comes with a monitor ROM for conventional assembler development and a FORTH ROM for interactive FORTH development. Software provided include a PC-based conventional Super8 Assembler, terminal emulation, disk server, and F83 FORTH for the IBM PC (and compatibles).

The Development Board contains a 20-MHz Super8 single-chip MCU with 600-nanosecond interrupt mode that can handle up to 40 interrupt sources. Included are an RS-232 interface, flexible addressing of four RAM/ROM sockets and eight 20-pin patterns in a Wire Wrap area. On-board FORTH ROMs contain embedded control applications. Supplied with the hardware and software are complete Super8 and FORTH documentation. The only requirements for using the Super8 Development Lab are a regulated 5-volt dc power supply and IBM PC or compatible computer. $295.

CIRCLE 43 ON FREE INFORMATION CARD

Standby Power System

Perma Power's (Chicago, IL) 1,200-VA Model SPS-1200 standby power system is claimed to provide all the features of on-line backup power systems at an SPS price. The unit protects against data loss and damage from blackouts, voltage sags and brownouts, high line voltages, spikes, surges and rfi/emi noise. It alerts the user to loads beyond its 1,200-VA capacity and automatically protects against overload.

Transfer time from power line to internal battery is 0.75 second typical or 1 millisecond maximum. Transfer back to ac line power is automatic, phase-synchronized and instant. Backup power is voltage regulated and current limited. Rated recharge time for a depleted battery is 3.5 hours maximum, and trickle charging keeps the internal calcium battery at full charge during standby.

Upon power-up, the SPS-1200's qualifying circuit determines if the ac line is safe before passing line power to the computer. Voltage suppression protects against transients and spikes on the power line and has a 160-Joule capacity in each mode (480 Joules total), with protection in both normal and common modes. The system automatically resets to line power, and the qualifying circuit prevents damaging high voltage commonly associated with return of utility power from getting to the computer. Convection cooling is used for silent operation.

Eight minutes of backup power is available at 1,200 VA; 40 minutes at 200 VA. A chirping buzzer sounds when the system is operating on backup power, is overloaded and when the surge suppresser is inoperative. The chirping changes to a rapid beep in the last 2 minutes of backup capacity. Included are indicators for

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Desktop Publishing Monitor

Moniterm's (Minnetonka, MN) Viking Portrait is a 19" vertical-format monochrome "publishing resolution" video monitor for desktop publishing. Designed for IBM PC/XT/AT or Personal System/2 Model 30-based workstations, it offers 960 × 1,280-pixel resolution, noninterlaced, and 63-Hz refresh rate for flicker-free viewing. The monitor features 110-MHz pixel frequency, 82-kHz scan rate, paper-white phosphor and square pixels. It includes a controller card with 2 megabits of video RAM and a Hitachi HD3484 Advanced CRT Controller (ACRTC) graphics coprocessor that provides fast hardware-based line drawing and hardware BITBLT for rapidly moving text and bit-map graphics in Windows and other programs.

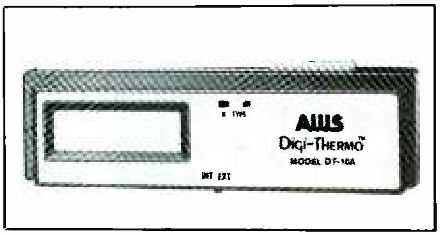
The 14" × 11" monitor allows detailed display of small fonts on the screen on a full tabloid page. It has bundled screen drivers for Windows and GEM, allowing it to put on-screen true WYSIWYG display of documents created by Aldus PC PageMaker, Xerox Ventura Publisher and Bestinfo Superpage II. The controller card also interfaces the monitor with software designed for lower-resolution MDA, CGA and Hercules-format video adapter cards on the IBM PC series and the IBM PS/2 Model 30. $2,595.

CIRCLE 46 ON FREE INFORMATION CARD

Power Line Normal, Power Line Out/Low Voltage, Power Line High Voltage, System Ready, Rapid Charging, System Overload an Surge Suppresser Failure. The unit measures 24"D × 8"H × 6"W and weighs 67 lbs. $1,299.

CIRCLE 44 ON FREE INFORMATION CARD

Digital Temperature Meters



Two new digital temperature meters that provide fast, accurate measurements in small packages have been announced by A.W. Sperry. The Models DT-5A and DT-10A instruments feature simple operation, retractable probes and built-in pocket clips. Both have 3½-decade liquid-crystal displays. The Model DT-5A has a measuring range of from 50 to 150 degrees Celsius, while the Model DT-10A covers the range from 58 to 302 degrees Celsius. K-type thermocouple inputs extend measurement range from 0 to 1,500 degrees Celsius for the Model DT-10A.

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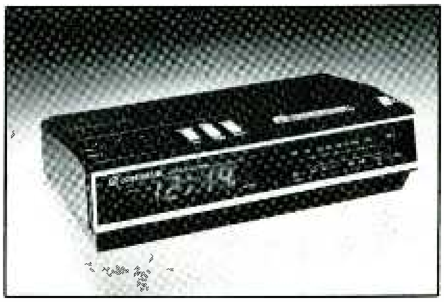
Radio Timer/Controller



You can control household lights and appliances from your bedside with the new Model CR512 clock radio timer/controller from X-10 (USA) Inc. This programmable unit is a timer, controller, alarm clock and AM/FM radio in a single compact unit. It lets you turn on and off up to eight X-10 modules at the touch of a button and even dims lights. You can program up to four X-10 modules to go on and off up to twice a day—every day, a single day only or at slightly different times

(Continued on page 90)

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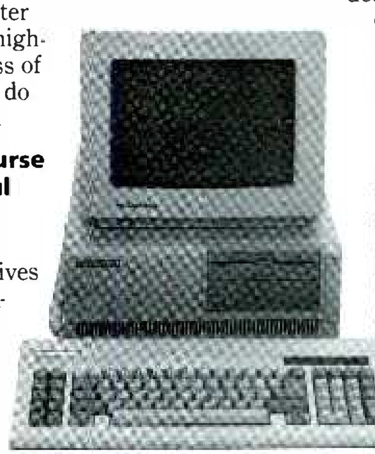

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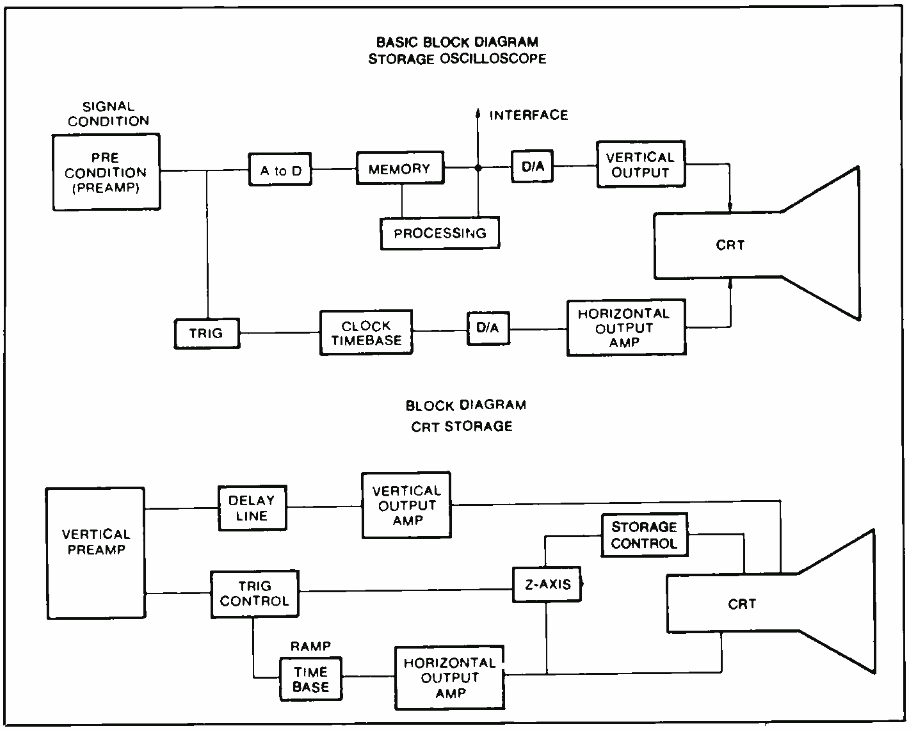
Digital Oscilloscopes

How digital scopes can extend your circuit measuring and testing abilities

By Bill Siuru, Jr., Ph.D., PE

There are two basic types of oscilloscopes: analog and digital. The former has been around since scopes were introduced a very long time ago. But times do change, as evidenced by the quickening acceptance of digital scopes. In comparing them to the still very much dominant analog oscilloscope, each has advantages and disadvantages, which we'll explore. As a result, it is not uncommon to see oscilloscope models that combine both designs in a single enclosure.

Digital storage oscilloscopes (DSOs) digitize incoming analog signals and can easily store them in memory, using solid-state devices or/and magnetic media. Consequently, they enable a user to store a waveform and compare it to a later one. For a service technician, this might mean having the troubleshooting edge of coming to the job with a portable DSO that has reference waveforms of the defective equipment already in its memory. It also makes it possible to view pre-trigger events. On the other hand, analog scopes display real-time events and reveal finer details of a scope trace.



These block diagrams illustrate the differences between a digital storage oscilloscope (upper) and an analog oscilloscope (lower) that has storage capabilities).

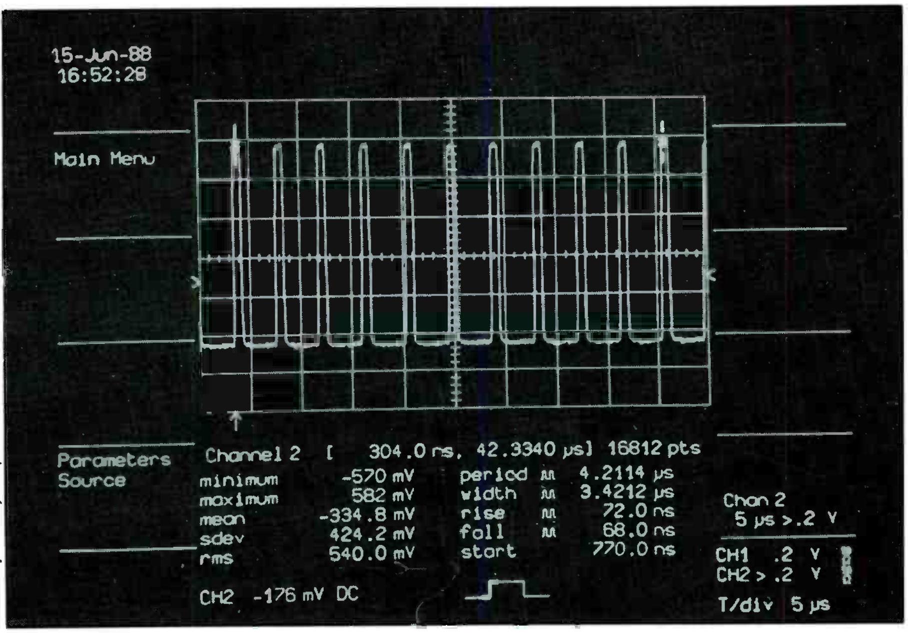
Of course, with all their advantages, DSOs are not the answer to everyone's scope needs. One major drawback of this new breed of test instrument is that it is much more costly than the analog instruments it is intended to replace on the service and design bench. The most expensive item in an analog scope is its cathode-ray tube (CRT). In the DSO, the CRT is relegated to a minor-cost role; instead, the costliest element in the DSO is its analog-to-digital (A/D) converter, sometimes abbreviated ADC.

Since the appearance of the DSO in the marketplace, the cost of A/D converters has come down while performance has increased. Now DSOs can be made inexpensively enough for most service facilities to afford them and even the well-heeled experimenter/hobbyist to eye them as a possible purchase item. The lowest-priced DSOs now cost between $1,000 and $2,000 for a basic instrument, though a laboratory-quality DSO with all the bells and whistles is likely to set you back $20,000 or more.

Your choice of an oscilloscope type is highly dependent on what kind of work you plan to do, of course. With the price of DSOs coming down and their capabilities increasing, you may well give this scope design a very serious look. Let's see how this newest breed of instruments works.

Theory of Operation

Before getting into how digital storage oscilloscopes operate, let's re-



Courtesy LeCroy Corp.

An example of the type of data that can be displayed on a DSO's screen.

Courtesy Tektronix, Inc.

Hand-held DSOs like this Tektronix Model T200 allow you to bring the digital scope to the job rather than restrict it to the workbench.

view the operating principles of the analog scope. An analog scope has one or more vertical channels into which input signals are injected and used to deflect the beam inside a CRT in the vertical direction. To get to the beam-deflecting plates, the input signals must first pass through attenuators, amplifiers and preamplifiers.

On an analog scope, the horizontal scale on the CRT's graticule (or the left-to-right sweep direction in the absence of a graticule) represents time. An important point to keep in mind with respect to horizontal sweep is that triggering determines when the trace should start sweeping across the screen (when the beam should begin moving left to right on the CRT screen).

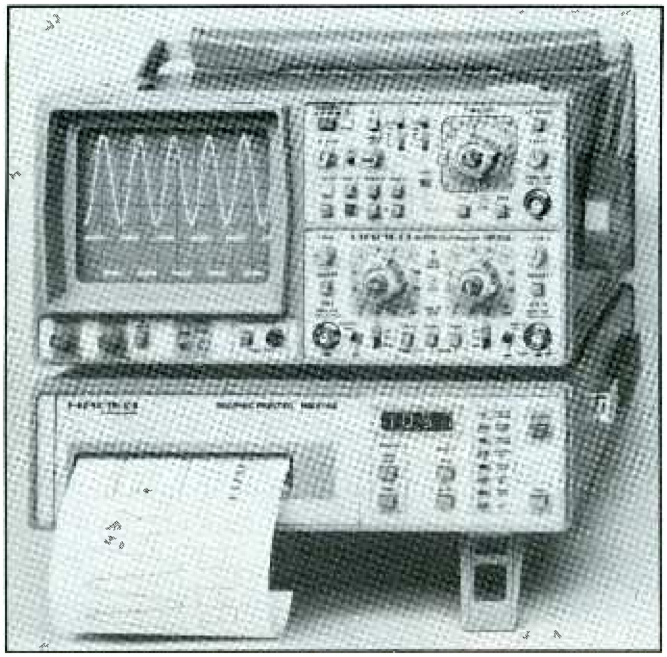
A key requirement of the CRT is that it and the electronics that drive it must be able to deflect the beam in the vertical direction as fast as the signal rises. This means that the bandwidth of the CRT must be the same as or better than the scope's input bandwidth.

As bandwidth increases, so does the cost of the scope. However, with increasingly wider bandwidth, accuracy and reliability of displayed results diminish. While it is possible to retain a trace on the CRT screen for a few seconds, the trace soon fades or blooms—usually at a much faster rate than your inspection allows. Therefore, for any permanent trace retention, the usual storage approach (though not the only one) is to snap a photo of the screen.

The key difference between an analog and a digital scope is that in the latter the input signal does not deflect the CRT's trace. Instead, the DSO discretely samples the input signal in very small increments and then reconstructs this data on the screen to portray the waveform. To accomplish this, the DSO is equipped with two features not found in analog scopes: an A/D converter and a "memory" system.

Though the concept of the digital scope, the class of which every DSO is a member, has been known for quite some time, it has only recently been that A/D converter technology has reached the stage where it is fast enough and accurate enough for oscilloscope applications. Even in light of recent memory-chip shortages, memories are also capable enough now to permit DSOs to be built for general use.

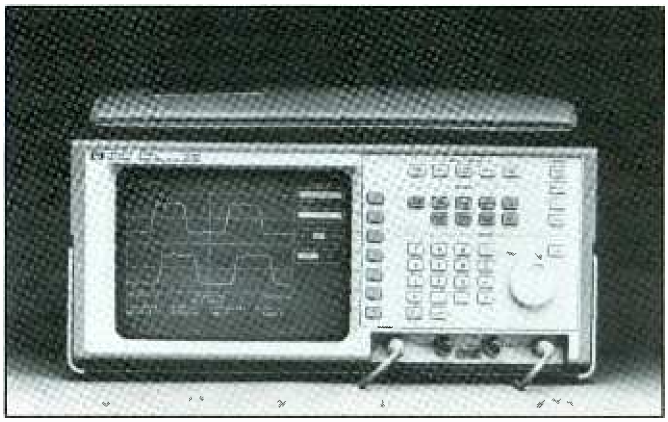
DSOs employ two different methods for sampling input information. One is single-shot or real-time sampling in which the points on the waveform are sampled when they occur and at a very high rate since all samples must be acquired in a single pass. The other method involves repetitive sampling, where points are recorded every time the waveform repeats and the final display is built up from the samples taken of the repetitive waveforms. This method is also referred to as equivalent-time sampling. One requirement of repe-



Courtesy Hameg, Inc.

Hameg's Model HM 205 DSO is shown here with its optional Intelligent Graphic Printer that gives a permanent copy of displayed information.

Hewlett-Packard's Model HP 64501A DSO uses computer-like controls almost exclusively.



Courtesy Hewlett-Packard

titive sampling is that the signal must repeat itself exactly, with no changes in the waveform. Repetitive sampling can be either random or sequential.

For sequential sampling, data is taken at predetermined intervals that are incremented on each pass and depend upon a trigger point to time the sample. While sequential sampling does not permit "negative-time" sampling (viewing data that occurs before the triggering point), it provides very accurate reconstruction of the waveform because it can be matched to a slower A/D converter that has higher resolution.

DSOs use real-time sampling so that they can capture both single-shot and repetitive waveforms. Some DSOs also have equivalent-time sampling capability to extend their useful frequency range.

Digitizing scopes use flash A/D converters (or so-called scan converters) to convert an analog signal into a binary word that can be used by the digital side of the DSO. The flash A/D converter is used when very rapid A/D conversion is required. For example, an 8-bit DSO requires more than 250 converters.

Less complex successive-approximation converters offer high accuracy at medium sampling rates. Scan conversion involves storing the information on a target in the CRT and reading off the data on the other side of the target. While quite expensive, this results in very wide effective bandwidths.

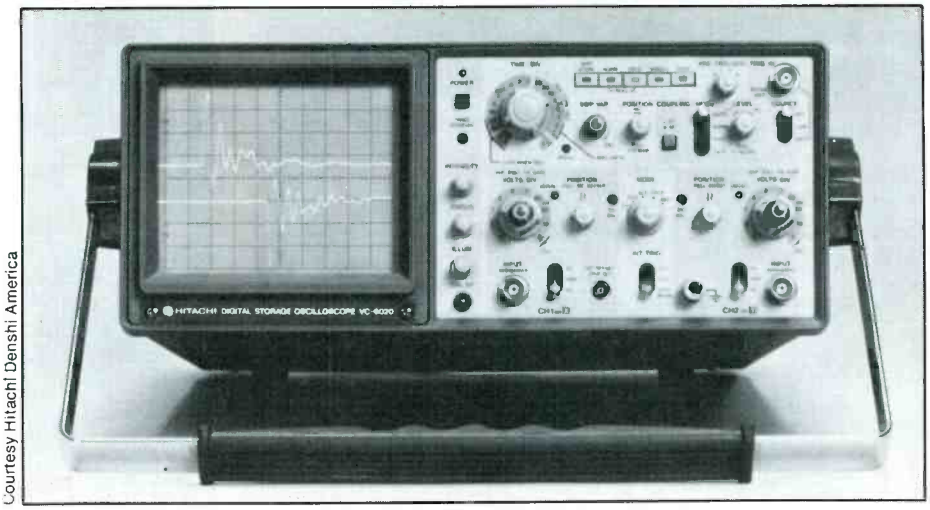
After it is converted into digital form, the signal is stored in a block of memory, where it can be held for further reference and analysis. This storage function is the DSO's chief advantage over the analog scope. To be effective, storage must be as rapid as the data is converted by the A/D converter. Charge-coupled devices (CCDs) are sometimes used on the analog side of the A/D converter to permit the waveform to be rapidly sampled and stored in the CCD and then permit conversion and storage at a more leisurely pace.

Many different types of memory systems are used in DSOs. In general, though, these can be divided into either of two categories: semiconductor, which includes CMOS, NMOS and ECL devices, and magnetic, which includes disk, tape or bubble storage devices.

Though ECL devices are best known for their rapid access, you must pay a penalty for their use in the form of high power consumption. Thus, CMOS and NMOS memory systems are usually preferred for DSO applications. Both NMOS and CMOS have relatively large memory capacities. As usual, though, there is a tradeoff in using these devices, between the higher cost and faster speed than is the case with CMOS.

Semiconductor memory devices can be subdivided into static and dynamic categories. Static memories can retain the data stored in them for days without having to be "refreshed." Dynamic memories, on the other hand, require continuous refreshing. Cost is another factor in the static-versus-dynamic memory game, with dynamic memories being less expensive. But the big advantages of dynamic memory are that they offer greater storage-cell density and consume less power than static memory.

Besides static and dynamic random-access memories (RAMs), read-



Courtesy Hitachi Denshi America

Hitachi's Model VC-6020 DSO uses rotary controls that are familiar and less intimidating to analog scope users.

only memories (ROMs) are sometimes used in DSOs. Being permanently programmed with data that cannot be, changed or erased by the user, ROMs are often used to store data like operating systems, algorithms for performing mathematical analyses and long-term retention of waveforms. Of the other memory devices—magnetic discs, tape and bubble memories—utilized in DSOs, the last is the most sophisticated and costly. Additionally, though magnetic in nature, bubble memories act more like RAMs and ROMs than like disks and tapes.

Finally, every DSO has some type of microprocessor that has overall control over all its functions. Depending on sophistication of the microprocessor, the DSO can perform such tasks as measuring and displaying on-screen time intervals, frequencies, rise and fall times and of providing an output signal to a printer to give you permanent hard copy of all these.

Buying a DSO

Perhaps the most confusing thing facing the prospective buyer of a digital storage oscilloscope is the list of technical specifications each manufacturer publishes for his instruments. These can be very informative to the knowledgeable buyer, but to the less knowledgeable, the sheer volume of published data can be very intimidating. To take some of the confusion out of this aspect of choosing a DSO, we will look at some of the key parameters that must be involved in any scope choice.

Let us start with resolution and accuracy, two parameters that are often confused for each other. These are both very important in any buy decision. In simple terms, resolution concerns the scope's ability to distinguish between the different parts of the displayed image, whereas accuracy describes the scope's precision in representing the image that models the quantities being measured. To "measure" accurately, a scope user must be able to resolve details to a finer degree than is possible with the accuracy level offered.

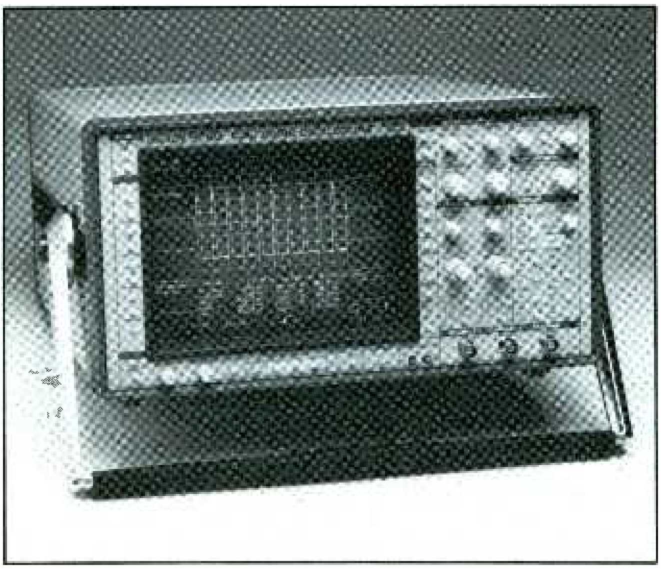
A DSO's resolution is determined by the bit capacity of the A/D converter it uses and is often described in terms of the least-significant bit (LSB). The LSB describes the smallest subdivision the A/D converter is able to resolve. Theoretically, the greater the number of bits, the finer the resolution, as the Table demonstrates.

Unfortunately, simply adding bits to an A/D converter's capacity does not always guarantee finer resolution. For example, if a CCD is used ahead of the A/D converter to permit greater bit capacity, the CCD often adds enough noise to the signal to negate the benefit one might otherwise obtain from the finer resolution. Thus, higher resolution is obtained by designs that not only have more bits in the A/D converter but that also reduce system noise.

A more descriptive specification for resolution is the "effective bits of resolution." This parameter, usually slower than the actual bit count of the A/D converter, takes into ac-

A/D Converter Resolution Capabilities

Number of Bit	Number of Levels Digitizer Can Measure	LSB (For 1V Input)
2	2	1,000.0 mV
2	4	333.3 mV
3	8	142.9 mV
4	16	66.7 mV
5	32	32.3 mV
6	64	15.9 mV
7	128	7.8 mV
8	256	3.9 mV
9	512	2.0 mV
10	1,024	1.0 mV



Courtesy LeCroy Corp.

At the lofty-priced end of the performance spectrum is this new LeCroy Model 9450 DSO that features a 350-MHz bandwidth, 200 MS/s sampling rate and 50K-byte memory system.

Courtesy Nicolet Instruments Corp.

This Nicolet Model 310 DSO includes twin floppy-disk drives and illustrates the portability of typical DSOs.

count internal system noise and is really a form os signal-to-noise ratio (S/N). Noise sources and nonlinearities within the components that make up the scope determine how much lower the effective bits of resolution is compared to the actual bits. By using "signal averaging," some scopes can effectively increase vertical resolution by a couple of "bits."

The accuracy of a DSO, as is the case with its analog counterpart, is presented for both the vertical and horizontal (timing) directions. There are four major contributors to accuracy in the vertical direction: amplifier gain, A/D converter resolution, linearity and gain.

Amplifier gain accuracy for a DSO, usually expressed as percent of full-scale, is determined by the dc error in the amplifier, just as it is for the analog scope. Some manufacturers publish only this value, calling it simply "accuracy," because it is easily determined and understandable, especially by those people who are already familiar with analog scope specifications.

Besides determining the number of discrete levels available to represent the input signal, a resolution error results from a quantizing error, since the signal can lie anywhere between the available levels. This error is, at most, one-half the LSB.

A/D converters do not have exactly equal analog increments for each level. Thus, linearity is the incremental percent difference of LSB steps. While noise is usually expressed in terms of an rms value, it can typically reach peak values of four to five times this value.

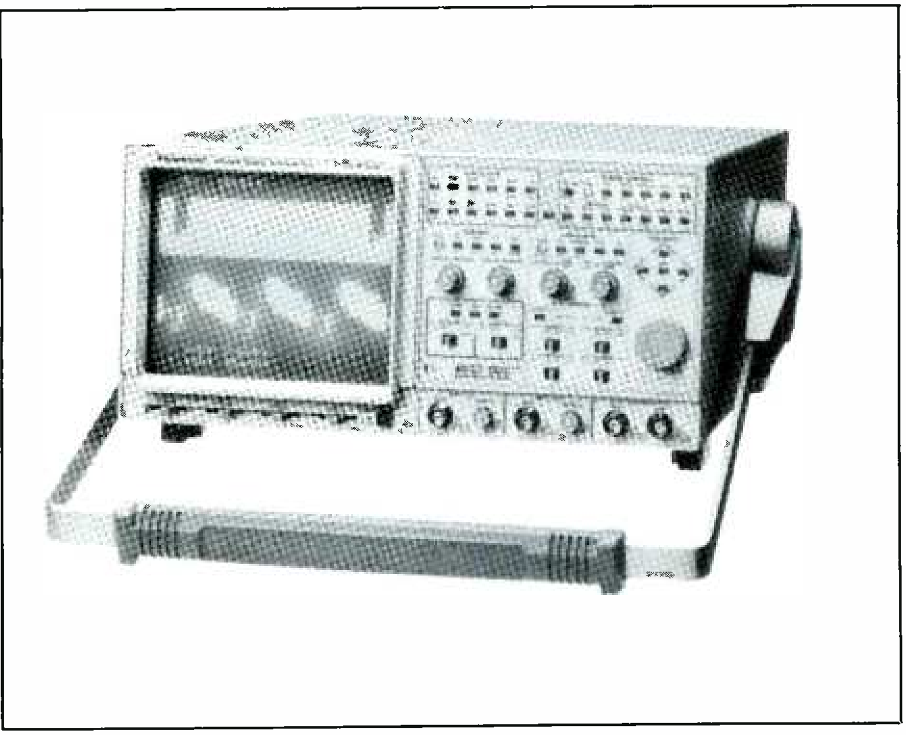
As an example of how to interpret vertical voltage accuracies presented on manufacturer specifications sheets, let us consider the following example:

Full scale (FS)	10 volts
Accuracy	0.25% FS
Resolution	0.025% FS
Linearity	0.1%
Noise	0.02 FS (rms), Peak = 4 × rms

For a 2-volt dc signal, the error would be: $V_{error} = 0.0025 \times 10\,V + 0.00025 \times 10\,V + 0.001 \times 2\,V + 0.0002 \times 4 \times 10\,V = 37.5\,mV$. This equates to a percentage error of: $Error = 0.0375\,V \times 10\,V = 1.875\%$. Similar calculations would reveal that for a 5-volt signal the percentage error would be about 1%.

Sampling rate, sometimes called the digitizing rate, can be expressed in a variety of ways. It can be given in terms of sampling frequency, such as the MHz sample rate. Probably the most common description is the "maximum" number of samples per second, such as million samples/second (MS/s). If the rate is presented as an information rate or number of bits stored per second, the sample rate can be determine by dividing this number by the number of bits used in the A/D converter. Capability, complexity and price usually increase with sampling rate.

One final specification sometimes used is the sample interval, or nano-


Courtesy Panasonic Factory Automation Co.

One of the many currently available mid-range, mid-priced scopes is represented by this Panasonic Model VP 5720A DSO.

seconds per point figure. This is simply the reciprocal of the frequency specification.

Two important parameters that describe a DSO are its length of record and memory. Record length tells you how many data points can be acquired and stored from the input signal. Depending on the sophistication of the DSO's design, this can range from 256 to more than 4,000 points per waveform. Memory length refers to the amount of total storage capacity the DSO has to store waveform data and, in some cases, operating systems and algorithms for performing mathematical analyses.

Long record lengths make it easy to trigger and capture single events and give fine signal detail, as well as make for very fast sampling rates. Large memories mean that much more data can be stored, as from complex and long time inputs.

One advantage DSOs have over analog scopes is their ability to manipulate stored waveforms, such as expanding and repositioning them on the screen. Once the waveform is stored in an analog scope, it cannot be changed. With the DSO, the number of waveforms you can recall, store and vary depends on the capacity of the scope's memory system.

Ease of use is an important consideration in scope selection. Many users, especially those who are familiar with analog scopes, like knobs to turn rather than buttons to push. With pushbutton operation, you have to think about the number to punch in, whereas a rotary control can be continuously adjusted until you get what you want.

User-friendly devices are great to help you along when you are first learning how to use a new piece of electronic equipment. However, once you become familiar with the device's operating controls, wading through numerous menus that are displayed to guide you can become very frustrating and time consuming. On the other hand, some front panels may intimidate a novice user even though they offer a wealth of programming capability for the seasoned researcher.

Being able to display two different waveforms on-screen simultaneously is often desired or required. With an analog scope, the most desirable means of doing this is to have a dual-beam scope that can display more than one channel. Since these are expensive instruments, many scope users have had to settle for "chop" or "alternate" mode devices to obtain multi-channel capability.

Multi-channel capability is quite a simple function to implement in a DSO. Multi-channel DSOs use duplicate A/D converters that permit data to be sampled and stored simultaneously. There is no problem with losing important information due to "holes" in the "chop" method or uncertainties in time relationship between waveforms when using the "alternate" mode.

In the final analysis, analog scopes still maintain an edge in the ability to display fine detail in a waveform. The persistence-type approach used for short-term storage probably more accurately displays such rapidly occurring events as one-time spikes. However, DSOs with peak detection capability can effectively capture glitches and spikes.

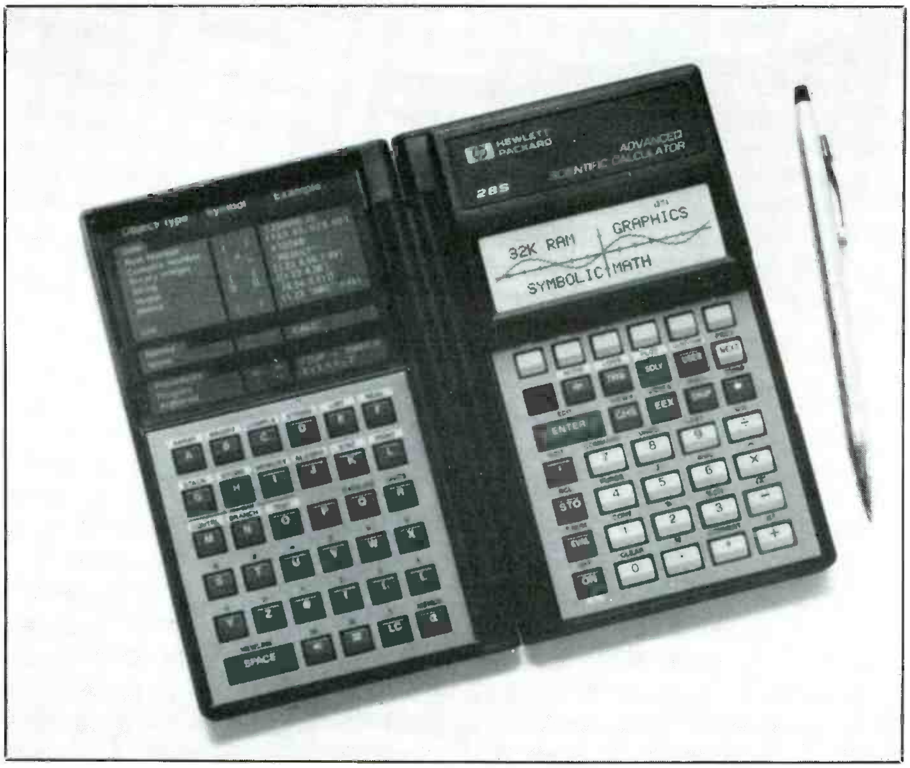
The bottom line is that with the new dimensions in analysis capability made available with the digital storage oscilloscope, these instruments are definitely the wave of the future in electronic work.

Our Digital Storage Oscilloscope Buyer's Guide, which lists prices and important technical specifications for a representative variety of instruments and models made by major manufacturers in the field, begins on page 64.

Calculator Music

How to create music programs and "sound graphs" on a Hewlett-Packard HP-28S scientific calculator

By David A. Nordquest



Hewlett-Packard's advanced scientific calculator is a fascinating state-of-the-art electronic device. Graphing, symbolic math and highly flexible programming features make it an experimenter's delight. Not so obvious, but very enjoyable, is its talent for music-making and sound graphs. Through use of its BEEP command, it can produce tones of up to 4,400 Hz and durations of up to 1,048.575 seconds.

On the 28S, BEEP uses two numbers to generate tones, a frequency value in stack level two and a value for duration in level one. By placing BEEP inside a loop set to repeat for as many times as there are notes in a musical composition, one can make the 28S play fairly complicated tunes. Each time the loop executes, it removes two numbers from the stack. Since the stack uses a last-on, first-off system, it is necessary to enter note information backwards—from the end of a song to its beginning.

Rather than entering these numbers one at a time, it is best to use program delimiters and to enter the values all together in a group, separated from each other by spaces or commas. The program made up of the numbers and the BEEP loop should be stored in a variable—"BACH," for example—and can then be played either by evaluating the variable or by fetching it from the User's Menu.

Unfortunately, it is a bit tedious to program in a number of multi-digit frequencies, such as 261.63, and fractional durations, such as .15. What is needed is some way of selecting, first, the number of steps up or down for some standard note, such as middle C, and, second, the multiplier for a standard duration, such as that of a sixteenth note. Because of the speed of 28S calculations, manipulations necessary to convert such numbers to the proper frequency and duration values can be built right into the BEEP loop. They barely slow the calculator down, allowing tunes to still be played so fast you can hardly hear the individual notes.

The technique I use to simplify music programming is straightforward, but effective nevertheless, and may be of interest to experimenters

using a variety of computers and calculators. It seems there is a number—1.0594631, or the twelfth root of 2—that when raised to a power of x and used to multiply the frequency of a musical note y gives a result that is precisely x half-tones up or down the scale from y.

Assume, then, that we wish to program the E above middle C. Since E is four half-tones up from C, we would need to multiply the frequency of C—261.63 Hz—by 1.0594631 raised to the fourth power. Instead of entering the desired frequency of 329.63 into the program, we would enter simply 4, leaving it to the BEEP loop to convert the exponent 4 to the proper frequency value. By properly selecting the standard frequency from which steps up or down are calculated, it is possible to specify most tones in a tune with a single-digit number. For steps down, it is, of course, necessary to use a negative number.

Duration information can similarly be abbreviated. The 28S seeks a number indicating time in seconds. Because that duration is too long for most musical notes, decimal values are usually required, adding numerous keystrokes. A better method is to enter whole numbers, representing multiples of a sixteenth note's duration, and then to divide these numbers by the necessary value in the BEEP clause. This makes it easy to adjust the speed of the tune from a crawl to a rush. The 28S' maximum speed is unbelievably fast!

One complication with this method is that both frequency and duration values have to be massaged within the BEEP loop. Fortunately, the 28S' SWAP command allows us to switch the contents of the first two stack levels back and forth, making it possible to perform such operations as raising the twelfth root of 2 to the required power from within the loop.

Repeats can be handled by loops within the main program. When first and second endings vary, the repeated material can be stored in another variable—"Z," in the example that follows—and can then be played whenever needed by placing the variable in the program at the proper place. Any additional or varied notes can be programmed in between.

To illustrate 28S music programming, I thought the "Star-Spangled Banner" would provide an appealing example. The complete note and duration information is included in the program listed below. If entered as printed and then stored in the variable "SSB," The National Anthem can easily be selected or programmed into other programs. The 28S could, for example, be programmed to WAIT for a given number of seconds (extending to hours or days) and then made to play the "Star-Spangled Banner" as an alert. The calculator could serve as a very patriotic alarm clock, too (for light sleepers, at least). A snooze delay could be inserted between reiterations of the song.

To program the "Star-Spangled Banner," first enter the following numbers and delimiters, which indicate tone and duration values for repeated material:

< <4 −2 4 2 4 5 4 10 4 10 2 9 2 7 8 9
4 10 2 12 6 14 2 5 2 5 8 5 4 4 4 2 4 10 1
12 3 14 8 10 4 5 4 2 4 −1 > >

Store this in "Z." Now enter the

main program, including the BEEP loop:

```
< <8 10 4 12 2 15 6 14 2 12 2
10 8 17 2 15 2 14 2 12 6 10 2 5 2 5
8 9 4 10 2 10 2 12 2 14 2 15 4 12 4
7 4 7 4 7 2 9 2 10 4 10 4 10 4 5 8 5
4 4 4 2 4 10 2 9 2 7 8 9 4 10 2 12 6
14 4 15 8 15 4 15 4 14 4 12 2 14 2
15 8 17 4 17 4 15 4 14 1 14 3 14 Z 1
2 3 5 Z 1 2 3 5 1 101 START
1.0594631 SWAP / 261.63 *
SWAP 8 / BEEP NEXT > >
```

As a memory aid, the program should be stored in "SSB." Once stored, "SSB" will automatically appear in the User's Menu, allowing the program to be run simply by selecting the proper soft-key.

The 28S' musical talents can also provide interesting illustrations of the behavior of mathematical function through what might be called sound-graphing. The SIN function, so important to electronics, provides an excellent example. The rising and falling of the SIN value can easily be heard in the following program, which should be run with the 28S in the "degrees" mode:

```
< <1 3600 FOR Y Y SIN 1 + 1000
* .1 BEEP 5 STEP > >
```

Exotic-sounding modern music can be obtained by running the program unaltered in the "radians" mode.

In programming sound-graphs, it is necessary to make sure that the frequency values obtained from the math function are sufficiently spread out over the 28S' range, that all fall below 4400 Hz, and that each is positive. By properly manipulating the values, these conditions can generally be met. In the case of the SIN program just listed, adding 1 to the SIN value moves the whole plot into the positive range. Multiplying by 1000 and selecting every fifth degree for sampling effectively spread out the sound graph. Visual graphing can be used to pre-test sound plotting.

While the 28S rarely loses a beat, it does pause ever so slightly when moving from one BEEP iteration to the next. Using conventional programming techniques, that would appear to rule out crude speech or singing. However, a clever machine-language programmer might be able to speed up calculations sufficiently. How articulate the 28S' buzzer would prove to be is another problem.

The musical capabilities of the 28S show another side of its character. On the surface, it may appear all left-brain—the complete hard-headed, no-nonsense analyst. However, it turns out to have a creative right-brain side, as well, because there is, one might say, a song in its heart. **ME**

UV Exposure Light

A professional-quality ultraviolet source for making photosensitized printed-circuit artwork and boards

By Ladislav Hala & Peter Hala

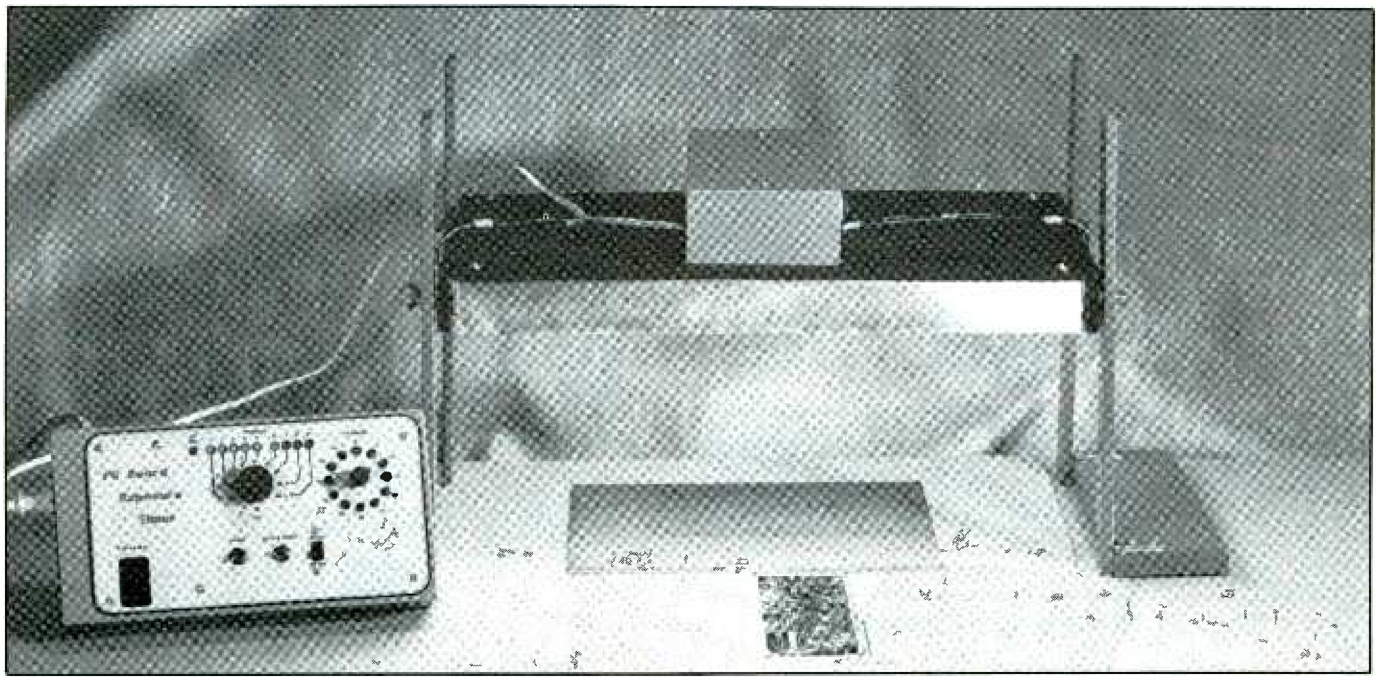
You can use any one of a number of different techniques to prepare printed-circuit blanks for your projects. Freehand drawing of the conductor pattern with a resist pen is workable for very simple circuits. For more complex one-of-a-kind circuits, careful work with the special rub-on patterns made for this process can be successful. For boards on which appear multiple IC patterns and especially for more complex boards on which are to be mounted surface-mount devices (SMDs), the so-called photographic process is the only practical way to go.

Advanced hobbyists and experimenters usually master the photographic process early on, using readily available chemicals and materials. Professional-quality ultraviolet light sources used to activate them are usually quite large and very expensive. In this article, we will detail how to build a suitable UV light source that can be used for preparing pc artwork and blanks measuring as large as 8 by 16 inches at moderate cost. This adjustable UV Exposure Light can be operated manually or, when used with the Programmable Appliance Timer described last month, fully automatically.

Technical Considerations

Anyone who has used the photographic technique to make pc boards is well aware of the instructions that warn against exposing the materials to ordinary light. Though this is a precaution that should certainly be heeded, one might be misled into thinking that using ordinary light from, say, a table lamp would be suitable for making a workable exposure. This might be possible, but it certainly is not practical, considering that it would take hours to make such an exposure and many multiples of hours of making test exposures to determine how long an exposure to use in the first place.

Using a sunlamp, as some instruction sheets recommend, speeds the exposure process up to the 10-to-20-minute range. With this source, you must still first determine correct exposure time by a time-consuming trial-and-error method. Unfortu-



nately, if exposure time is lengthy, the heat generated by the sunlamp can damage the photosensitive coating or material before the determined exposure time is up. Additionally, because of the high level of UV radiation, you must cover all exposed flesh and wear goggles to protect you from "sunburn."

Although a sunlamp is frequently recommended by manufacturers and suppliers of photosensitive chemicals and materials, these lamps can be very awkward to use. Other possible UV emitters, such as a carbon arc or 1,000-watt photoflood light, are impractical because of the excessive current they draw and heat they generate or the extended period of time required to produce a successful exposure.

For purposes of pc photo-fabrication, the band of wavelengths of interest lies between 320 and 400 nanometers (nm), which is commonly referred to as the near-ultraviolet spectrum and is popularly known as "black light." UV sources that radiate in this range include F15T8BL and F15T8BLB fluorescent tubes. Both provide satisfactory UV energy to properly expose photosensitive pc materials in a relatively short time with no detrimental physical effects to the materials themselves from heat and other undesirable side effects.

Both tubes measure 18 inches long and are 1 inch in diameter. These are the same dimensions of the FL-15D "daylight" (white-light) fluorescent tubes used in home utility lighting fixtures. Hence, the hardware from such fixtures can be used directly in building this project.

Though the F15T8BL and F15-T8BLB tubes both produce about the same results in pc photofabrication, the F15T8BL is the better choice because it is more readily available from specialized lighting retailers and department stores and can usually be ordered through hardware and home-center outlets. Depending on availability and whether or not the retailer must order it from a wholesaler, the F15T8BL tube will cost between $10 and $20 each.

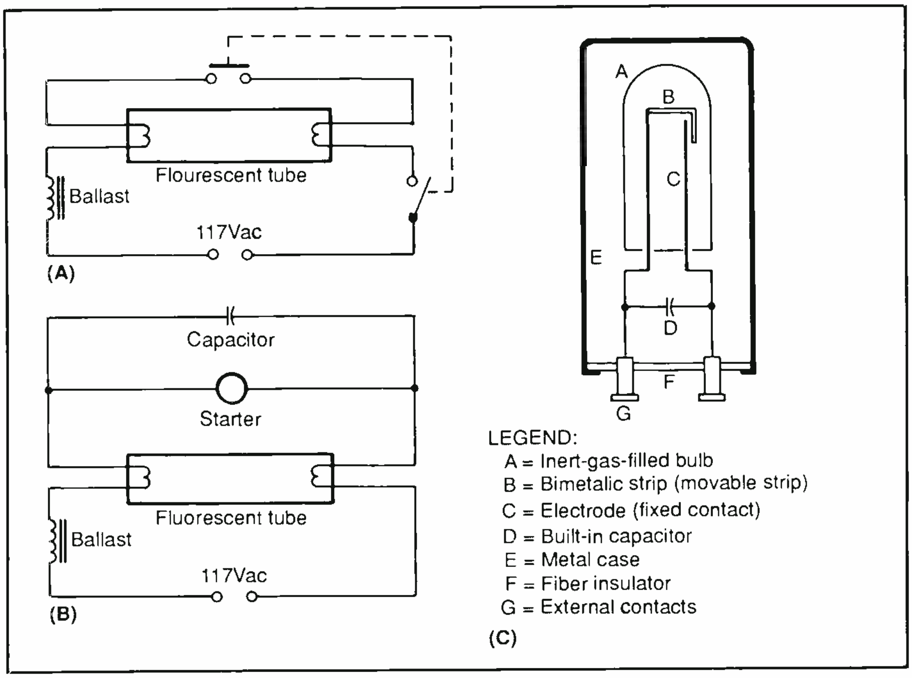


Fig. 1. Manual-start (A) and automatic-start (B) circuits for preheat-cathode fluorescent tubes and internal details (C) of glow-switch starter.

If you do not plan on fabricating very large pc boards, you might be tempted to build a smaller version of this project, using a shorter UV tube. This is one instance where smaller can be a disadvantage, however. Shorter tubes emit less-intense UV radiation, which will add to exposure times. Furthermore, the shorter UV tubes actually cost *more* than the F15T8BL does.

Theory of Operation

Being a preheat-cathode type of tube, the F15T8BL's electrodes must be preheated before high voltage is applied. Tubes designed for such operation have two connector pins at each end that are used to apply the heating current to the electrodes inside the tube. Preheating takes a few seconds and can be accomplished manually with the circuit arrangement shown in Fig. 1(A). Alternatively, preheating can be done automatically with the circuit arrangement shown in Fig. 1(B).

The manual switch in Fig. 1(A) is a pushbutton arrangement made up of one pair of line contacts and one pair of momentary-action contacts. The line contacts place the tube's electrodes in series across the output of a ballast when the button is pressed and held in that position for 2 to 3 seconds. During this period of time, the momentary-action contacts allow current to flow through and heat both elements. When the button is released, the line switch remains closed, but the contacts of the momentary-action switch spring open, disabling the current flow through the filaments.

Due to opening of the momentary-action switch while it is under load, a transient potential is developed in the circuit. This inductive "kick" aids in igniting (turning on) the tube.

The disadvantages of the manual starting switch arrangement are that you can start only one tube at a time and that starting may require you to make several attempts if the button is

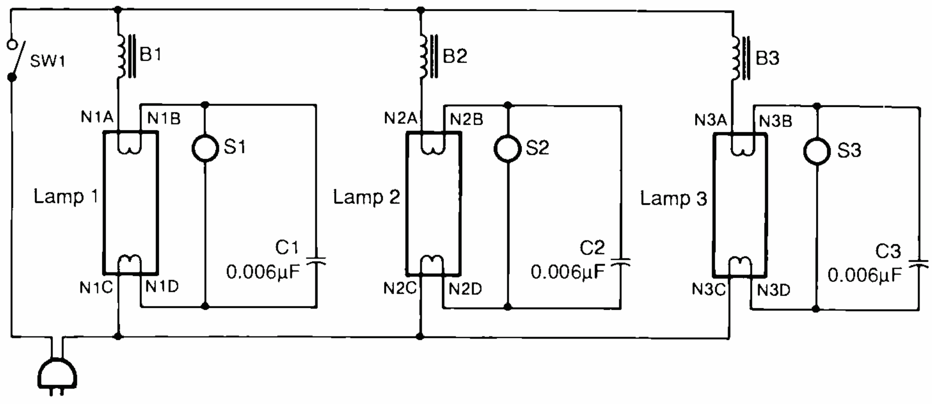


Fig. 2. Complete schematic diagram of project's circuitry.

PARTS LIST

B1,B2,B3—Type KS600A 15-watt ballast (see text)
C1,C2,C3—0.006-µF Mylar capacitor (part of S1, S2 and S3—see text)
N1,N2,N3—F15T8BL UV fluorescent tube (see text)
S1,S2,S3—FS-15 15-watt glow-switch starter
SW1—Spst slide or toggle switch
Misc.—Printed-circuit board or perforated board and suitable soldering hardware; ac line cord with plug; medium bi-pin fluorescent-tube sockets (6 each—see text); 18-gauge or heavier hookup wire; solder; etc.

not held pressed long enough. On the other hand, if the button is held pressed for too long a time, the lamp's filaments may overheat. The result is shortened tube life due to excessive loss of electron-emitting material from the filaments.

Several types of automatic starters for preheat-type fluorescent tubes have been developed over the years. The first was a magnetic vibrator type that repeatedly opened and closed a set of contacts. Each closing allowed the cathode to heat more and more until electron flow was sufficient to start the ignition arc. This starter made possible quick ignition, but it consumed up to 2 watts of power continuously thereafter while the fluorescent tube was in operation. Also, the tiny moving parts inside the starter were a constant cause of maintenance problems.

A later development was the thermal starter, which used a bimetallic contact strip to pass current through the tube's filaments. When sufficient heat built up, the contacts sprang open and the tube ignited. Normal operating current for the lamp through the heater coil held the bimetallic-strip switch open, which resulted in an unnecessary constant load of 1 to 2 watts.

The glow-switch starter, whose internal details are illustrated in Fig. 1(C), was a still later development. This starter consists of a small glass bulb that is filled with some inert gas like argon, helium or neon, the particular gas being used depending on the voltage characteristic desired.

On starting, when the line switch is closed in a glow-switch starter circuit, practically no voltage drop is developed across the ballast, and the voltage at the starter is sufficient to produce a glow discharge between the contact of the bimetallic strip and fixed electrode. The heat from the glow discharge distorts the bimetallic strip to allow heating to begin as the movable contact touches the fixed contact. In turn, this short-circuits the glow discharge, the bimetallic strip cools and, in a short time, the contacts open to apply open-circuit voltage in series with an inductive spike voltage. If the tube fails to ignite, the open-circuit voltage again develops a glow discharge in the bulb and the entire sequence of events repeats.

Under normal operation, not enough of a voltage drop appears across the tube to permit further glow discharges of the starter's gas-filled bulb. Hence, its contacts remain open. A small capacitor, whose value is on the order of 0.006 microfarad, is usually placed across the starter to reduce radio-frequency interference (rfi) and to set up oscillations that in effect make the inductive kick from the ballast last longer.

Advantages of the glow-switch starter include no continuous power consumption once the fluorescent tube ignites, automatic restarting until the tube does ignite, simple mechanical construction and low cost. These all add up to make the glow-switch starter the most popularly used starter for preheat tubes.

Another essential part of the fluorescent tube's starting circuit is the ballast, which is simply a coil of wire wound around a laminated iron core. Placed in series with the tube, the ballast limits current flow to the level for which the tube is designed.

The foregoing explains operation of the project's circuitry, which is shown schematically in Fig. 2. In this circuit, starters *S1*, *S2* and *S3* are standard FS-20 (20-watt) glow types, and 0.006-microfarad Mylar capacitors *C1*, *C2* and *C3* are built into the starters themselves. Ballasts *B1*, *B2* and *B3* are simple transformer-type KS600A units.

Construction

For this project, the ballasts were salvaged from existing fluorescent-light fixtures, as were the bi-pin sockets for the UV tubes. Unless you can find a source that supplies these as

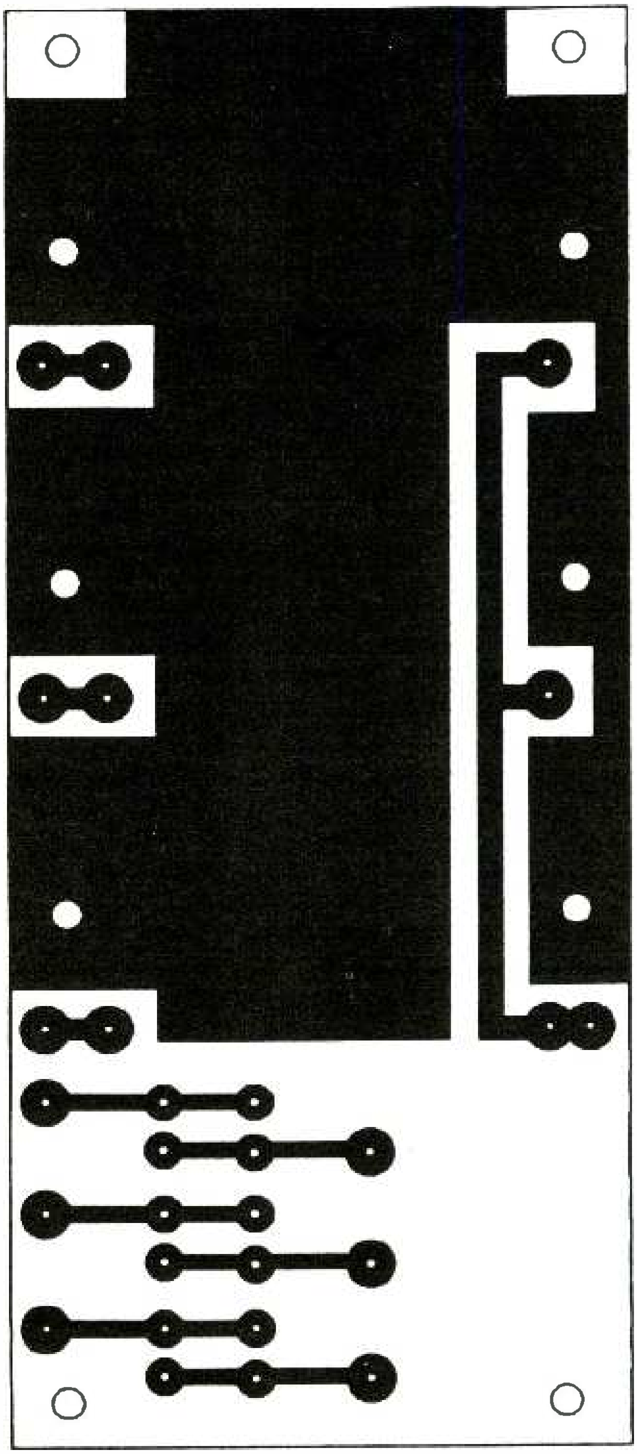
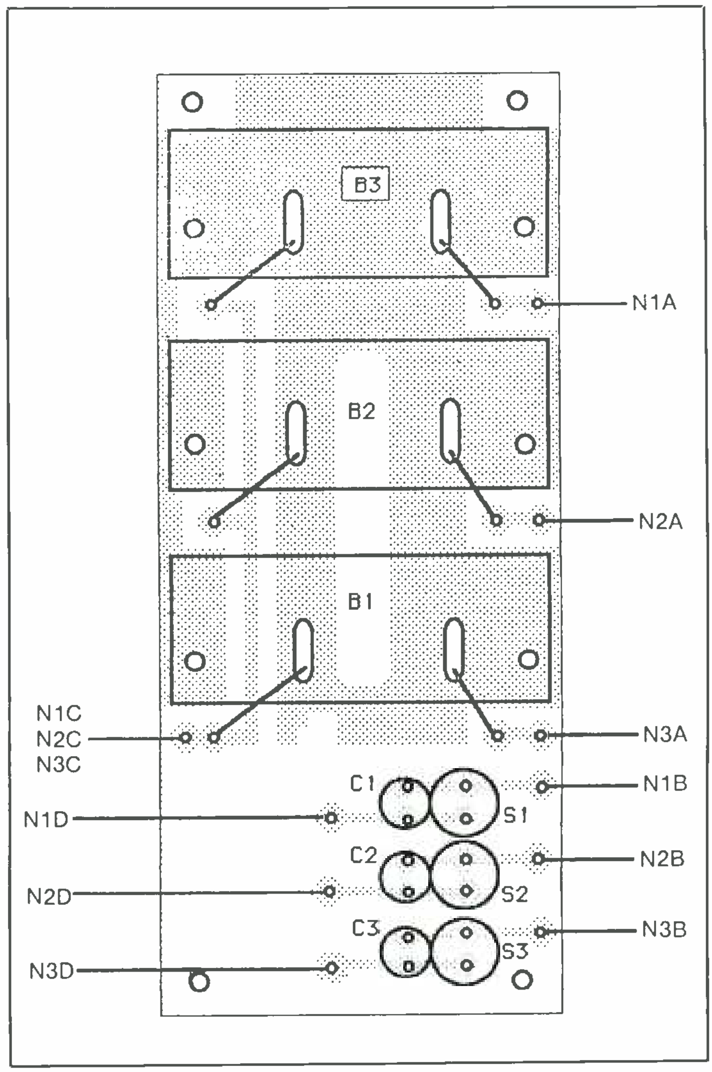


Fig. 3. Actual-size etching-and-drilling guide for control circuit's printed- circuit board.

Fig. 4. Wiring guide for pc board.



separate components, you may have to go the route we followed, which should not be too expensive if you shop the discount stores.

You can wire the project's circuitry on a printed-circuit board you fabricate yourself using the actual-size etching-and-drilling guide shown in Fig. 3. Alternatively, you can wire the project on perforated board, using suitable soldering hardware.

From here on, we will assume you are using the pc board, and the following details will apply to this method of construction. If you wire the circuit on perforated board, follow the same general layout given in the wiring diagram in Fig. 4.

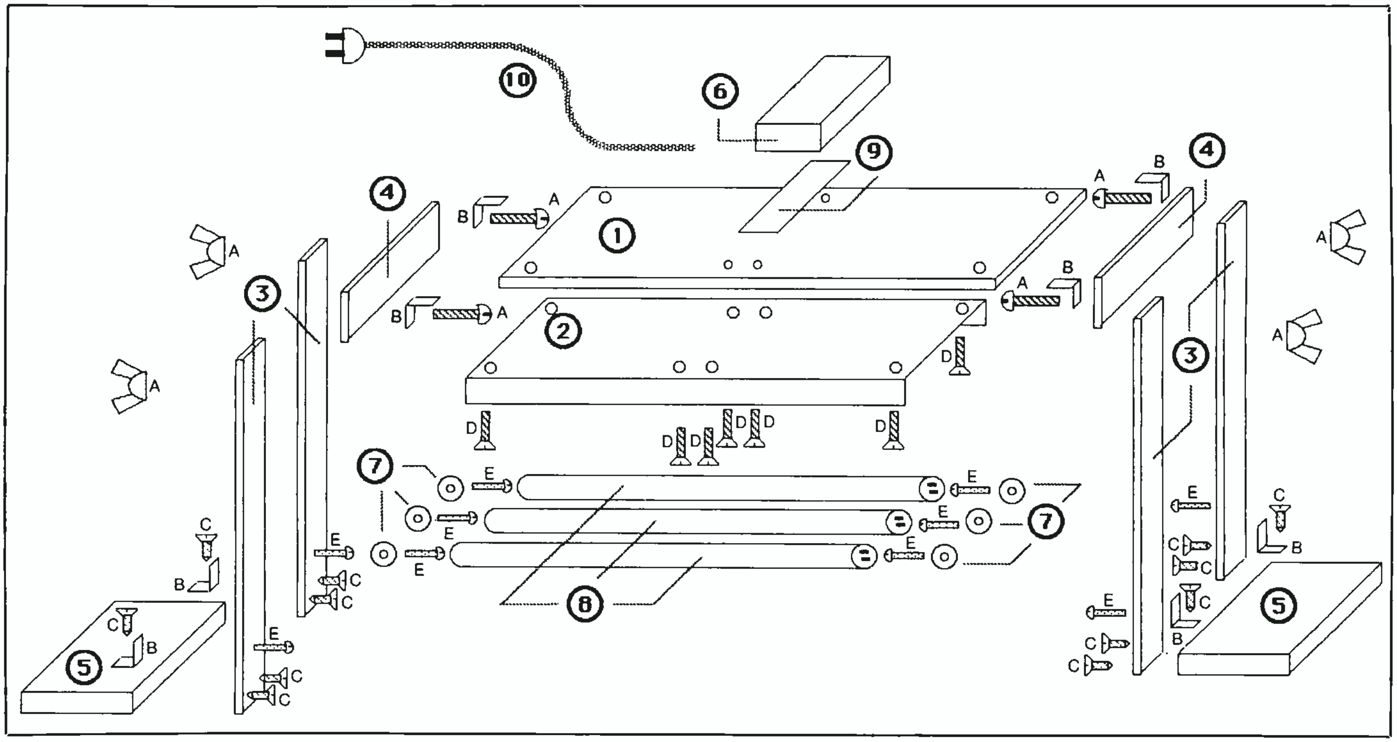


Fig. 5. Assembly drawing of UV Exposure Light stand made from aluminum flashing and lumber.

BILL OF MATERIALS

1—Top panel: 18¾" × 9¾" × ¼" plywood or Masonite
2—Reflector: 16½" × 12¼" aluminum flashing
3—Vertical stand bars: 13¾" × 1¼" × ¼" pine (4 required)
4—Light attachment bars: 9¾" × 1¾" × ¼" pine (2 required)
5—Base pieces: 9¾" × 3½" × ¾" pine (2 required)
6—Control board housing: Top panel—8¼" × 4⅜" × ¼" plywood or Masonite; Side panels—8¼" × 2¼" × ¼" plywood or Masonite (2 required); End panels—4¼" × 2¼" × ¼" plywood or Masonite (2 required)
7—SK-20 fluorescent-tube sockets (6 required—see text & Parts List)
8—F15T8BL ultraviolet fluorescent tubes (3 required—see text)
9—Control circuit-board assembly (see text)
10—Ac line cord with plug
A—⅜" × 1" bolt and matching wing nuts (4 sets required)
B—Small L bracket (8 required)
C—⅛" × 1½" flat-head wood screw (12 required)
D—6-32 × ½" round-head machine screw and nut (4 sets required)
E—6-32 × ½" flat-head machine screw and nut (8 sets required)
Misc.—Wood glue; etc.

When the board is ready, drill a final ⅛-inch-diameter hole, centering it in the blank area at the lower-left of the board and mount here a No. 6 solder lug with 4-40 machine hardware. Begin populating the board by mounting ballasts *B1*, *B2* and *B3* to the board with suitable hardware. Trim their leads as necessary and strip ¼ inch of insulation from them. Tightly twist together the fine wires in each lead and sparingly tin with solder. Then plug these wires into the appropriate holes and solder them into place.

Carefully open the cases and remove the starters and capacitors. Trim or desolder the starter and capacitor leads from the socket pins and separate the two from each other. Install and solder the capacitors in the indicated locations on the board. Then do the same for the starters.

Cut to 36-inch lengths eleven 18-gauge or heavier stranded hookup wires, if possible, using five different colors of insulation to keep of what you are doing. Use one color of insulation for all N1 wires, another for all N2 wires, a third for all N3 wires, a fourth for the N1,N2,N3 wire and a final wire that will be crimped but not soldered to the solder lug. Strip ⅜ inch of insulation from one end of all wires. Then tightly twist together the fine conductors and sparingly tin with solder.

Install a solder post in the N1,N2,N3 hole and solder into place. Plug one end of these wires (except for the one that goes into the N1,N2,N3 hole) into the indicated holes and solder these into place. Crimp one end of the remaining wire to the solder post and solder the connection, The other ends of these wires will be connected later.

For now, temporarily set aside the circuit-board assembly.

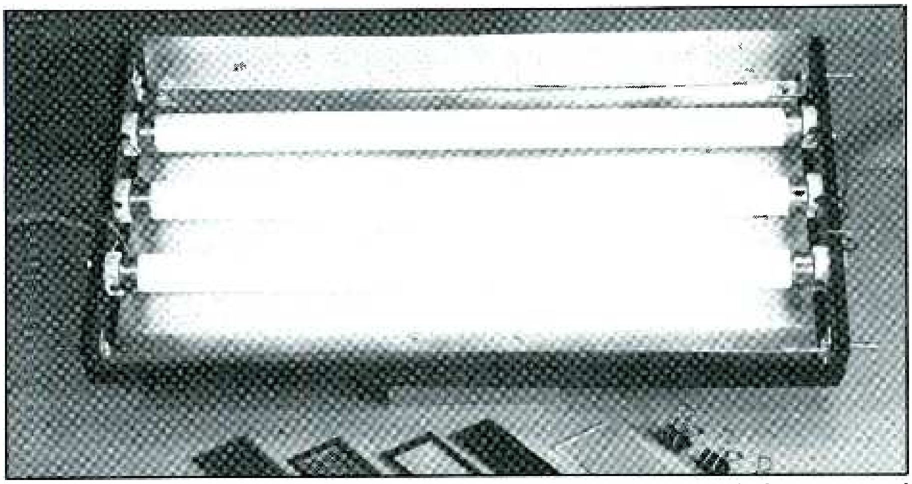
In deciding upon the design of the UV Exposure Lamp, we had to choose between two basic options—an exposure box or stand arrangement. To keep things as simple as possible and not tax the shop skills of the builder, we opted for the stand arrangement, which is simpler to execute and much more flexible to use because it allows you to make adjustments to suit different needs that are not possible with a box-type arrangement.

Materials for the stand are simple to locate because all you need are aluminum flashing, which can be obtained from just about any hardware store, and some lumber. These and their dimensions are detailed in the Bill of Materials that accompanies the drawing shown in Fig. 5.

Cut all lumber to the dimensions given in the Bill of Materials. For the top of the stand, identified at part No. 1, use either ¼-inch plywood or Masonite. The remaining lumber pieces should be pine, except for the small box on the top that houses the control circuit-board assembly and can be the same material as the part 1 top panel.

Once you have cut the lumber to the proper dimensions, strike a line down the center of each No. 3 vertical stand bar and drill $^{5}/_{16}$-inch-diameter holes ¾ inch apart and starting ½ inch from one end down the center of all four. If you have access to a drill press, clamp together the bars and drill through all four pieces simultaneously. Otherwise, drill the holes individually through each bar. Measure up $^{3}/_{16}$ inch from the other end of all four pieces and strike a line across their widths. Then measure $^{3}/_{16}$ inch from both ends of each line and strike cross lines at these points. Drill wood screw starting holes at both locations of all four pieces.

Place a No. 5 stand base flat in front of you and stand the end with the two side-by-side holes drilled through it upright against the side of the No. 5 piece. Holding the two pieces together in that orientation, place a small L bracket atop the No. 5 piece and align its upright hole with the line drawn down the center of the No. 3 piece. Strike a short line across the first one at the center of the hole. Remove and set aside the No. 5 piece and L bracket.



Light/reflector assembly showing wiring to tube sockets routed along top and around edges of assembly. Wiring can also be routed through holes drilled in one end member, as described in text.

Mark the same location on the three remaining No. 3 pieces. Then drill a $^{5}/_{16}$-inch-diameter hole through each piece centered on the crossed marks. Next, spread a thin layer of wood glue across the bottom end of one No. 3 piece and align it against the one edge of a No. 5 piece and secure the two together with two ⅛ × ½-inch flat-head wood screws. Then use another wood screw and a ⅛ × ½-inch round-head machine screw and nut to secure the L bracket in place to the No. 5 and No. 3 pieces, respectively. Repeat for the remaining No. 3 and No. 5 pieces. Make sure all four No. 3 pieces are perpendicular to the No. 5 pieces.

Cut the aluminum flashing to size. Then bend the two side edges of the aluminum flashing to form the reflector assembly into a U channel with legs 1½ inch high. Use two straight boards to help you make the bends.

When it is ready, place the flashing flat on your work surface, channel legs pointing upward. Center the control circuit-board assembly box across the channel and use a soft pencil to mark its outline on the flashing. Set aside the box. Now measure 1 inch from each corner along the long sides and strike a cross line at each measured point, extending these lines about 1 inch from the outline.

Replace the box on the flashing within its outline. Without moving either piece, set a small L bracket against the box, aligning it with one of the last-drawn lines, centering the line in the mounting hole and draw the outline of the bracket's holes on both the flashing and box wall. Do the same for the three remaining lines.

Drill $^{5}/_{16}$-inch-diameter holes centered in each hole on both the flashing and box. Also drill three ¼-inch-diameter holes for exit of the wiring from the circuit-board assembly, entry of the line cord and for mounting POWER switch *SW1*. Locate these holes near where N1, N2 and N3 on the lower-left of the board will be. Secure the L brackets to the box with 6-32 × ½-inch machine screws and nuts. Feed the screws through the holes from the inside of the box. Then mount the switch in its hole.

Center the flashing all around on

top panel No. 1 and draw the outlines of the four holes in the flashing onto the panel. Remove the flashing and set it aside. Then drill ⁵⁄₃₂-inch-diameter holes through the center of all three marked locations. Loosely secure the flashing to the panel with four sets of ⅛ × ½-inch flat-head machine bolts fed through the panel and then flashing and matching machine nuts.

Place the assembly on your work surface with the channel legs pointing up and align a No. 4 light attachment bar with one end of the channel so that it is flush with the top and both side edges. Place a small L bracket in one corner of the flashing channel and against the No. 4 piece and draw the outline of the hole in it on the panel. Do the same with another L bracket and the opposite corner.

Check the hole outline locations against the spacing of the holes drilled through the No. 3 pieces in one previously prepared assembly. Do this at more than one level of holes in the latter to make sure that they are trued. If the holes do not line up, adjust the spacing of the outlines on the No. 4 piece so that they do. Then drill ⁷⁄₁₆-inch diameter holes through the centers of both new hole outlines. Then do the same for the other No. 4 piece.

Secure the No. 4 pieces to the No. 3 pieces with ⅜ × 1-inch bolts and wing nuts. Choose the top hole pairs in both vertical stand bar assemblies for this. Invert one assembly and align it against the top assembly. Draw the outlines of the holes in the L brackets onto the flashing. Then repeat for the other assembly.

Set aside the two vertical stand bar assemblies and drill ⁵⁄₃₂-inch-diameter holes through the centers of all four hole outlines going through flashing and top panel. Test fit the flat-head machine hardware to make sure that everything goes together properly.

Retrieve the control circuit-board assembly box and drill two ¼-inch-diameter holes (make these slightly larger if you are using an aluminum utility box to accommodate small rubber grommets) through one long wall, spacing them about 1 inch apart and about halfway between the top and bottom of the panel. One hole is for entry of the ac line cord, the other for entry of the wiring from the six tube sockets.

Remove the No. 4 light attachment bars from the vertical stand bars and strike a line down the center of each. Strike a line across each of these lines centered from end to end. Measure 2 inches along the long lines from these marks and mark the measurements in all four instances. You have now defined where each of the six SK-20 tube sockets will be mounted. Strike a line down the length of each No. 4 piece ⅜ inch from the top edge. Drill the holes for the wiring between the control circuit-board assembly and tube sockets. You need four ¼-inch-diameter holes in all—separate holes for the N1, N2 and N3 wires and one for the common N1,N2,N3 wire coming from the circuit-board assembly.

Mount the circuit-board assembly in place inside its housing using ½-inch spacers and suitable machine hardware. Drill holes for the hardware as needed. If you are using an all-metal utility box, line the wire and ac line cord holes with small rubber grommets. Then route the ac line cord into the box and tie a strain-relieving knot in it about 6 inches from the free end inside the box. Tightly twist together the fine wires in both conductors and sparingly tin with solder. Crimp and solder one conductor to the N1,N2,N3 post. Then crimp the other conductor to the No. 6 solder lug on the board and solder the two-way connection.

Collect the three N1 wires and route them through one hole in the box. Label this hole N1. Then collect the N2 and N3 wires, route the bundles through separate holes and label the holes accordingly. Finally, route the two remaining wires through any of the three holes.

Mount the six bi-pin tube sockets into place on the No. 4 light attachment bars and route the wires through the holes drilled for them in the one bar. Neatly route the free ends of the wires to the appropriate lugs on the socket and trim to neat lengths. Strip ¼ inch of insulation from the end of each, twist together the fine conductors and tin with solder before connecting and soldering each into place. Daisy-chain wire two 3-inch lengths of prepared wires from N1D to N2D to N3D (see Fig. 2) and connect the free end of the remaining wire coming from the solder lug on the circuit-board assembly to any of these three lugs.

Double check all wiring and soldering. If you suspect any connection, reflow the solder on it to correct what might be a problem later on if left untouched. Make doubly sure that the ac line cord is wired into the circuit properly, and check all wire runs against both Fig. 2 and Fig. 4. When you are certain that everything is properly wired, insert the tubes into the sockets and plug the project's line cord into an ac outlet. Flip the POWER switch to on. If everything is okay, the tubes should light after only a short delay. If not, correct the problem before putting the UV Exposure Light into service.

Using the Project

This project is very simple to use. However, it will take some trial-and-error tests to determine how far away from the photosensitized materials it should be and what exposure times to use for different situations. This procedure can be greatly simplified by using the UV Exposure Light with a programmable timer like the Programmable Appliance Timer presented last month, although there is no reason why you cannot use it in a purely manual mode. ME

A Digital Milliohmmeter Adapter

Lets you accurately measure less than 1 ohm with a DMM

By Mike McGlinchy

Ordinary 3½-decade digital multimeters do not have the resolution required for you to measure very-low resistance values. Consequently, such an instrument will not measure any value less than 1 ohm with any degree of accuracy. In this article, we will show you how you can use the ordinary DMM in its dc volts function to accurately measure resistances down to about 1 milliohm.

This is an adapter that just about anyone who has a serious interest in electronics and owns a 3½-decade DMM will want to have handy. It can be used to check whether a ground connection in a circuit is really at zero ohm or that battery-cable connectors in a car or truck are making the required low-milliohm connection and not the near-1-ohm value that can fool an ordinary ohmmeter function of a DMM into indicating a short circuit.

Measuring Resistance

Ordinary DVMs (and the dc volts function of DMMs) measure resistance indirectly, by measuring a voltage dropped across a resistive element, as shown in Fig. 1.

When unknown-value resistor R_x is connected between the output and inverting (−) input of an operational amplifier as shown, the negative feedback that results holds the inverting input at 0 volt, or virtual ground potential. Since *R1* has a fixed potential of −2 volts across it, the current through *R1* is constant. This current flows through R_x to give an output voltage that is sent to the succeeding analog-to-digital (A/D) converter in the meter. This current is very small, too small, in fact, to produce an appreciable voltage drop across R_x of less than 1 ohm.

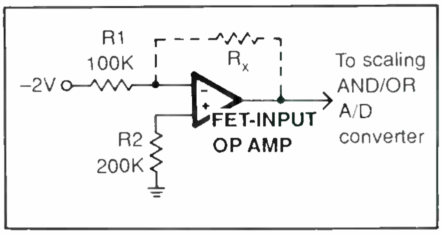


Fig. 1. Inside a DVM or DMM, unknown-value resistor R_x connects from the output to the inverting input of an op amp.

An obvious solution to the above problem is to pump a relatively large current through R_x to force a greater voltage drop and then use a DVM to measure the drop. This is exactly what is done in our milliohmmeter accessory. A current of 1 ampere was chosen so that there would be no need to have to juggle a conversion factor when taking measurements. Thus, all readings taken with the DVM are read out directly—as, for example, when a measured voltage drop is 36 millivolts, R_x would be directly read as 36 milliohms.

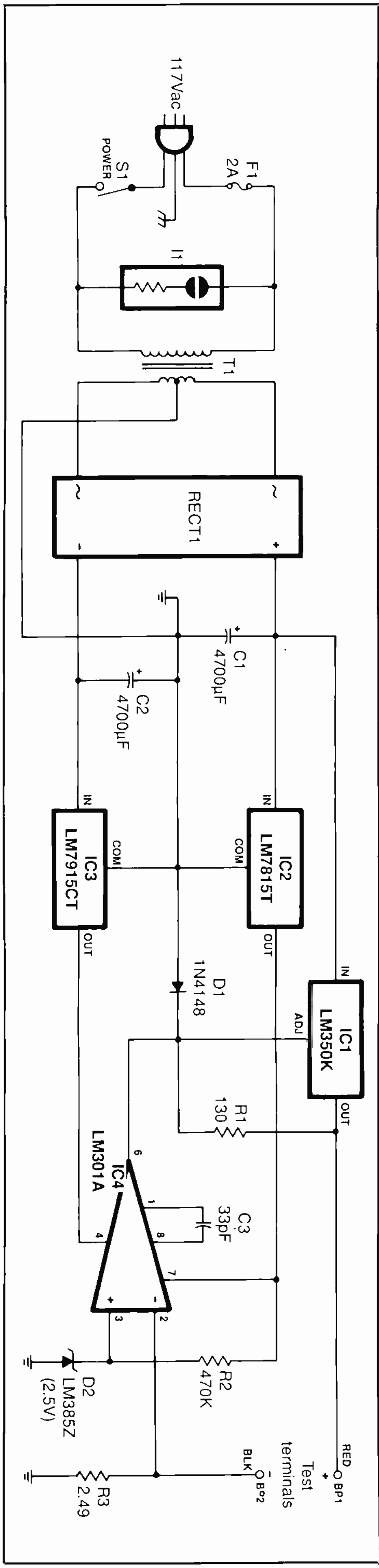
About the Circuit

Shown in Fig. 2 is the complete schematic diagram of the Digital Milliohmmeter Adapter's circuit. Adjustable positive voltage regulator *IC1* is capable of supplying 3 amperes over a 1.2-to-33-volt range. The output from this LM350K regulator is the potential of the adjustment (ADJ) terminal plus 1.2 volts. If the adjustment terminal is grounded, the chip will act as a simple 1.2-volt positive voltage regulator.

The decided-upon 1 ampere test current is pumped through unknown-value resistor R_x by *IC1*. The current is sensed by *R3*, a 2.49-ohm, 1% tolerance, 20-watt resistor. This sense voltage appears at the pin 2 inverting input of LM301A op amp *IC4*, which is configured here as a dc error amplifier.

The 2.5-volt reference potential at noninverting (+) input pin 3 of *IC4* is provided by two-terminal precision reference *D2*, an LM385Z device. Since *IC4*, *IC1* and R_x make up a negative-feedback control system, the voltage at the inverting input of *IC4* is equal to V_{ref}. Therefore, 2.5 volts will be maintained across *R3*, forcing 1 ampere of current to flow through it and R_x, which is in series with *R3*. The maximum value of R_x is limited only by *IC1*'s output potential minus the 2.5-volt reference.

Because of the amount of current required for making measurements with this circuit and the relatively high dc voltages needed to drive the op-amp circuit, the only practical power supply for the accessory is an ac-line-operated one. This consists of power transformer *T1*, bridge rec-



PARTS LIST

Semiconductors

D1—1N4148 or similar silicon small-signal diode

D2—LM385Z 2.5-volt precision reference

IC1—LM350K adjustable positive voltage regulator

IC2—LM7815T +15-volt regulator

IC3—LM7915CT −15-volt regulator

IC4—LM301A operational amplifier

RECT1—4-ampere, 100-volt bridge rectifier

Capacitors

C1,C2—4,700-µF, 35-volt electrolytic

C3—33-pF Mylar or ceramic disc

Resistors

R1—130 ohms, ¼-watt, 5% tolerance

R2—470,000 ohms, ¼-watt, 5% tolerance

R3—2.49 ohms, 20-watt, 1% tolerance

Miscellaneous

BP1,BP2—Five-way binding post (one red, one black)

F1—2-ampere slow-blow fuse

I1—Neon-lamp assembly with built-in limiting resistor

S1—Spst slide or toggle switch

T1—25.2-volt, center-tapped, 2-ampere power transformer (Radio Shack Cat. No. 273-1512 or similar)

Printed-circuit board or perforated board with holes on 0.1" centers and appropriate Wire Wrap or soldering hardware; suitable enclosure; ac line cord with plug; fuse holder; small rubber grommet; ½" spacers; machine hardware; hookup wire; solder; etc.

Fig. 2. Complete schematic diagram of project's circuitry, including its ac-operated power supply.

tifier *RECT1*, filter capacitors *C1* and *C2*, +15-volt regulator *IC2* and −15-volt regulator *IC3*. Neon indicator lamp *I1* with built-in current-limiting resistor wires across the primary of *T1* as shown and turns on when POWER switch *S1* is closed.

Construction

This is a fairly simple circuit in terms of component count. It can be wired on a printed-circuit board of your own design or on perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware. Whichever way you go, be sure to use a socket for *IC4*. When you plan your layout, be sure to make provisions for mounting the power transistor off the board inside whatever enclosure you choose.

Wire the project on the circuit board exactly according to Fig. 2. Components that mount off the board are *F1*, *S1*, *T1*, *BP1* and *BP2*. Start wiring the board by installing and soldering into place the socket for *IC4*. Do *not* install the IC in the socket until after you have made voltage checks.

Once the socket is in place, install and solder into place the resistors. Because *R3* will be dissipating considerable power and, thus, heat up, mount this resistor so that it sits about ¼ inch above the board's surface to allow air to circulate around it. Then install the capacitors and diodes, making sure that they are properly oriented before soldering their leads into place.

Mount the bridge rectifier assembly to the circuit-board assembly with suitable machine hardware and follow with installation of the regulators. Make sure the latter are properly based before soldering their leads into place.

Now wire the + and − lugs of the rectifier assembly into the circuit. This done, strip ¼ inch of insulation from two heavy-duty 5-inch lengths of hookup wire. Tightly twist together the fine conductors at both ends of both wires and sparingly tin with solder. Connect one end of each wire into the appropriate points on the circuit-board assembly and solder both connections. The other ends of these wires will be connected later.

You can use any enclosure that will accommodate the circuit-board assembly and power transformer and that has panel space for mounting the indicator lamp and POWER switch on the front panel and the fuse holder and entry hole for the line cord on the rear panel. Suitable enclosures include an all-aluminum utility box and a plastic project box that has a removable metal top panel.

Machine the enclosure as needed. That is, drill mounting holes for the circuit-board assembly and power transformer through the floor panel, mounting holes for the POWER switch and indicator lamp through the front panel and a mounting hole for the fuse holder and entry hole for the ac line cord through the rear panel. Deburr all holes as needed. Then line the ac cord's entry hole with a small rubber grommet if this hole is drilled through a metal panel.

Feed the free end of the ac line cord through its hole and tie a knot in it about 6 inches from the free end inside the enclosure. Tightly twist together the fine wires in both conductors and tin with solder. Connect the secondary leads, including center-tap lead, of the transformer to the appropriate points in the circuit-board assembly and solder all three connections.

Use suitable machine hardware to mount the transformer into place. Then mount the circuit-board assembly in its location, using ½-inch spacers and 4-40 × ¾-inch machine screws, nuts and lockwashers. Mount the fuse block on the rear panel of the enclosure and the switch, binding posts and neon-lamp assembly on the front panel. Label the binding posts + for red and − for black.

Now crimp and solder one line-cord conductor to one fuse holder lug and the other conductor to one switch lug. Crimp but do not solder one primary lead of *T1* to the other fuse holder lug and the other *T1* lead to the other switch lug. Use hookup wire to lengthen the leads of the neon-lamp assembly as needed, insulating the connections. Crimp and solder one lead to the fuse-holder lug to which *T1*'s primary lead is connected. Do the same with the other lamp lead and the switch lug to which *T1*'s other primary lead is connected. Finally, crimp and solder the free ends of the two heavy-duty stranded hookup wires to the lugs of the binding posts, the one coming from *IC1*'s OUT pin to red and the other one to black.

Checkout & Use

Insert a 2-ampere slow-blow fuse into the fuse holder and then plug the project's line cord into an ac outlet. Clip the common lead of a dc voltmeter or multimeter set to its dc volts function to the negative lead of *C1* or positive lead of *C2*. Touch the "hot" meter probe to pins 7 and 4 of the *IC1* socket and note the readings obtained. If they are not +15 and −15 volts, respectively, power down the project and unplug it from the ac outlet. Rectify the problem before proceeding.

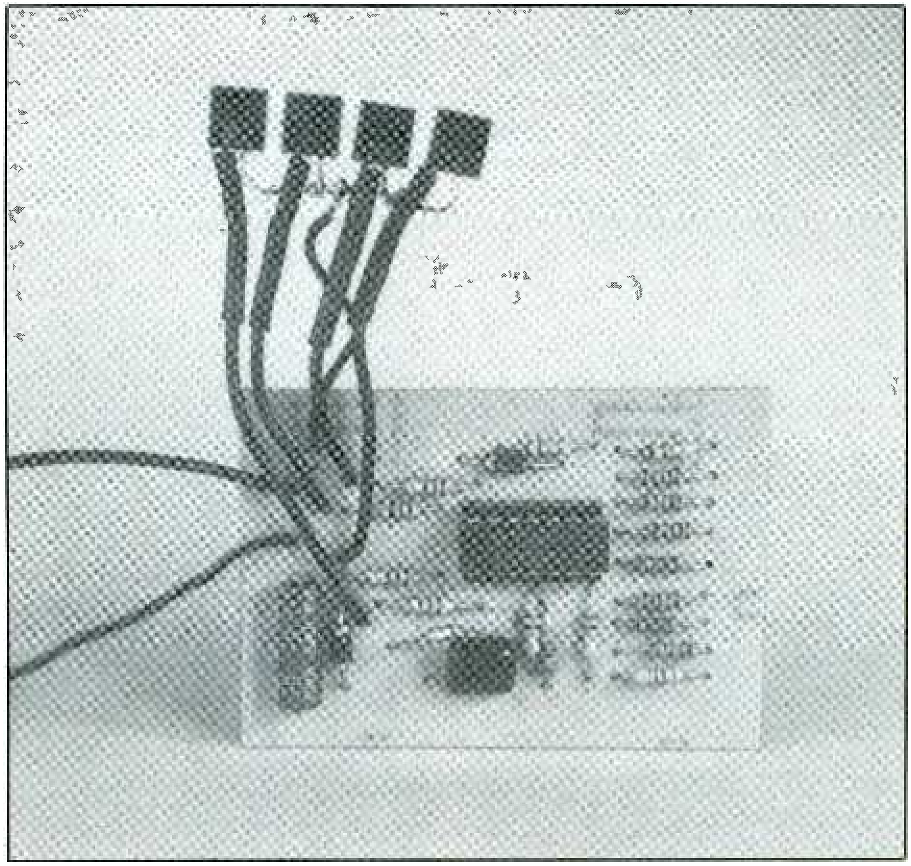
Once you are certain that the project is properly wired, power it down and allow sufficient time for the charges to bleed off *C1* and *C2*. Then install *IC4* in its socket. Make certain it is properly oriented and that no pins overhang the socket or fold under between IC and socket as you push the op amp home.

The procedure for using the Digital Ohmmeter Accessory is simple. Just plug its line cord into an ac outlet, connect your DVM (or DMM set to its dc volts function) between the binding posts. Observe proper polarity. Then connect the unknown resistance between the two binding posts, turn on the project and meter and observe the reading in the latter's display. If you wish to use this project for in-circuit tests, use short test leads to bridge from the binding posts to the circuit under test. **ME**

Automotive Battery/Charging System Analyzer

Simple low-cost circuit uses a series of LEDs to report on vehicle electrical system status

By Anthony J. Caristi



With labor cost so expensive today, it makes sense to diagnose and repair as many automotive problems as possible instead of having a service center do it. This was the motivation behind the development of the Automotive Battery/Charging System Analyzer described here. This instrument gives professional-quality diagnostics of a vehicle's electrical system that will help in repairing common defects. It checks the battery, alternator and voltage regulator in a vehicle while the engine is being started and is running. If it is permanently installed in a vehicle, it can provide advance warning of impending trouble so that you will be able to take corrective action before a problem disables your vehicle. A series of four light-emitting diodes, each assigned a specific unambiguous reporting task, provide all indications of electrical system status.

In addition to saving on the cost of labor, this Analyzer helps pinpoint the cause of a problem to a specific component, which minimizes your cost for parts as well. The project is easy to build, low in cost and accurate in performance. It can be used as a stand-alone instrument that can be carried from one vehicle to another, or it can be permanently installed to provide continuous monitoring of a vehicle's electrical system. The Analyzer requires no power supply to set it up for operation. Simply connect its color-coded leads in proper polarity, and whatever power is needed to drive the circuit is drawn from the vehicle's electrical system.

About the Circuit

The key to diagnosing the condition of the battery and charging system in a motor vehicle is making measurements of the battery's voltage under specific conditions. Since most motor vehicles now on the road employ a six-cell 12.6-volt lead-acid battery to supply electrical power, it is a simple matter to provide a dedicated electronic device that compares battery voltages encountered to a built-in voltage reference.

Voltage measurements on a battery must be made under two operating conditions—starting (cranking) and running. To provide meaningful results, four voltage levels are

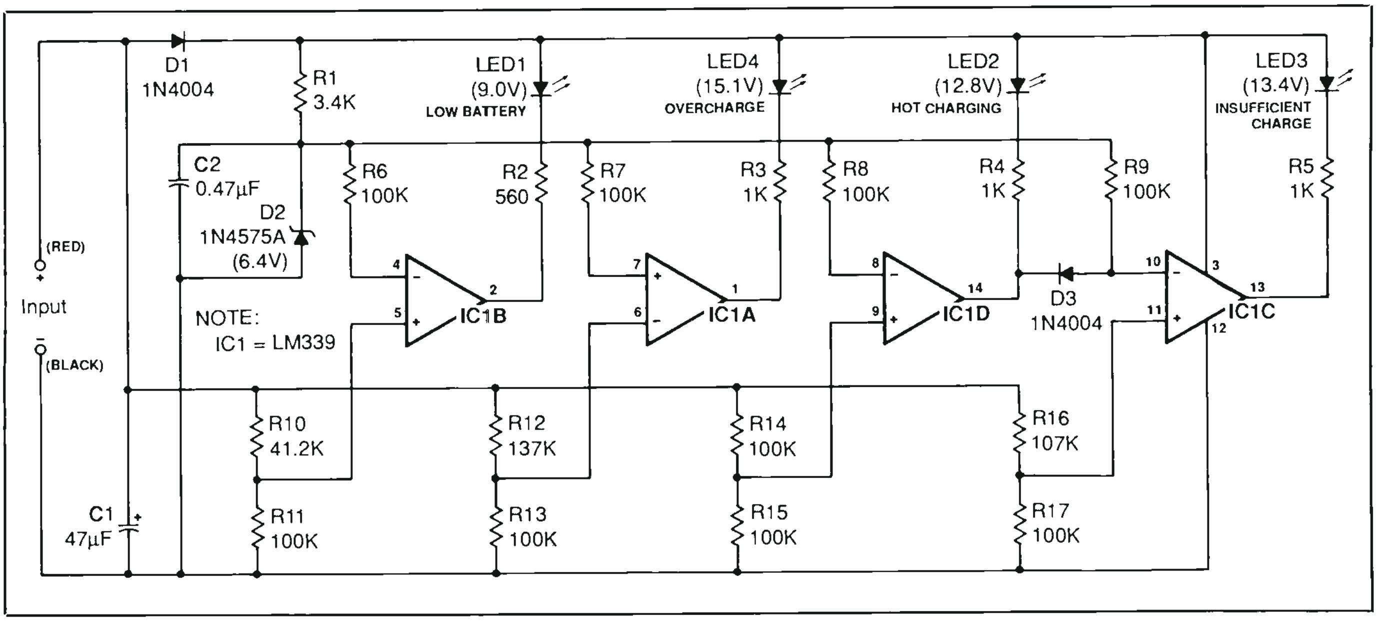


Fig. 1. Complete schematic diagram of the project's circuitry.

programmed into the Analyzer to allow you to determine if the vehicle's electrical system is operating within acceptable limits. If they are not, one of the four LED indicators will light, which one depending on the condition detected.

LED indicator voltage levels are provided for 9.0, 12.8, 13.4 and 15.1 volts. Hence, the Analyzer checks the battery and charging system for an under-charged or defective battery, no charging action, insufficient charging voltage level and overcharging. The circuit then lights the appropriate LED for the condition detected. If all is well with the vehicle's battery and charging system, none of the LEDs will be lit.

A properly operating battery and charging system will have a battery terminal potential of about 12.6 volts when the engine has been idle for some time. The potential will be between 13.5 and 15.0 volts when the battery is being charged by the vehicle's alternator. During the period the engine is being cranked, a battery that is in good condition will have terminal potential of not less than 9 volts. This Analyzer has been "programmed" to accurately detect these voltages using a temperature-compensated zener diode as a reference.

Shown in Fig. 1 is the complete schematic diagram of the Automotive Battery/Charging-System Analyzer's circuit. The heart of the circuit is four-section comparator *IC1*. As its name implies, a comparator actually "compares" one voltage to another, which causes its output stage to be at one of two logic levels. These levels are high and low or on and off, depending on how you view these conditions.

A comparator is similar to an operational amplifier that is running at full amplification with no feedback resistor network in the circuit. As a result, the output voltage will swing from ground level to V+ and vice-versa as the voltages fed to the two inputs (both referenced to circuit ground) become unequal. The LM339 comparator IC used in this project has an "open-collector" output transistor that is either held in cutoff or driven into full saturation according to the polarity of the difference potential fed to the two inputs.

Zener diode *D2*, which is designed to generate a very accurate zener breakdown potential of 6.4 volts at a current of 2 milliamperes, serves as the circuit's reference. This 6.4-volt potential is fed through isolation resistors to the reference input of each voltage comparator (*IC1A* through *IC1D*). Since the four comparator circuits in this instrument operate in the same manner, an explanation of how one works will suffice for all.

The 9.0-volt comparator is composed of *IC1B* and its associated components. The voltage reference of 6.4 volts drives the negative (–) input of the comparator at pin 4, while the voltage fed to the positive (+) input is a portion of the vehicle's battery potential as determined by the *R10/R11* voltage divider.

The values of these two resistors must be chosen so that the comparator's switch-over point occurs when the battery potential is 9.0 volts. This causes the output transistor in *IC1B* to cut off when the potential is greater than 9 volts and be saturated when it is at a lower potential. With the output transistor in cutoff, *LED1* extinguishes. On the other hand, when the transistor is switched on, current flows through and lights *LED1* to indicate a defective or under-charged battery.

PARTS LIST

Semiconductors
D1,D3—1N4004 or similar silicon rectifier diode
D2—1N4575A or similar 6.4-volt zener diode (see text)
IC1—LM339N quad comparator
LED1 thru LED4—2-volt, 20 mA light-emitting diode (see text)
Capacitors
C1—47μF, 25-volt electrolytic
C2—0.47-μF, 25-volt ceramic disc
Resistors
(¼-watt, 1% tolerance metal-film)
R1—3,400 ohms
R10—41,200 ohms
R11,R13,R14,R15,R17—100,000 ohms
R12—137,000 ohms
R16—107,000 ohms
(¼-watt, 5% tolerance carbon)
R2—560 ohms
R3,R4,R5—1,000 ohms
R6 thru R9—100,000 ohms
Miscellaneous
Printed-circuit board or perforated board with holes on 0.1″ centers and suitable Wire Wrap or soldering hardware; socket for IC1; suitable enclosure (see text); large color-coded alligator clips (for portable version only); red- and black-insulated stranded hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire printed-circuit board, $9.95; set of nine 1% tolerance metal-film resistors, $3.50; LM339N, $2; 6.4-volt zener diode, $3.75. Add $1.50 for P&H per order. New Jersey residents, please add state sales tax.

Each remaining comparator circuit operates in the same manner, except that they successively detect and indicate potentials of 12.8, 13.4 and 15.1 volts. These potentials were selected to light LEDs that inform you when such electrical abnormalities as NOT CHARGING (*LED2*), INSUFFICIENT CHARGING (*LED3*) and OVERCHARGING (*LED4*) exist.

You will note that the positive and negative inputs of *IC1A* are connected opposite to those for the other three comparators. The reason for this is that the Analyzer must light *LED4* when battery potential exceeds 15 volts to indicate an overcharging condition. The other three comparators are used to detect potentials that fall below the specified voltage levels.

To obviate an ambiguous display when the charging system is not working at all, diode *D3* causes a "not-charging" condition to bias the negative input of *IC1C* to cause *LED3* to extinguish. This is accomplished by the output from *IC1D* pulling to ground the reference input of *IC1C*. Consequently, when the vehicle's charging system is not working at all, NOT CHARGING *LED2* will be on and INSUFFICIENT CHARGING *LED3* will be extinguished.

The function of diode *D1* in this circuit is to prevent damage to the project in the event the polarity of the input leads are accidentally reversed when connecting the Analyzer to the vehicle's electrical system.

Construction

Except for the light-emitting diodes, the entire circuit of the Analyzer can be assembled on a small circuit board that measures approximately 1.75 × 2.75 inches. Because only dc voltages are dealt with by this circuitry, there is nothing critical about component layout or conductor routing. Therefore, you can use a printed-circuit board or perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware to assemble the circuit.

If you wish to make your own pc board, use the actual-size etching-and-drilling guide shown in Fig. 2. If you want pc construction but do not want to go through the bother of fabricating your own board, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. Alternatively, use perforated board. Whichever way you go, it is a good idea to use a high-quality DIP socket for *IC1*.

From here on, we will assume you are using a printed-circuit board. With this in mind, orient the board in front of you as shown in the wiring guide shown in Fig. 3. (If you are using perforated board, use Fig. 3 as a rough guide to component layout.) Then install the socket in the indicated location and solder it into place.

Install and solder into place the resistors, capacitors and diodes. Make sure the diodes and electrolytic capacitor *C1* are properly polarized before soldering their leads to the copper pads on the bottom of the board. Bear in mind that just one of these components installed backwards will render the circuit inoperable and may even cause damage to one or more components in the Analyzer.

Now strip ¼ inch of insulation from both ends of five 3-inch lengths of *stranded* hookup wire. If possible, use four black- and one red-insulated wires. Tightly twist together the fine conductors at both ends of all five wires and sparingly tin with solder. Plug one end of the black-insulated wires into the holes labeled LED1 K through LED4 K and solder into place. Plug one end of the remaining red-insulated wire into the hole labeled TO ALL LED ANODES and solder it into place.

Carefully inspect your circuit-board assembly. Check that all components are in their correct locations and those that are polarity-sensitive are properly oriented. Then flip over the board and check all soldered connections. Reflow the solder on any suspicious connection and use desoldering braid or a vacuum-type desoldering tool to remove any solder bridges that might have been created between closely spaced pads and conductors.

Slip a 1-inch length of small-dia-

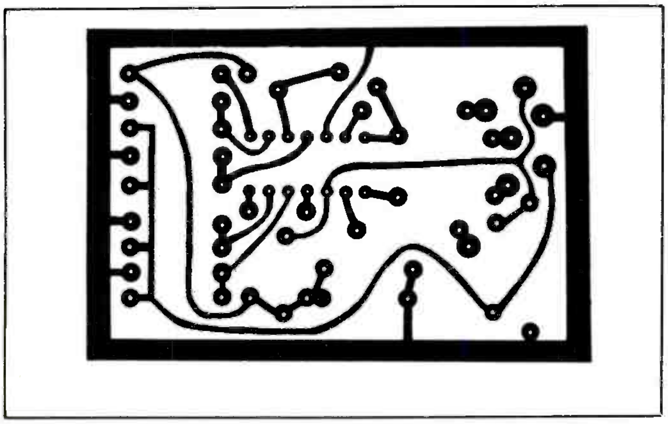


Fig. 2. *Actual-size etching-and-drilling guide for fabricating a printed-circuit board for the project.*

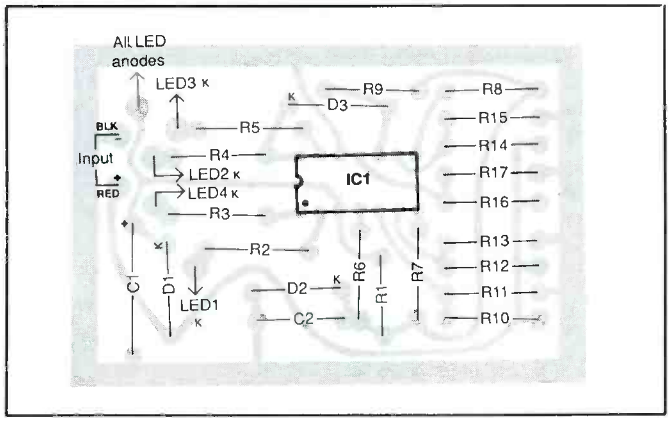


Fig. 3. *Wiring diagram for pc board. Use this as a rough guide to component placement when wiring the project on perforated board.*

meter heat-shrinkable or plastic tubing over the free ends of all four black-insulated wires. Identify the cathode leads of the four LEDs and clip each to a length of ½ inch. Form a small hook in the remaining lead stubs. Then crimp and solder the free ends of the four black-insulated wires to the cathode leads of the LEDs. Push the heat-shrinkable or plastic tubing up over the connections until all are flush against the bottoms of the LED cases and shrink into place.

It is important that you use the resistors specified in the Parts List for the voltage-divider networks. These are 1-percent-tolerance metal-film resistors. The accuracy of your Analyzer depends on the accuracy of the values of these resistors. Ordinary carbon-composition resistors do not have sufficient accuracy or stability for use in this part of the circuit. Additionally, zener diode *D2*, which also determines the accuracy of the instrument, *must* be a temperature-compensated reference diode. Do *not* substitute an ordinary zener diode for *D2*.

Whether you plan on using the project as a portable instrument or to permanently install it in your vehicle, house the circuit-board assembly in any enclosure that will accommodate it. If you wish to limit the amount of machining needed, you can use a small plastic project box. Otherwise, a small metal utility box will do.

Machine the box as needed. This includes drilling mounting holes for the LEDs and an entry hole for the test leads that will be used with the project. You do not have to drill mounting holes for the circuit-board assembly. It will be mounted in place inside the enclosure with a layer of thick double-sided foam tape. However, if you plan on installing the project permanently in a vehicle, drill a pair of holes to mount it in place where it will be easily seen from the driver's seat.

You will notice in the lead photo that LEDs with rectangular-shaped cases were used in the prototype of the project. Use of these requires that you cut a slot in which to mount each LED. If you do not have the proper tools for making such slots, use LEDs that are housed in round cases. Also, if you are using a metal utility box, deburr all holes and line with a small rubber grommet the one through which the project's leads will be routed.

Whether the project is to be a portable test instrument for a variety of vehicles or part of the instrument cluster in only one vehicle, it needs input leads. These must be stranded hookup wire, preferably with red insulation for positive and black insulation for negative. Light-duty wire will do, since the project draws very little current. The lengths of the leads will depend on how the project is to be used. If it is to be a portable instrument, 36- or even 24-inch leads will suffice. For permanent installations, the length of the positive lead will be dictated by where the project is mounted with respect to the battery's location, though the negative lead can be much shorter, since it need only go to a convenient nearby chassis ground point.

Prepare the input leads as you did for the LED wires above. If this is to be a portable instrument, route one end of each through the hole drilled for the input cable and tie a strain-relieving knot in the wire pair about 5 inches from the free end inside the enclosure. Plug these leads into the board holes labeled INPUT and solder into place. Then terminate the other ends in large color-coded alligator clips. For a permanent installation, simply route the leads into the enclosure, tie a knot in them, plug them into the board holes and solder into place. The other ends will be terminated later.

Once the input leads have been connected to the circuit-board assembly, mount the latter firmly inside the enclosure, using thick dou-

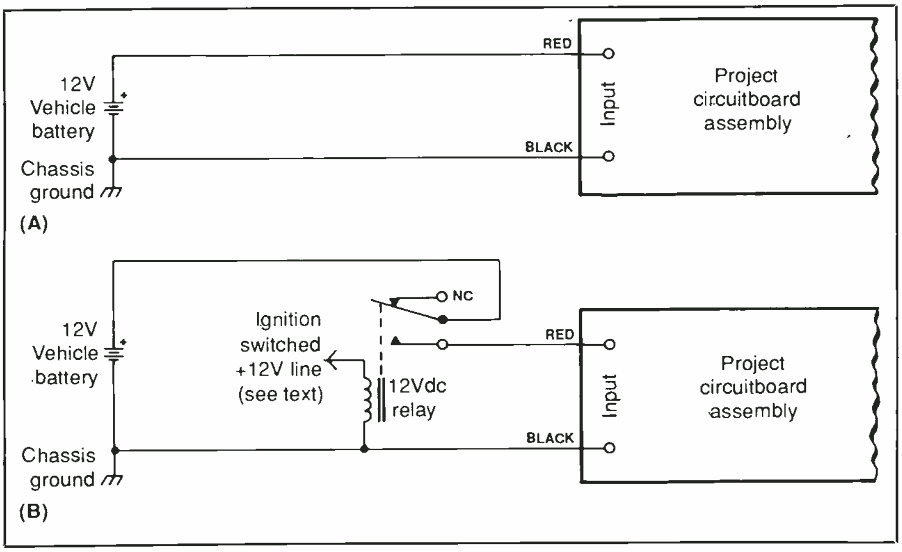


Fig. 4. Alternative means of enabling and disabling a permanently installed Analyzer. In (A), power is turned on and off manually with a slide or toggle switch. In (B), power is automatically applied and removed by the contacts of a relay that is energized when the vehicle's ignition is turned on and deenergized when it is turned off.

ble-sided foam tape. At this point, *IC1* should *not* be installed in its socket, nor should it be until after preliminary voltage checks have been made.

Connect the input leads to a dc power source, such as a variable bench supply set for an output between 9 and 15 volts or even a 9-volt battery. Make sure the polarity of the connections is correct. Then connect the common lead of a dc voltmeter or a multimeter set to measure dc volts to the negative lead of *C1*. Touch the tip of the meter's "hot" probe to pin 3 of the IC socket. The meter should register a reading of whatever the power supply is set to or the battery is rated at, and no other pin should give a reading when the "hot" probe is touched to it. If you do not obtain the proper indications, power down the circuit and rectify the problem. Do not proceed until you have ascertained that the power buses have been properly wired.

Label the LED positions on the front panel of the enclosure with legends that identify the condition each LED is to indicate (see Fig. 1). If you use a dry-transfer lettering kit, protect the legends with several light coats of clear spray acrylic. Let each coat dry before spraying on the next.

Now plug the LEDs into their respective holes in the enclosure's panel. If the LEDs do not remain in place by friction alone, secure them with plastic or fast-setting clear epoxy cement. Then tie together the anode leads of all four LEDs. Crimp the free end of the remaining wire coming from the circuit-board assembly to the four-lead bundle and solder the connection. Heat sink the anode leads of the LEDs to prevent heat damage to these devices. Then install the IC in the socket. Make sure that it is properly oriented and that no pins overhang the socket or fold under between IC and socket.

Checkout & Installation

Before actually installing the project in your vehicle or using it to conduct a test session, it is a good idea to check it out on your testbench. Use an adjustable dc power supply and an accurate dc voltmeter or multimeter set for measuring dc volts for this test. The supply must be capable of having its output vary between 8 and 16 volts. For maximum accuracy, the meter should be a digital type that has at least a 3½-decade display.

Connect the voltmeter and input leads of the project to the output terminals of the power supply. Observe polarity in both cases. With the supply's control set for minimum output voltage, turn on the power. Slowly adjust the setting of the control while observing the meter's display until a reading of 8 volts is obtained. At this point, both LOW BATTERY *LED1* and NOT CHARGING *LED2* should be on.

Slowly increase the setting of the supply's control until *LED1* extinguishes, which should occur at a meter reading of 9.0 volts. Continue adjusting the supply's control until *LED2* extinguishes and note that INSUFFICIENT CHARGING *LED3* simultaneously turns on. This should occur at a meter reading of 12.8 volts.

Continue adjusting the supply's control until the meter registers 13.4 volts. At this point, all LEDs should be off. Finally, adjust the supply's setting until OVERCHARGING *LED4* comes on, which now should occur at a meter reading of 15.1 volts. *Caution:* Do *not* permit the output voltage to exceed 16 volts while the project is connected to the power supply; if you do, irreversible damage will take place in *IC1*.

If you obtain the responses indicated above, the project is working properly and you can proceed to installation or actual use in a test situation. If not, you must troubleshoot the circuit and rectify the problem and then conduct again the operational checkout procedure. In all cases, the potentials at which the LEDs change state should be within 0.1 volt of that specified. If your project does not perform within this tolerance, it would be prudent to parallel one of the resistors in the voltage-divider network feeding the affected comparator with another resistor

(Continued on page 84)

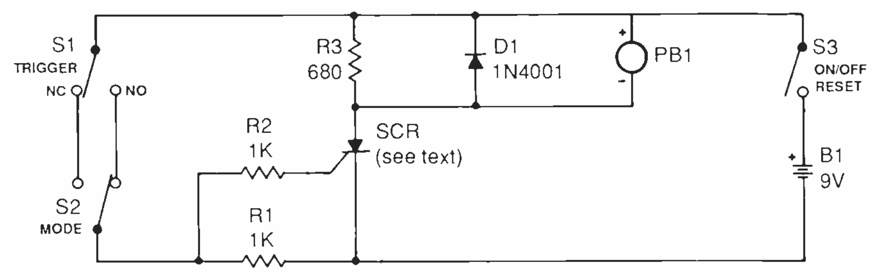
A Personal Security Alarm

Sounds a buzzer when it detects intrusions for both inward- and outward-opening doors

By James H. Brown

The Personal Security Alarm described here sounds an audible alert any time someone tries to open a protected door, even if the door is on a cabinet or storage box. It doesn't matter if the door opens inward or outward; the device will work in either case.

You can use this Alarm to monitor any single door, at home, in your office and while traveling. Take it with you when you travel to set against the door of your hotel or motel room. Flip a switch to the appropriate position and arm the alarm to rest assured that the protected entry is secure. The project is simple to use, simple in design and takes up very little extra space in your luggage.



PARTS LIST

Semiconductors
D1—1N4001
SCR1—Any general-purpose 1-ampere silicon-controlled rectifier (Radio Shack Cat. No. 276-1662 or similar)

Resistors (½-watt, 10% tolerance)
R1,R2—1,000 ohms
R3—680 ohms

Miscellaneous
B1—9-volt battery
PB1—Electromechanical Buzzer (Radio Shack Cat. No. 273-051 or similar)
S1—Spdt roller-type lever switch (Radio Shack Cat. No. 257-017 or similar)
S2—Miniature spdt slide or toggle switch
S3—Miniature spst slide or toggle switch
Suitable enclosure (Radio Shack Cat. No. 270-233 or similar—see text); 5-lug solder-type terminal strip; epoxy cement; lettering kit; clear spray acrylic; small block of wood (see text); machine hardware; hookup wire; solder; etc.

Fig. 1. Complete schematic of Personal Intruder Alarm circuit.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the Personal Security Alarm. As you can see, this very simple circuit contains very few components. Foolproof in operation, the circuit contains perhaps the simplest of all active elements, silicon-controlled rectifier *SCR1*. This is an electronic "latching switch" that, once activated, must be reset to turn it off.

Power for the circuit is supplied by 9-volt battery *B1*. Closing POWER/RESET switch *S2* feeds power to the circuit as needed. With TRIGGER switch *S1* and MODE switch *S2* set so that the circuit from the positive side of the battery is open to the junction of *R1* and *R2*, no trigger voltage reaches the gate of *SCR1*. (Switch *S2* can be set to allow the project to work with either an inward- or an outward-opening door.) In this condition, the circuit is armed.

Setting either *S2* or *S3* to its alternate position without setting the other to its alternate position delivers a dc voltage to the gate of *SCR1*. When this occurs, the circuit is triggered on. Current flows through *SCR1* and turns on piezoelectric buzzer *PB1*, which now sounds an audible alert.

The alarm continues to sound until power to the circuit is interrupted by setting *S1* to its "off" position. However, even if this is done and neither of the other two switches is set to its alternate position, the circuit to the gate of *SCR1* will remain complete. Therefore, if the Alarm should sound and *S1* is flipped off and then on again, the alert will still sound.

Switches *S2* and *S3* are ordinary slide or toggle types whose functions are fairly obvious, but *S2* is a special type that has a spring-loaded lever at the end of which is a roller bearing. It has both normally-open (NO) and normally-closed (NC) contacts, both of which are used in this project. The Alarm is armed for an outward-open-

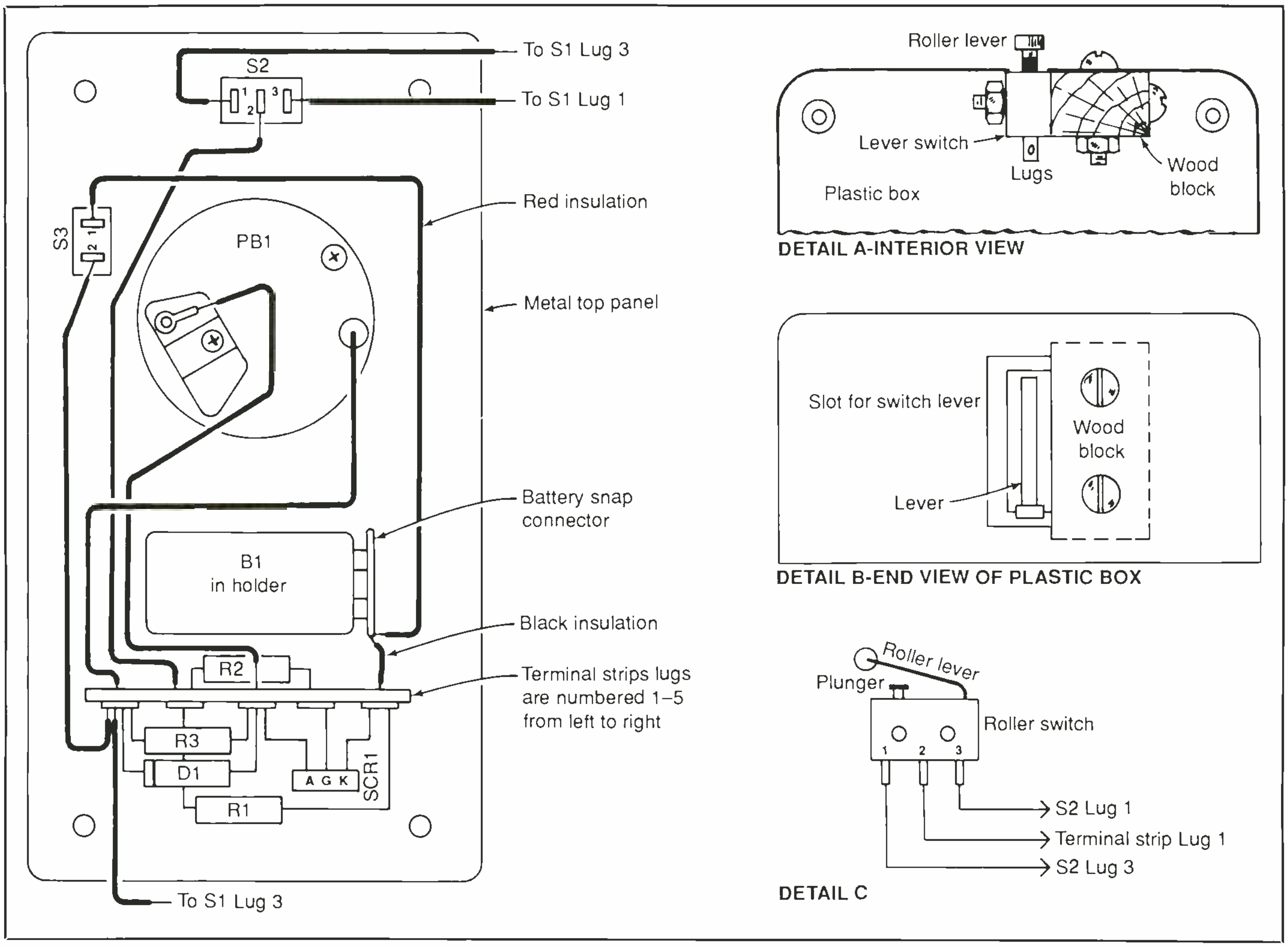


Fig. 2. Construction and wiring details for project.

ing door with the NO contacts held closed by pressing the project's roller switch against the door so that its lever sets the switch to its alternate position. (The project is armed for an inward-opening door by placing it so that the roller is just touching the door and not pushed in.)

Once the project is set so that *S1* is in its armed condition for an outward-opening door, *S3* is flipped to "on." If the Alarm is moved, spring action causes *S1* to go to its other position and the Alarm to sound. Now *S3* must be flipped to off and *S2* to its alternate position. When *S3* is flipped back on, without moving the project, the Alarm will be silent.

For an inward-opening door, the action is just the opposite. That is, when the door is opened, it pushes the lever and causes *S1* to go to its alternate position to complete the trigger circuit.

Should a burglar or intruder attempt to flip *S3* to off and then to on while the buzzer is sounding, he'll find that the alert continues to sound. To rearm the Alarm, he must place it exactly as it was when he found it and flip *S3* to off and then back to on and not touch it again to keep it silent.

Construction

Because of the very low component count in this project's circuit, it easiest to build the Alarm using a five-lug solder-type terminal strip and point-to-point wiring. The most difficult part about building the project is machining its enclosure. The Parts List specifies a Radio Shack plastic enclosure that has a removable top panel, but any other type of enclosure can be used as well.

Except for roller switch *S1*, all components mount on the metal top panel of the enclosure, as illustrated in Fig. 2. Begin machining this panel by drilling mounting holes for *S2* and *S3*, the holder for *B1* and for mounting the five-lug terminal strip. This done, place the piezoelectric buzzer on the panel, centering it between the two long sides and about 1 inch away from the hole drilled for *S2*. Scribe the outline of the buzzer onto the panel. Set aside the buzzer and drill a ¼-inch or larger hole near the scribed line inside the circle. Then use a nibbling tool to cut the round hole needed for mounting the buzzer in place. Deburr all holes.

Mount the switches, buzzer, battery holder and terminal strip in place. Use fast-setting epoxy cement to secure the buzzer in place. Then, trimming their leads as needed, mount the resistors, diode and SCR on the terminal strip as shown. Crimp each lead tightly to the appropriate lug to assure a good mechanical joint in each case. Make absolutely certain that the diode is properly oriented and that the leads of *SCR1* are properly based. Do *not* solder any connection just yet.

Strip ¼ inch of insulation from both ends of five 6-inch lengths of hookup wire. If you're using stranded wire, tightly twist together the fine conductors at all ends and sparingly tin with solder. Do the same for the free ends of the wires connected to the battery snap connector and piezoelectric buzzer.

Crimp the free end of the battery connector's black-insulated wire to terminal strip lug 5 and solder the three-point connection. Solder the two-point connection of terminal strip lug 4. Crimp one end of the indicated wire coming from *PB1* to lug 3 of the terminal strip and solder this four-point connection. Crimp one end of a prepared hookup wire to terminal strip lug 2 and solder this three-point connection. Then crimp one end of two of the remaining three hookup wires and the free end of the other *PB1* wire to lug 1 of the terminal strip and solder this five-point connection.

Now crimp and solder the free end of the red-insulated lead of the battery snap connector to lug 2 of *S3*. Crimp and solder the free end of one of the hookup wires connected to terminal strip lug 1 to lug 1 of *S3*. Locate the wire coming from terminal strip lug 2 and crimp and solder its free end to lug 2 of *S2*. Crimp and solder one end of the remaining two hookup wires to lugs 1 and 3 of *S2*. The free end of the remaining wire coming from lug 1 of the terminal strip and two wires coming from *S2* will be connected later.

Referring to Details A and B in Fig. 2, cut a rectangular slot in the end of the plastic case opposite that where *S2* will be located. Make this slot just slightly longer and wider than the dimensions of the switch itself. Use a small block of wood to mount the roller switch in place as shown. When properly mounted in place, the switch should be aligned with the wall through which its lever protrudes.

When you finish mounting *S1*, check out its operation. Connect one probe of an ohmmeter or audible continuity checker to lug 2 and the other probe to either lug 1 or lug 3. Stand the project's case on-end on a tabletop so that the lever of *S1* is pushed in and turn on the meter or checker. If you get an indication of continuity, lift the case. If the indication doesn't change, you'll have to reposition the switch so that its lever protrudes far enough out of the case to set the switch to its alternate condition.

When you're satisfied that the switch is properly located, place the plastic case and metal top-panel assembly side by side, orienting them as shown in the main drawing and Detail A in Fig. 2. Now, referring to Detail C and taking careful note of the orientation of the roller switch, crimp and solder the free end of the wire coming from lug 1 of *S2* to lug 2 of *S1*. Then, to complete the construction phase, crimp and solder the free end of the wire coming from lug 3 of *S2* to lug 1 of *S1*. This done, snap a 9-volt battery into the connector and snap the battery into its holder.

Use a dry-transfer lettering kit to label the two positions of *S2* but not the function of POWER switch *S3*.

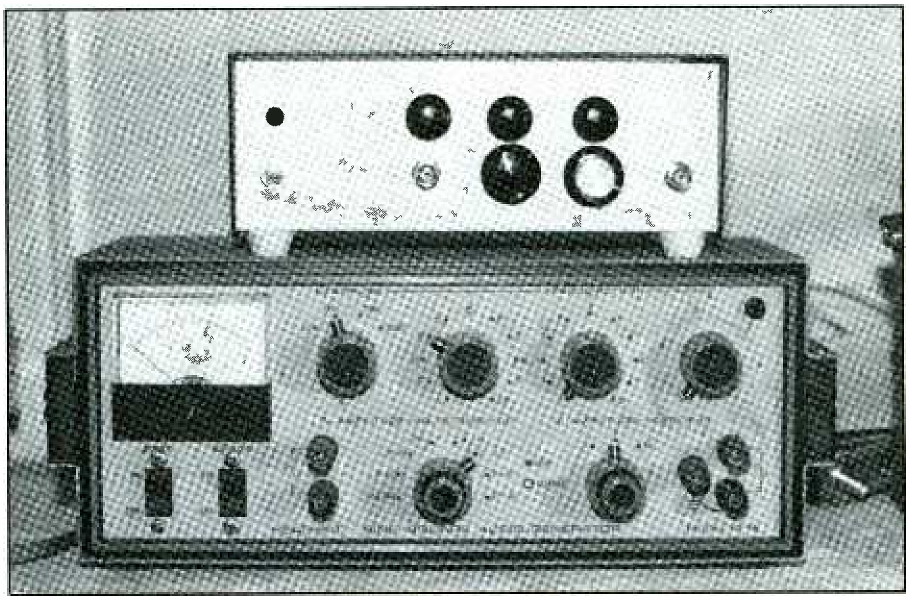
Checking it Out

Turn on your Personal Security Alarm by setting *S3* to its "on" position. If the buzzer sounds, label the position to which MODE selector switch *S2* is set OPEN OUTWARD. Turn off the Alarm and set *S2* to its alternate position. Turn on the alarm once again. This time, the buzzer should remain off until you push the lever on *S3* in, which means that you label this position of *S2* OPEN INWARD. Do not label the function of roller switch *S1*. Use tape to mask around the legends for *S2* and *S3* and spray several coats of clear acrylic over the lettering to protect it from abuse. Allow each coat to dry before spraying on the next, and don't let any acrylic touch anywhere else on the panel. **ME**

Upgrading an Audio Signal Generator

Modification plans to add swept frequencies and output of triangle waves, variable-width pulses and sine/cosine waveforms to a classic sine/square-wave generator

By Joseph J. Carr



The function generator is a descendant of the classical sine/square-wave audio generator. Modern instruments add pulse and triangle output waveforms to the usual sine and square waves of older audio generators. A typical example of the latter is the Heath Model IG-18 audio generator that has worked well for this author for almost 20 years. Now, however, I have a need for more versatility, so I decided to upgrade my old Heath generator to give much the same performance one obtains from a sweep/function generator. Described here is a converter circuit that upgrades virtually any basic audio generator to provide function-generator capabilities.

This accessory adds triangle waves, variable-width pulses and sine/cosine output waveforms to the existing sine and square waves of a basic audio generator. It can be used with any generator that can output a signal amplitude of 1 volt peak-to-peak or any potential near that level. Its circuit design is fairly simple and relatively easy to assemble from inexpensive and readily available components.

Basic Theory

Conversion of a sine wave into a triangle waveform is accomplished in this project using the Miller integrator circuit, which is shown schematically in Fig. 1(A). The basic circuit consists of an operational amplifier wired in an arrangement that looks like an ordinary inverting follower circuit. However, this configuration has a capacitor in the feedback loop instead of the usual resistor. The capacitor charges under the influence of output voltage V_{out} that, in turn, is a function of input voltage V_{in}. Although the mathematics that defines the integrator is taken from calculus, the only thing you need to know is that the output voltage is the time-average of the input voltage.

Output waveforms for the standard Miller integrator are illustrated in Fig. 1(B). In this particular case, the input signal waveform is a square wave that is generated symmetrically around the circuit's zero-volt reference. When the square wave is at logic high, the output of the Miller integrator starts out low but ramps upward as the capacitor charges. Then when the output waveform goes low, the capacitor begins to discharge and proceeds to charge in the opposite direction. The result of ramping up and down is a triangle waveform. This is how a triangle waveform can be obtained from a square-wave pulse.

Use of a comparator circuit allows the pulse to be generated from the triangle waveform. A comparator is

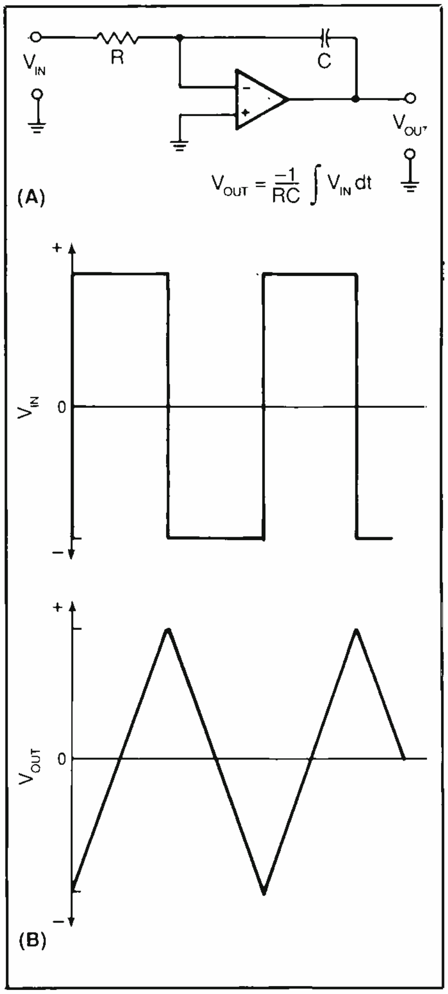


Fig. 1. Simplified Miller circuit schematic diagram(A) and output waveforms (B) from it.

basically an amplifier that has too much gain and, thus, saturates with a very-low-amplitude input signal. An op amp that is run wide open with no feedback network is an example of how a comparator can be made, as shown in Fig. 2.

The gain of the Fig. 2 circuit arrangement is the open-loop gain of the op amp. The open-loop gain of the inexpensive and commonly available 741 op amp, for example, is 300,000. So for a maximum output of 10 volts, the input saturates at an input level of 10 volts/300,000, which is a minuscule 33 microvolts! The output of a comparator can be summed up as follows: (1) When V_{in}

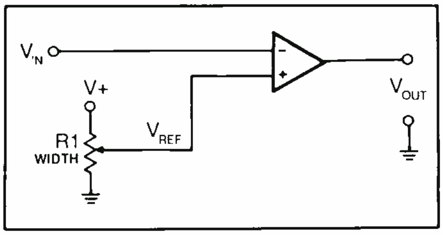


Fig. 2. A simple comparator circuit can be made from an ordinary operational amplifier run "wide open" with no feedback network.

= Vref, the output is low; (2) When $V_{in} = V_{out}$, the output is 0; (3) When $V_{in} = V_{out}$, the output is high.

In Fig. 2, the comparator is shown wired so that a reference voltage is applied to the noninverting (+) input and the triangle waveform is applied to the inverting (−) input. Figure 3 shows the waveforms under two circumstances: (A) is the input waveform (a bipolar triangle waveform), and (B) is the output waveform when the reference voltage is at V1. In this case, the threshold is not tripped until near the peak of the triangle; so the output is low for only a short period of time. When the reference voltage is adjusted to the V2 level, however, the triangle waveform is greater in amplitude than the reference potential for a longer time. The result is a wider output pulse.

About the Circuit

Shown in Fig. 4(A) is the schematic diagram of the accessory's circuitry minus its power supply. The active elements in this circuit are commonly available operational amplifiers. Use of 741 and CA3140 op amps keep the cost of components for the project low. They are easy to obtain from most mail-order and many local electronic component distributors.

Input stage *IC1* is configured in Fig. 4 as a noninverting follower circuit that has a gain of 2. The reason for selecting this particular circuit configuration is its extremely high input impedance, which does not load down preceding circuits. Amplifier *IC2* is a gain-of-1 inverter that produces an output that is the same as that of *IC1*, except that its output waveform is 180 degrees out-of-phase with that from *IC1*.

Op amps *IC3* and *IC4* make up the Miller integrator. These CA3140 devices have extremely high input impedance (specified at 10^{12} ohms) that far exceeds that of the 741 op amp. The reason why we need extremely high input impedance is that the input bias currents are microscopic and will not generate an output voltage that will erroneously charge the feedback capacitor.

The actual integrator here is *IC3*, while *IC4* serves as a buffer to the outside world. If circuits and op amps were perfect performers, there would be no need for *IC4*.

Shown in Fig. 4(B) is the feedback network for the Miller integrator. This consists of a 12-position non-

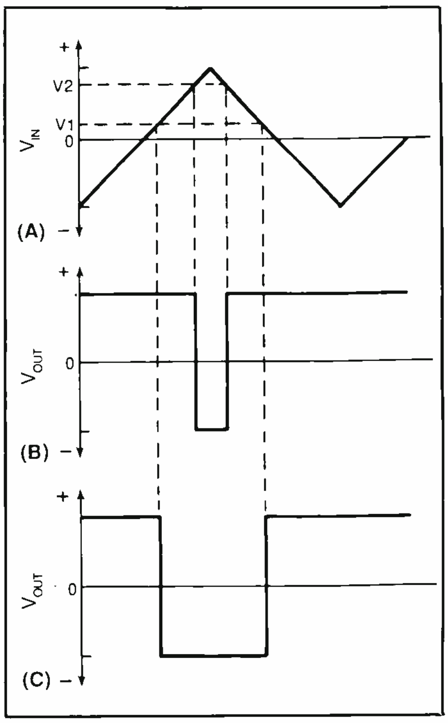


Fig. 3. Waveforms from Fig. 2 circuit: (A) bipolar triangle input waveform and (B) output waveform when reference voltage is at V1 level.

shorting rotary switch that is used to select various values or capacitors and resistors. The resistors convert the integrator into an amplifier that has a gain of −R (in kohms)/12 kohms. Because the gain of an integrator is −1/RC, you must be very careful to avoid using too low a capacitance value if you wish to avoid excessive gain. To this end, *R18* keeps the capacitor discharged in the event that some form of offset voltage (or dc component in the input signal) charges the capacitor.

In Fig. 4(A), you see an OFFSET control at the input to the integrator. This front-panel control has three uses. Firstly, it can cancel the effects of drift. By critical setting of the control, you can insert a "counter-current" that corrects the effects of offsets and bias currents in the op amp. Secondly, the control compensates for offset biases in the input signal. Finally, the control can be used to shape the waveform to something a little different from the norm.

Pulse circuits in Fig. 4(A) are *IC5* and *IC6*. Comparator *IC5* is an LM311 device. Internally based on an operational amplifier, the LM311 is a special-purpose IC comparator. A pull-up resistor is needed between its output and V+ rail. In this case, pull-up resistor *R10* has a value of 5,600 ohms. The value of *R10* is not critical, as long as it is between 3,900 and 10,000 ohms. The comparator's output is the required pulse, which is inverted in *IC6* to make available both polarities.

Amplifier *IC7* serves as the output stage of the project. It is a 741 op amp connected in an inverting-follower configuration. Its gain (0 to −1) is obtained by making the *R8* feedback resistance element a variable LEVEL control that can be adjusted for a value equal to the input resistance to the amplifier at maximum setting. This front-panel control is used as a "master gain" control for the project.

OUTPUT SELECT switch *S2* controls

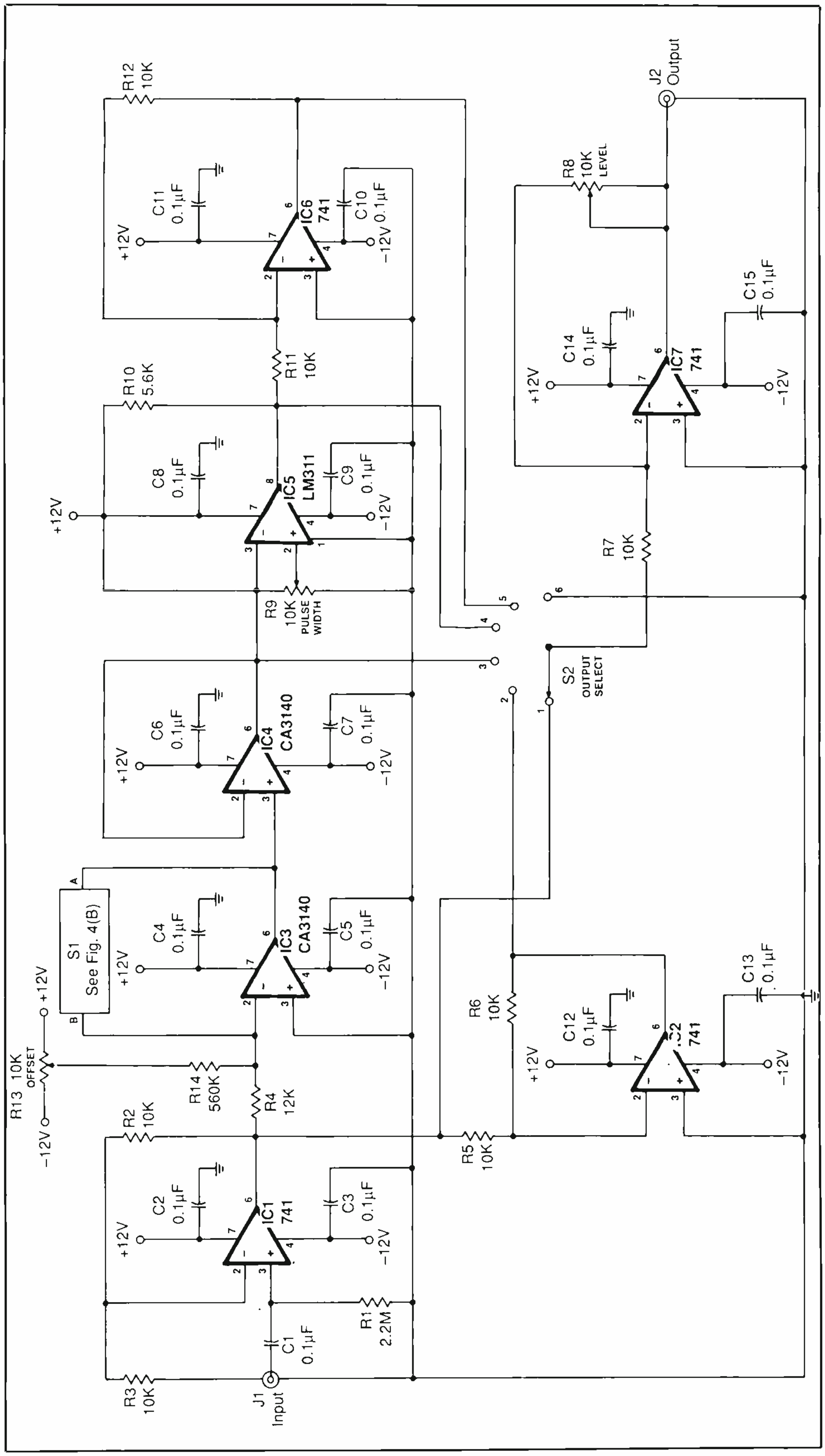


Fig. 4(A). Main schematic diagram of project's basic circuitry minus its ac-operated power supply. Details for S1 circuit are shown in Fig. 4(B).

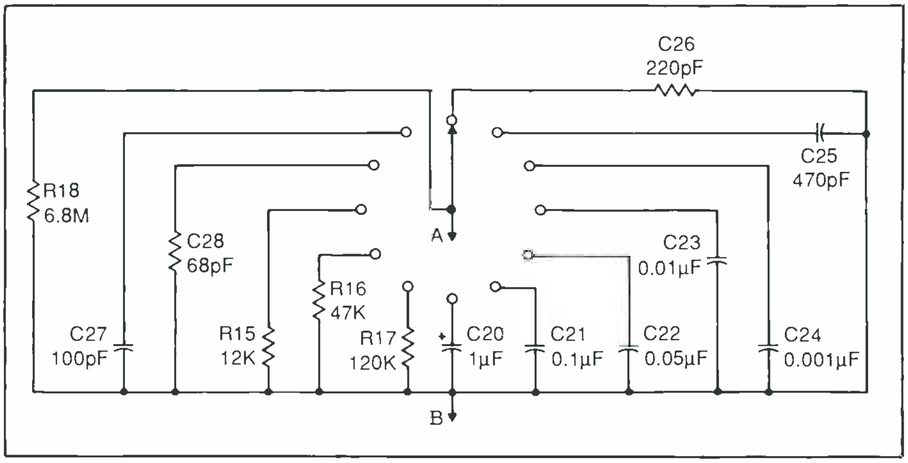


Fig. 4(B). Circuit details for S1.

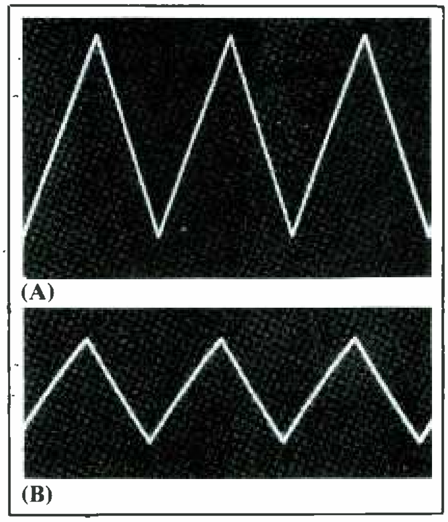


Fig. 5. Triangle output waveform (A) from project driven by 1-volt p-p, 400-Hz input signal (B).

PARTS LIST

Semiconductors

D1,D2—1N4007 silicon rectifier diode
IC1,IC2,IC6,IC7—741 operational amplifier
IC3,IC4—CA3140 operational amplifier (RCA)
IC5—LM311 comparator
IC8,IC9— + 12-volt regulator
RECT1—50-volt, 1-ampere bridge rectifier

Capacitors

C1 thru C15—0.01-µF ceramic disc
C16,C17—2,200-µF, 35-volt electrolytic
C18,C19—100-µF, 25-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1—2.2 megohms
R2,R3,R5,R6,R7,R11,R12—10,000 ohms
R4—12,000 ohms
R10—5,600 ohms
R14—560 ohms
R8,R9,R13—10,000-ohm panel-mount potentiometer

Miscellaneous

F1—0.6-ampere slow-blow fuse
J1,J2—Panel-mount BNC connector
S1—12-position non-shorting rotary switch
S2—6-position nonshorting rotary switch
S3—Spst slide or toggle switch
SO1—Chassis-mount ac receptacle (optional—see text)
T1—12-0-12- or 25.6-volt center-tapped, 250-mA power transformer (see text)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware; see text); sockets for all DIP ICs; holder for F1; suitable enclosure (see text); optional neon-lamp assembly with built-in limiting resistor (see text); ac line cord (see text); knobs for controls and rotary switches (2 with pointers); lettering kit; clear spray acrylic; machine hardware; hookup wire; solder; etc.

which waveform will be delivered to the input of output amplifier *IC7*. These waveforms are as follows:

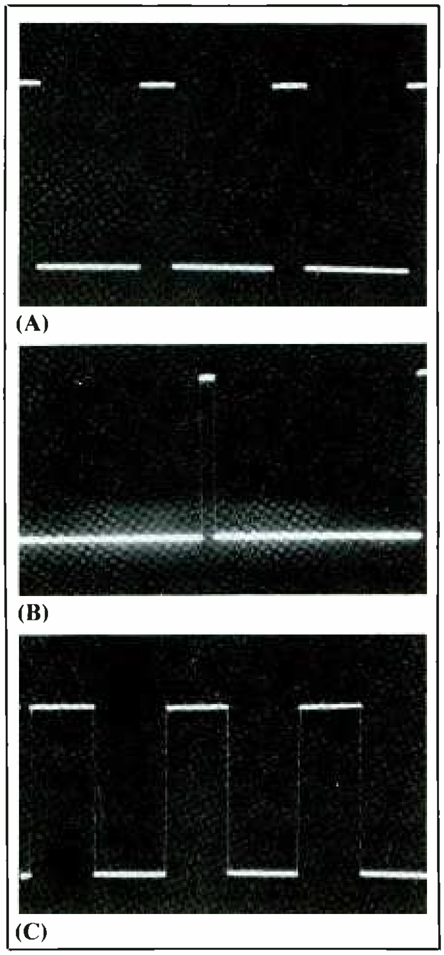
1—Input waveform amplified 2×
2—Inverted version of position 1 waveform
3—Triangle waveform
4—Negative-going pulse
5—Positive-going pulse
6—No output

The function-converter project produces several different waveforms: triangle, pulse, cosine and amplified versions of any waveform applied to its input. Figures 5, 6 and 7 were photographed using a 1-volt peak-to-peak input signal from my function generator. Except for the trace shown in Fig. 7, the input waveform in each case was a 400-Hz square wave.

Figure 5 shows a triangle output waveform. Note here that there are two different amplitudes displayed. The difference between them was not the input waveform (both were 1 volt p-p, 400-Hz square waves) but the gain of the integrator—that is, the value of the capacitor used in the feedback network. These differences are switch selectable with controls on the front panel of the project.

Three different pulse widths are shown in Fig. 6. The difference between the waveforms was the setting of potentiometer *R9*. The waveform shown in Fig. 6(C) is the maximum attainable level with this circuit and is nearly a square wave. The narrower pulses in Fig. 6 (A) and (B) are more clearly "pulse-like" waveforms.

One function of the Miller integrator is its its ability to phase-shift a sine wave by 90 degrees. If the input waveform is taken to be a sine, then the output of the Miller integrator will be a cosine waveform. Figure 7 shows the input and output waveforms superimposed on each other. Note here that the similarity of amplitudes is false except at one setting of the integrator switch. Normally, the output waveform's amplitude will be either lower or higher than that of the input waveform. How-



(A)

(B)

(C)

Fig. 6. Three different-width pulses produced by project: (A) is maximum attainable level; (B) and (C) are more clearly "pulse-like" in nature.

form at the integrator's output is clipped. Correct setting of the OFFSET control will eliminate this.

Dc power for the project can be supplied by a pair of 9- to 12-volt dc batteries. However, it is better to use an ac-operated dc power supply. The schematic diagram for this power supply circuit is shown in Fig. 9. This is a standard ±12-volt, 250-milliampere supply. Bridge rectifier *RECT1* should be rated at not less than 50 volts and 1 ampere PIV, while power transformer *T1* should be either a 12-0-12 volt ac or 25.6-volt ac center-tapped unit rated to deliver at least 250 milliamperes.

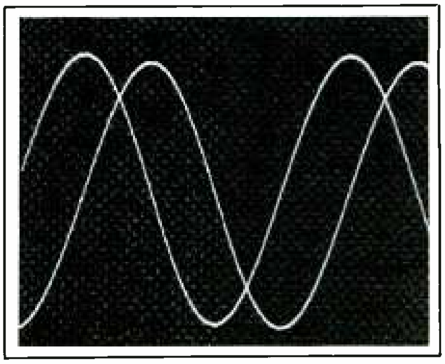


Fig. 7. Input and output waveforms of project superimposed on each other. Amplitudes have been rearranged by adjusting scope's vertical input to more clearly show phase shift.

ever, I have rearranged the amplitudes by adjusting the oscilloscope's vertical input to more clearly show the phase shift.

Figure 8 illustrates two misadjustments of the project's front-panel controls. In (A), you see incorrect selection of the integrator's time constant (the value of the feedback capacitor). Selecting a different capacitor with the front-panel switch will correct this defect, unless the pseudo-sawtooth is really the waveform you want.

The result of misadjustment of the OFFSET control is illustrated in Fig. 8(B). In this case, the triangle wave-

Construction

There is nothing critical about component arrangement or wire routing. Therefore, you can use any traditional wiring technique to assemble the project. If you wish, you can design and fabricate a printed-circuit board. Alternatively, you can assemble the components on perforated board that has holes on 0.1-inch centers using appropriate Wire Wrap or solder-type hardware, as is shown in the interior view of my prototype in Fig. 10. Whichever way you go, however, be sure to use sockets for the DIP integrated circuits.

Carefully follow Fig. 4 (A) and (B) for wiring the main circuit and Fig. 9 for wiring the power-supply circuit. As you make each conductor and component run, trace it on the appropriate schematic diagram or a photocopy of it. This way you will keep track of what you have done and what remains to be done. Do *not* install the ICs in their sockets until after you have made preliminary voltage checks to ascertain that the circuit has been correctly wired.

Once the circuit-board assembly has been wired, select an enclosure for the project. Though I used a so-called "instrument" case for my prototype (see lead photo), you can use any other type of enclosure that will accommodate the circuit-board assembly and power transformer on its floor and has ample room on its front panel for mounting the various controls, switches and jacks.

Machine the enclosure as needed, drilling mounting holes through the floor for the circuit-board assembly and power transformer. This done, drill an entry hole for the ac line cord and another hole for mounting the fuse holder through the rear panel. (Note: If you wish, you can replace the ac line cord with a chassis-mount male ac receptacle and use a separate plug-in ac line cord for the standard line cord normally used in such projects, as I did in my prototype.) Finally, drill mounting holes for the controls, switches and jacks through the front panel. If you wish, you can also wire a neon-lamp with current-limiting resistor directly across *T1*'s primary conductors after the POWER switch. If you do this, drill yet another hole in the front panel, above the hole for the POWER switch, in which to mount the lamp. Deburr all holes and line the ac cord's entry hole with a rubber grommet.

Pre-wire one lead of *C20* through *C28* and *R5* through *R18* to the appropriate lugs of rotary switch *S1*, as illustrated in Fig. 4(B). Neatly bundle all free capacitor and resistor

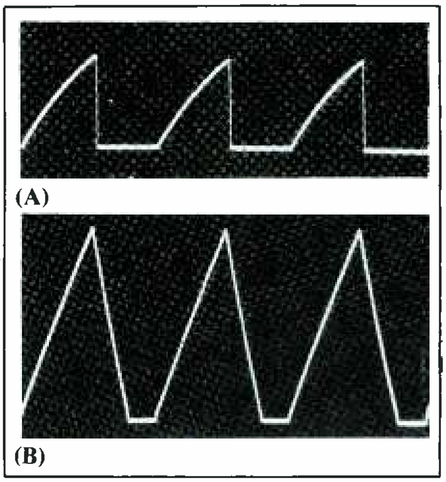


Fig. 8. Results from misadjustment of project's controls: (A) incorrect selection of integrator time constant and (B) wrong adjustment of OFFSET *control.*

leads together. Strip ½ and ¼ inch of insulation from opposite ends of a 6-inch-long hookup wire. If you are using stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Tightly wrap the end from which the ½ inch of insulation was stripped around the capacitor-and-resistor-lead bundle and solder the connection.

Loosely mount this switch in the hole drilled for it through the front panel and place on its shaft a pointer-type control knob. Rotate the knob through each switch position without allowing the switch to move and lightly mark the position on the panel where the pointer on the knob comes to rest in each case. If the marks are not symmetrically located, remove the knob and reposition the switch as necessary. Replace the knob and once again rotate it through each switch position, marking the location the pointer comes to rest. Remove and set aside the knob and switch. Repeat the entire operation for rotary switch *S2*.

Label the switch positions and functions of all front-panel controls. If you use a dry-transfer lettering kit, protect the legends with several light coats of clear acrylic spray. Allow each coat to dry before spraying on the next.

When the spray acrylic has completely dried, mount the fuse holder on the rear panel and route the ac line cord through its grommet-lined hole (or mount the male ac receptacle in its hole). Then mount the power transformer on the floor of the enclosure and wire its primary circuit to the fuse holder, POWER switch and line cord (and neon indicator if you are using it, lengthening its leads as necessary with hookup wire and insulating the soldered connections with small-diameter heat-shrinkable tubing or insulating plastic tubing).

Set the circuit-board assembly inside the enclosure near the power transformer and wire the latter's secondary leads to the appropriate points in the circuit. Then mount the controls, switches and jacks (and neon lamp, if used) in their respective holes in the front panel. Run appropriate lengths of hookup wire between the lugs of these components and the points in the circuit to which they are shown connected in Figures 4 and 9.

Before mounting the circuit-board assembly in place, carefully check all component installations for proper wiring and all soldered connections. If you locate a component that is installed in the wrong location or is installed backward, remove it and correct the installation(s). Reflow the solder on any suspicious connection. When you are satisfied with your wiring, mount the circuit-board assembly in place on the floor of the enclosure using ½-inch or longer spacers and suitable No. 4 or No. 6 machine hardware.

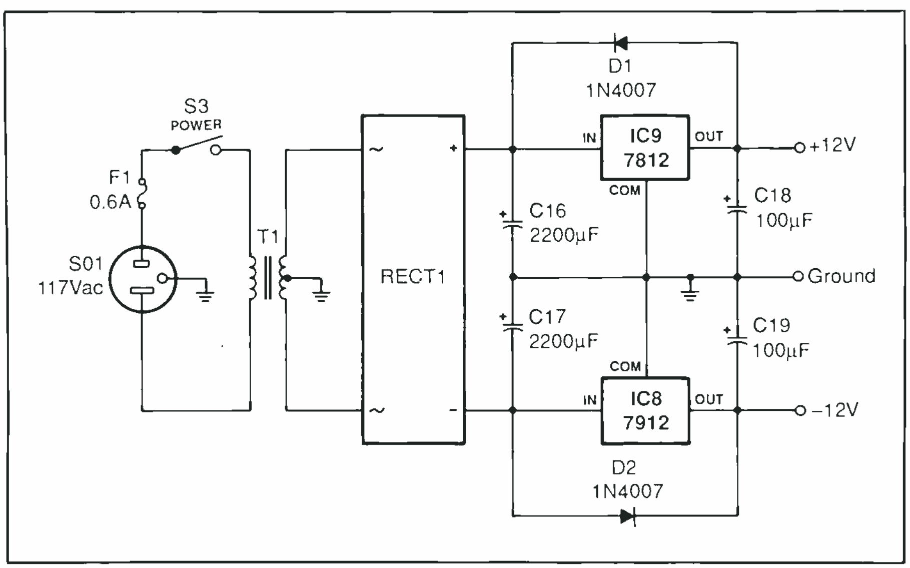


Fig. 9. Schematic of ac-line-powered ±12-volt dc supply recommended for powering the project.

Checkout & Use

With the ICs still not installed in their sockets, plug the project's line cord into an ac outlet and flip the POWER switch to "on." If you installed the optional neon POWER indicator, it should come on.

Connect the common lead of a dc voltmeter or multimeter set to the dc volts function to a convenient circuit ground point, such as the negative lead of *C16* or positive lead of *C17* and leave it so connected for all voltage tests. Now touching the meter's "hot" probe to pin 7 of all IC sockets except that for *IC5*; you should

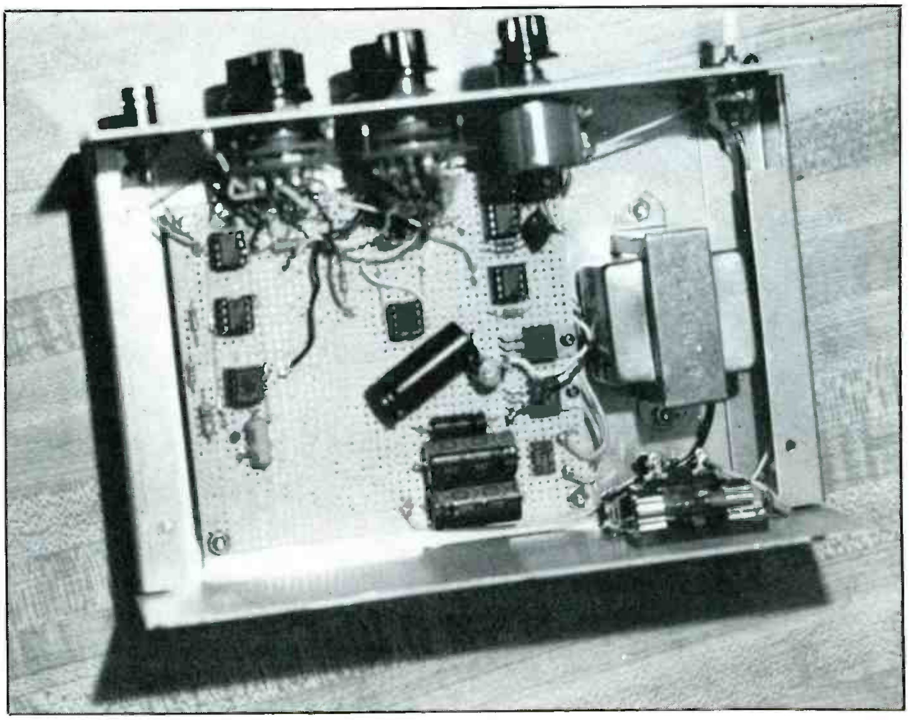


Fig. 10. Interior view of author's prototype. Note that all controls, switches and jacks mount on front panel, circuit-board assembly and power transformer mount on floor of enclosure, and fuse holder mounts on rear wall above entry hole for ac line cord.

obtain a meter reading of +12 volts. Touching this probe to pin 8 of the *IC5* socket should yield the same reading. Now touch the "hot" probe to pin 4 of all IC sockets; this time the reading should be −12 volts.

If you do not obtain the +12 or −12 volts at any of the points mentioned, check the output line(s) of the power supply. If you fail to obtain a reading or get an incorrect reading at any single point in the circuit, you must power down and troubleshoot to correct the wiring error. Do not proceed to installation of the ICs in their respective sockets until you are certain your wiring is correct.

Once you are sure of your wiring, power down the circuit and allow sufficient time for the charges to bleed off the electrolytic capacitors. Then carefully install the ICs in the sockets. Make sure you install each in its correct socket and that no pins overhang the sockets or fold under between ICs and sockets.

The only way to learn how to use this project is to experiment with the settings of the various controls. Use suitable cables to connect the output of your signal generator to the INPUT jack of the project and OUTPUT jack to the input of your oscilloscope and go to town experimenting with various control and switch settings until you become familiar with the project's operation.

With this accessory, you will breathe new life into your dated audio signal generator. If you do not have an audio signal generator, you can still use this project; simply build any of a number of sine- and/or square-wave generating circuits using operational amplifiers and use these to drive the project. **ME**

Note: Some of the material in this article is based on the author's IC User's Casebook *published by Howard W. Sams & Co., No. 22488; $12.95.*

Air Conditioner Brownout Protector

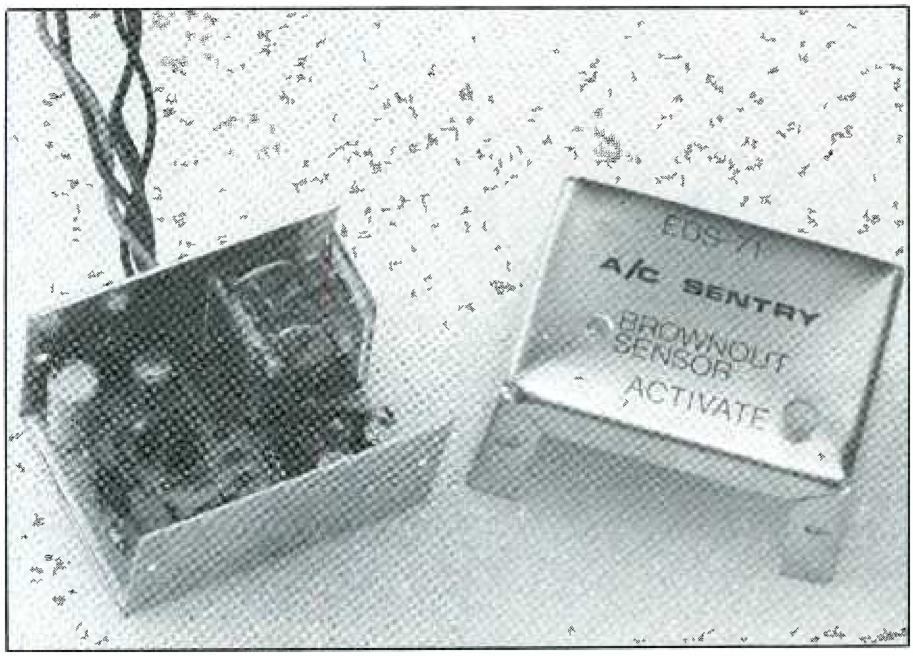
Low-cost device prevents air conditioner compressor damage due to brownouts or blackouts, and also boosts operating efficiency up to 15 percent

By David Miga, CET

It costs a lot of money to repair or replace the compressor in a home air conditioner. Since this expensive component can be easily damaged by an intermittent power condition, such as a commonplace electric power brown-out or blackout, the simple protective device described here should interest anyone with home air conditioning.

Called the "A/C Sentry," it's designed primarily for use with central air-conditioning systems, where installation is very easy. It can be used to protect a room window air conditioner, too, with the addition of a low-voltage power transformer and some extra labor.

Before we examine the relevant circuitry, let's first discuss air-conditioning principles and how the A/C Sentry overcomes home air conditioner design inadequacies that expose the compressor to costly damage.



A/C Basics

Air conditioning (and refrigeration) works on the thermodynamic principle that heat naturally transfers itself to a colder object. The object losing heat gets colder, while the one receiving heat gets warmer. Among key elements in an air-conditioning system that make use of this law of physics are a gaseous refrigerant called Freon, a compressor, a condenser, and an evaporator, with a supportive cast of blower motors, relays, filter, etc.

For cooling, the compressor is switched on. Typically powered by 220 volts ac, the compressor's electric motor draws the low-pressure Freon gas from the line and compresses it to a high-pressure (200 to 300 psi), high-temperature gas. The hot gas moves through condenser coils, where it's cooled through a heat-exchange process that transfers heat to the outside air with the help of a large fan blower motor, and condensed to a liquid.

The liquid then flows through an expansion valve (or "capillary tubes" on smaller systems), where pressure is lowered to between 30 and 65 psi. It then moves through evaporator coils, evaporating to a gas as it absorbs heat from filtered warm air surrounding it that was relayed from the return-air blower. Theory aside, just recall that when a liquid evaporates, it creates a cooling condition, and you've got the principle of air conditioning down pat.

While the newly cooled air continues on its merry way through ducts to various outlet grilles in rooms, the now-heated refrigerant is quickly sucked into the compressor, where the cycle starts again to get rid

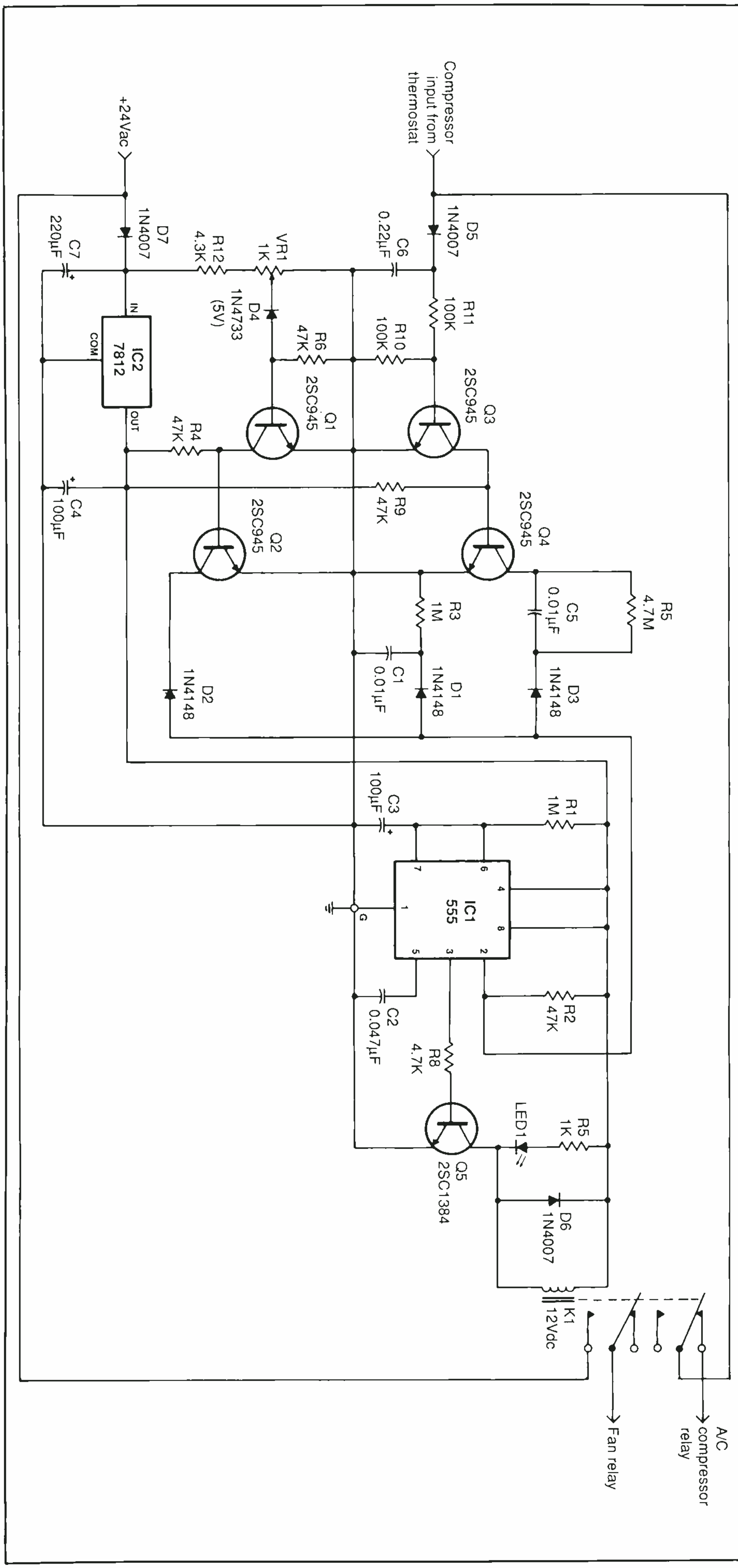


Fig. 1. Complete schematic diagram of A/C Sentry's circuit.

of the heat and supply cooled refrigerant anew to absorb heat from a home's air.

It's apparent from the foregoing discussion that the compressor is a particularly hard-working component. Furthermore, if anything goes wrong with it, you can't repair it because it's hermetically sealed. To make matters worse, its motor-driving mechanism isn't very powerful, making it susceptible to damage during the electrical brownout and blackout occurrences that increasingly plague our developed society.

Here's why intermittent-power conditions can be so deadly to an a/c compressor. When the compressor first turns on, the pressure at its input and output has usually equalized. Consequently, the compressor motor has just enough strength to start up. After operating a few seconds, the pressure on the inlet to the compressor may drop to 50 psi, while the pressure on the outlet side may be 275 psi.

As long as the motor continues to run, inertia maintains motion. However, if power to the compressor should fail for a few seconds and then reappear, the weak compressor motor cannot restart against such a high pressure differential. What results is a locked rotor that will quickly cause the motor's windings to overheat and eventually burn out.

Although there are some safety devices installed in central air-conditioning systems, such as a main circuit breaker, these do *not* operate quickly enough to prevent damage from occurring in the system. In fact, the main function of these safety devices is prevention of fire and explosion—not for preventing damage to the air-conditioning system! These safety devices usually let a problem exist for a minute or so before activating, which is more than long enough to do irreparable damage to the compressor system. Also, if a brownout should occur, there will in effect be no safety devices at all in the system; hence, an already weak motor will rapidly overheat and lock up.

To provide effective protection for your air-conditioning system, the A/C Sentry is designed to continuously monitor the ac power line. At the slightest hint of a power-line problem, the project shuts down the compressor for 3 minutes, which has been determined to be long enough for Freon pressures at the input and output sides of the compressor to equalize. The project then restarts the compressor.

The A/C Sentry is designed to be used with almost any home central air-conditioning system. The sensitivity of its threshold voltage prior to triggering the time-delay countdown as well as the duration of the time delay itself are both adjustable to suit virtually any possible system requirements.

The A/C Sentry does more than just protect your air conditioner's compressor during normal operation. Instead of both the compressor and fan shutting down when the desired room temperature is reached, the A/C Sentry continues to run the fan for 3 minutes longer to prevent wastage of the cool temperature around the evaporator. By forcing the cool air into the room, the off time of the compressor is extended, thus saving you both energy and money.

This project will work with any standard 24-volt ac thermostat in central air, HVAC systems with air conditioning and heat or HVAC systems with reverse cycle. The project was designed primarily for use with central air-conditioning systems. It can be adapted to protect window air conditioners, too, but you will have to supply it with a source of 24 volts ac because individual units normally do not have power transformers.

PARTS LIST

Semiconductors

D1,D2,D3—1N4148 or 1N914 small-signal diode
D4—1N4733 or similar 5-volt, 1-watt zener diode
D5,D6,D7—1N7007 or similar 1,000-volt, 1-ampere silicon rectifier diode
LED—Super-bright light-emitting diode (Radio Shack Cat. No. 276-066 or similar)
IC1—NE555N timer/oscillator
IC2—7812 +12-volt regulator
Q1 thru Q4—2SC945 or similar 60-volt, 200-mA general-purpose npn silicon transistor
Q5—2SC1384 or similar 75-volt, 1-ampere general-purpose npn silicon transistor

Capacitors

C1—0.1-μF, 50-volt Mylar
C2—0.047-μF, 50-volt Mylar
C3,C4—100-μF, 25-volt electrolytic
C5—0.01-μF, 50-volt Mylar
C6—0.22-μF, 50-volt Mylar
C7—220-μF, 50-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1,R3—1 megohm
R2,R4,R6,R9—47,000 ohms
R5—1,000 ohms
R7—4.7 megohms
R8—4,700 ohms
R10,R11—100,000 ohms
R12—4,300 ohms
VR1—1,000-ohm, 10-turn, pc-mount trimmer potentiometer

Miscellaneous

RLY1—12-volt dc relay with 4-poles and 3-ampere/pole capacity (Radio Shack Cat. No. 275-214 or similar)
Printed-circuit board; suitable enclosure (2.75" × 2.0" Radio Shack Cat. No. 270-235 or similar); small L brackets; clip light for LED; machine hardware; hookup wire; solder; etc.

Note: The following items are available from Electronic Design Specialists, Inc., 951 SW 82 Ave., N. Lauderdale, FL 33068: ready-to-wire pc board with layout, $15 + $3 P&H; complete kit of parts, including enclosure and instructions, $49 + $6 P&H. Florida residents, please add state sales tax.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the A/C Sentry's circuit. As you can see, the circuit derives its power directly from the 24 volts ac that already exists at the central air-conditioner's control relay box. This 24 volts ac is rectified to pulsating dc by *D7* and filtered to dc by *C7*. The dc potential is about 34 volts (24 volts rms × 1.414). This is continuously monitored by the *R12* through *Q2* brownout-sensing ("glitch") circuit, whose sensitivity is adjustable via trimmer control *VR1* and can be set to the ideal brownout trigger potential of 100 volts ac.

Even though the sensor circuit is actually monitoring a dc potential, any drop in the ac voltage fed to the circuit will show up as a decrease in the dc voltage. So, *R12* through *Q2* are indirectly keeping tabs on the ac potential. To make the response time of the glitch detector circuit less than 0.25 second, the value of *C7* provides a minimum of filtering.

Except for the glitch-detector circuit, the rest of the project requires a 12-volt dc power source. To obtain this, the 34 volts dc at the output of the rectifier/filter combination is passed through voltage regulator *IC2*. Additional pre- and post-regulation filtering are provided by *C7* and *C4*, respectively.

In Fig. 1, 555 timer *IC1* can be triggered by three different conditions through *D1*, *D2* and *D3*. On any blackout that lasts longer than 0.25 second, *C1* triggers *IC1* into its high state through *D1*. This sends *Q5* into conduction and energies *K1*. When this occurs, one set of contacts disconnects the line from the thermostat to the compressor relay, and the other parallels the thermostat's switch to the fan relay, turning on the fan. With *LED1* wired across the relay's coil, the light-emitting diode will be on whenever *RLY1* has been energized.

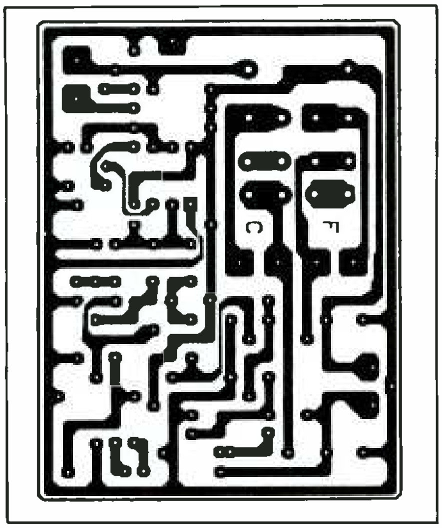


Fig. 2. *Actual-size etching-and-drilling guide for project's printed-circuit board.*

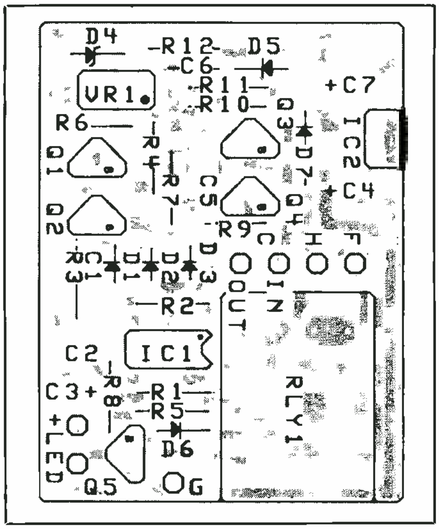


Fig. 3. *Wiring guide for pc board. Use this as a rough layout guide if you use perforated-board construction.*

Connected across *C1* as shown, *R3* serves as a discharging device for this power-on trigger capacitor so that the A/C Sentry will be ready for another blackout within 1 second or so. The brownout circuitry doesn't simply trigger *IC1* through *D2*; it holds the timer chip in its high state for as long as the brownout is in effect. To achieve this, a lesser-known feature of the 555 timer chip is utilized, with the chip neither in a retriggerable or a non-retriggerable monostable state but somewhere between the two.

Through *D3* is the third way of triggering *IC1* . The circuit to accomplish this is made up of *D5* through *Q4*, which monitors the compressor relay output line from the thermostat to the compressor relay. When the compressor is switched on by the thermostat, the collector of *Q4* is brought to a high-impedance state. This allows *C5* to build up equal voltage on both sides by *R7*. When the compressor is switched off under normal operating conditions by the thermostat, *Q4*'s collector goes low and triggers *IC1*. When this occurs, *RLY1* energizes and applies power to the fan for 3 minutes to move whatever cool air is still in the evaporator chamber into the living area.

You can vary the length of *IC1*'s time delay (the period during which the fan remains on) by changing the value of *C3*. For example, if your compressor requires only 1.5 minutes of rest for Freon pressure to equalize, use a 47-microfarad capacitor for *C3*. On the other hand, if your compressor requires more than 3 minutes to achieve the balanced-pressure state, use a 220-microfarad capacitor. If you aren't sure of the required time, you can call the manufacturer of the air conditioner or the dealer from whom you purchased it for the exact time, but a 3-minute delay should work for most a/c units used in private homes.

Construction

Being that this circuit deals basically with dc potentials, there is nothing critical about component layout and wire routing. Therefore, just about any traditional wiring approach can be used to build the project, including a printed-circuit board and perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Printed-circuit construction is highly recommended, however, because it will withstand temperature and vibration extremes better than most point-to-point wiring will.

From here on, we'll assume you're using pc construction. You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 2. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

When the board is ready to be wired, orient it as shown in Fig. 3. Start populating the board by installing and soldering into place the resistors, then the transistors, capacitors, 555 timer chip, relay and regulator chip, in that order. Hold off installing the LED until you've selected an enclosure in which to house the circuit-board assembly. Your choice may require the LED's leads to be lengthened with hookup wires for it to mount on one wall of the enclosure and still reach the appropriate holes in the board. After installing them, make certain that the electrolytic capacitors are properly polarized and that the diodes and LED are properly oriented before soldering their leads to the copper pads on the bottom of the board. Use plenty of solder on each connection you make to the circuit-board assembly but not so much that it creates unwanted solder bridges.

When all components have been installed, strip ¼ inch of insulation from both ends of five 18- to 24-inch lengths of *stranded* hookup wire. Use wires with different colors of insulation—preferably yellow, red, green, black and orange—to identify where each wire is to go. The first three colors conform to the color-coding scheme commonly used in a/c wiring (see Fig. 5). Black and orange can be used for the OUTPUT and system common or ground. Tightly twist together the fine wires at both ends of all wires and sparingly tin with solder. Plug one end of each of these wires into the holes labeled F, G, H, IN and OUT. Insulation

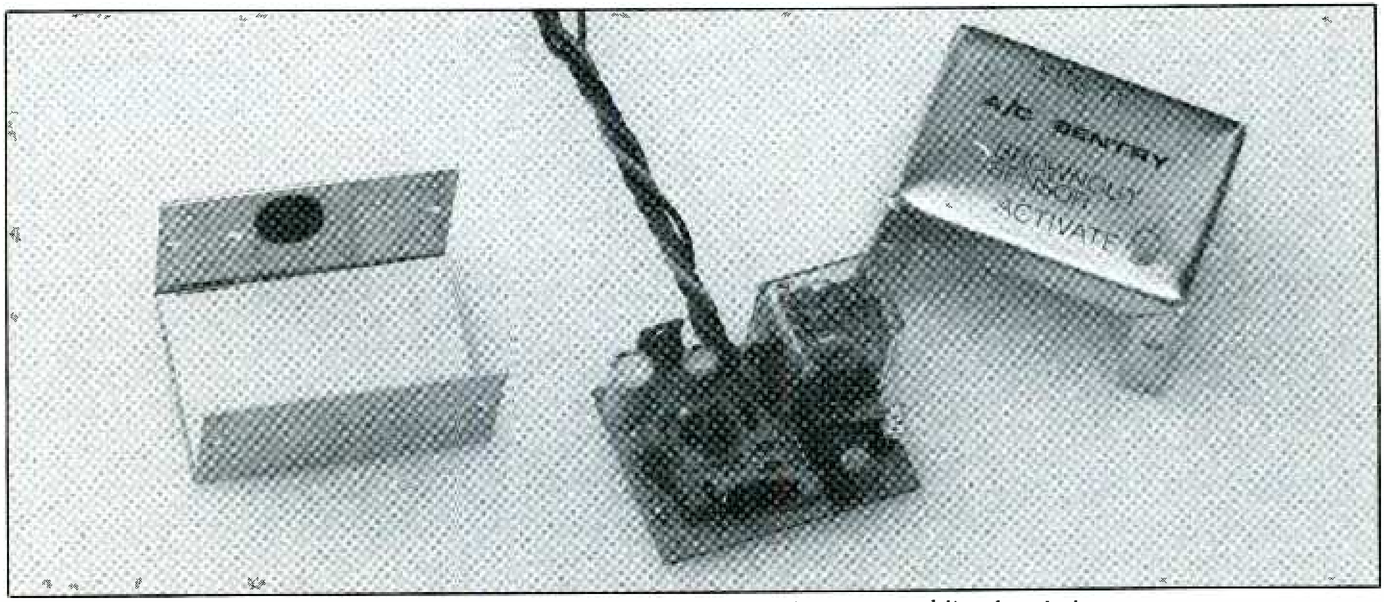


Fig. 4. Interior view of completed project prior to assembling box halves.

color coding is as follows: green for the F (fan) hole, black for G (system ground), red for H (24 volts ac), yellow for IN (input) and orange for OUT (output) and solder into place.

Select an enclosure for the project that's large enough to accommodate the circuit-board assembly. A small metal utility box like that shown in the lead photo is an ideal choice. Machine the enclosure as needed by drilling an exit hole for the five conductors that connect to your air-conditioning system's wiring (⅜ inch), a mounting hole for the LED (¼ inch), an access hole to the adjustment slot on trimmer *VR1* (5/32 inch), and a mounting hole for the voltage regulator (5/32 inch).

Before drilling the LED and trimmer holes, make sure you accurately locate their positions on the panel with reference to the locations of the two components on the circuit board when the latter is finally mounted in place. While you're at it, drill small holes to accommodate sheet-metal screws that will secure a pair of small L brackets to the enclosure for mounting the project in the selected location, or replace two of the screws supplied with the box with slightly longer ones and mount the L brackets in place with these when you assemble the box.

With the circuit-board assembly in place in the lower half of the enclosure, plug the leads of the LED into their holes and hold the device vertical to the board's surface while sighting across the two upright walls. If the domed case of the LED sticks up beyond the height of the case's walls, solder the leads into place, first making sure that the LED is properly polarized.

If the domed case doesn't sit higher than the enclosure's walls, the LED's leads must be lengthened with hookup wire. To do this, strip ¼ inch of insulation from both ends of 2-inch red- and black-insulated wires. If you're using stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Plug one end of the red-insulated wire into the LED hole identified with a + and solder into place. Then solder one end of the black-insulated wire in the other LED hole. Slip over the free ends of both wires a 1-inch length of small-diameter heat-shrinkable or insulating plastic tubing.

Identify the cathode lead of the LED and trim it to length of ½ inch. Form a small hook in the remaining lead stub and crimp this to the free end of the black-insulated wire. Solder the connection. Do the same with the red-insulated wire and anode lead. Then slide the tubing up over the connections until it is flush with the bottom of the LED's case. If you're using heat-shrinkable tubing, shrink the tubing into place.

Push a "cliplight" into the LED's hole. Before installing the circuit-board assembly inside the box, cement a thick layer of insulating cardboard (like Bainbridge or other heavy art board) to the floor. Set the circuit-board assembly in place, and secure the voltage regulator to the enclosure's wall with a 4-40 machine screw. Place a mica insulator between the regulator and wall and use a shoulder fiber washer with the machine screw. No part of the circuit, including the regulator, should be allowed to make electrical contact with the enclosure! Shown in Fig. 4 is the completed project just before the utility box in which it is housed is finally assembled.

Place a small rubber grommet in

the hole drilled for the five wires that connect the project into your air-conditioning system through the grommet-lined hole. Then route the wires through the grommet. Slide the LED into it if it's connected to the circuit board via wire leads or carefully slide the top half of the enclosure onto the bottom half, making sure the LED's case enters the open end of the clip, if the LED is mounted directly on the board.

Installation & Alignment

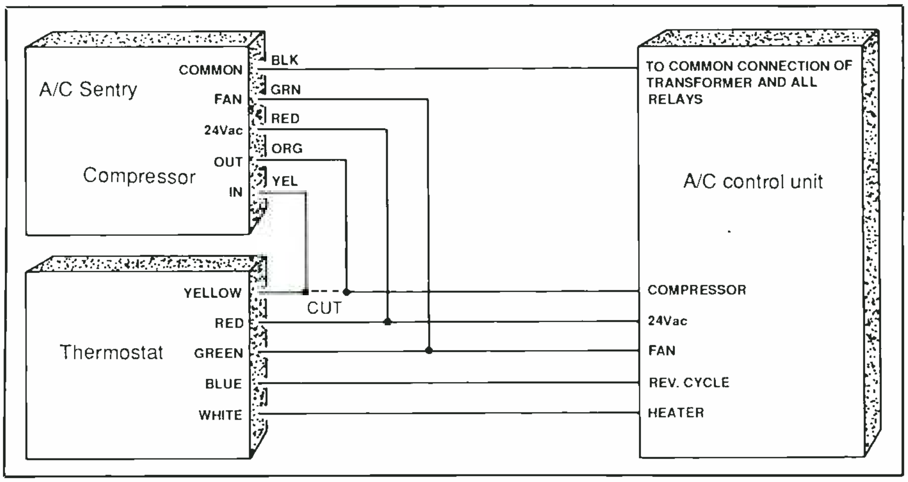


Fig. 5. A typical HVAC wiring diagram, with connections shown for project.

Figure 5 is a typical HVAC (heating/ventilating/air conditioning) wiring diagram, with areas labeled where the A/C Sentry is to tie into the system. Whether your system is central air only, HVAC (heating and cooling) or a reverse-cycle unit, hookup is still the same.

A five- or six-conductor cable usually connects the thermostat to the air-conditioning system's control relay. Insulation colors for these wires is an industry standard: red for the source of 24 volts ac, green for the fan relay, yellow for the compressor relay, and (in HVAC systems) white for the heater coil. In reverse-cycle systems, blue insulation is used on the wire to the reversing relay.

Note in Fig. 5 that the project requires connection to only three of the five or six wires in the system. It does, however, require a fourth connection to the system's electrical ground. This is *not* in the thermostat, but at the unit's relay control box. Therefore, you'll want to mount the project close to the relay box.

To locate the system's common conductor, first find the 24-volt ac power transformer and trace its output wires. One will connect to the red-insulated wire in the harness to that goes to the thermostat; this is your 24-volt ac line. The other wire from the transformer will connect to the common coil connections of all relays in the system; which identifies it as the common "ground" for the system and the logical tie point for the project's ground lead.

Before you do anything electrical in the a/c system, *turn off ac power to it*. Do this by flipping off the circuit breaker or removing the fuses. Then when ac power is completely disabled, wire the A/C Sentry into the system exactly as shown in Fig. 5. Note that the red-insulated, green-insulated and common system wires are simply tapped into. You must cut the yellow-insulated compressor relay wire and join the cut ends with the INPUT and OUTPUT wires coming from the project as shown. Before restoring ac power to the system, turn the adjustment screw of *VR1* at least 10 turns counterclockwise. Make sure that the thermostat is set to coldest so that the system doesn't cycle on and off while you are aligning the project.

Turn on the circuit breaker or replace the fuses and set the system for cooling, fan on automatic. The fan will come on but the compressor will remain off, and the project's LED will be on. After the 3-minute delay, the LED will extinguish and the compressor will operate.

Now use a small screwdriver to slowly adjust the setting of *VR1* clockwise. At about five turns or so, the LED should light and the compressor turn off, signaling that the brownout sensor adjustment was turned beyond threshold. Adjust *VR1* counterclockwise one-half turn and wait for the delay to time out.

When the compressor turns on again, adjust *VR1* clockwise even more slowly than before. Note the exact point at which the LED turns on and readjust the setting of the trimmer control counterclockwise *exactly* half a turn. This calibrates the A/C Sentry to turn off the compressor with a 10-volt drop. Some older homes have marginal electrical systems, which will cause the project to falsely trigger too often. To correct for this condition, turn *VR1* counterclockwise three-quarters of a turn, which will now give a 15-volt "window."

A final note: If you installed an "en-ergy-efficient" programmable ther-mostat and have come home to find your air-conditioning system's breakers off, this is because the thermostat switched from warmer day period to the cooler night period before the compressor had sufficient time to power down. This kind of thermostat, when used by itself, can damage your compressor. The Air-Conditioner Sentry will prevent such damage because it allows the compressor to power down for 3 minutes even though the thermostat may be attempting to run the compressor **ME**

BOOKS

Mastering WordPerfect 5 by Susan Baake Kelly. (Sybex Inc. Soft cover. 709 pages. $21.95.)

This massive volume is an authoritative guide on the use of the latest version of the popular WordPerfect word processor. Though meant to supplement the manual that comes with the software, this book can easily be used in its stead. It assumes no prior familiarity with WordPerfect, making it suitable for those people who have no prior experience with this word processor. This is not to say that it is just a beginner's manual; actually, it is a guide for even power users. The material contained in this book's 20 chapters successively builds user power, starting with the very basic and proceeding to the advanced functions.

The book is divided into three sections—fundamentals, advanced features and supplemental features. Following an opening chapter that introduces WordPerfect in the first section, the book goes on to simple creation, editing and printing of a document and then devotes the next three chapters to more extensive editing, text formatting and using the block feature. With the basics taken care of, the advanced features section proceeds with controlling page layout, search and replace, advanced formatting, maximizing printer use, automating functions, footnotes and endnotes, producing documents with multi-column layouts, creating graphics illustrations, and using desktop publishing techniques. Supplemental features introduces file management tools, merging, the built-in calculator, sort and select, macros and use of the speller and thesaurus. Throughout the book are numerous screen illustrations that help to clarify the text material.

Discussed in detail are all the new desktop publishing capabilities of WordPerfect 5, including text formatting with several font styles, adding graphics to documents and laser printing. A new new color-coded Sybex "Fast Track" feature at the beginning of each chapter summarizes the chapter's contents, lists the steps needed to complete specific tasks and refers to the page on which more detailed information can be found.

Separate appendices cover installation of WordPerfect on floppy- and hard-disk systems; cursor movement chart and ASCII table; and companion programs. A removable WordPerfect 5 Desktop Reference chart, printed on heavy cardboard stock and bound in at the back of the book, is perforated for easy removal and use. If you already have or are planning to buy WordPerfect 5, plan on getting this book—you will be glad you did.

Instant Access Guide to LOTUS 1-2-3 by Nancy Mann. (Price Stern Sloan. Spiral bound, 248 pages. $14.95.)

"Just give me the facts, ma'am." This is essentially what author Ms. Mann does for the ever-popular Lotus 1-2-3 integrated spreadsheet/database/graphics program. This is a fast-retrieval user's reference book for one of microcomputer software's evergreens.

The text uses mostly a visual approach to various commands rather than heavy text. Plenty of command-key symbols and illustrations make it easy to use or learn how to use the many features of 1-2-3. Succinct explanations support the key strokes shown. A refreshing what, why and how presentation, together with good overall organization, should endear this book to anyone who works with the program on an infrequent basis or wants a neat guide that's also a learning tool.

NEW LITERATURE

TMOS Wall Chart. Small-signal and power MOSFET products in both n- and p-channel polarities are shown in a variety of package options on Motorola's free "Power To Go!" wall chart. Device ratings from 30 to 1,000 volts and current ratings ranging from 0.1 ampere to 60 amperes are listed and pictured. Table headings are by package type. The tables include voltage ratings, maximum on resistance with the associated test conditions, current ratings and power ratings. For a free copy, write to: Motorola Literature Distribution, P.O. Box 20912, Phoenix, AZ 85036.

Linear Cross-Reference Guide. A new cross-reference guide that lists the company's replacements for industry standard linear integrated circuits is available from Linear Technology. The brochure also lists pin-for-pin LTC replacements that have improved performance or enhanced electrical specifications over industry standard products from a variety of IC manufacturers. For a free copy, write to: Gary Evans, Advertising Manager, Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7487, or call 800-637-5545.

Digital Storage Oscilloscope Buyer's Guide

This section contains abbreviated technical specifications for a representative line-up of digital storage oscilloscopes. Though not meant to be a complete buyer's guide, this listing includes models from most major manufacturers of these instruments. These models cover the entire spectrum of available DSOs, ranging from the low end of the price spectrum to near the highest end. They include bench-only models and portable instruments for field service. For more information on any product listed, contact the manufacturer/supplier in writing by addressing mail to the appropriate address given in the Names & Addresses box or by calling the number given. Accuracies are for vertical data. Sampling rate is usually the maximum. All dimensions are in height × width × depth.

Hand-Held Digital Storage Oscilloscopes

Createc Scout SC 01
(Also available from Tektronix)

Display	LCD (128 × 128 points; 2.3″ × 2.3″)
Bandwidth	10 MHz repetitive; 2 MHz single-shot
Sampling rate	20 MS/s
Resolution	7 bits vertical; 7 bits horizontal
Accuracy	1% + 1 LSB
Memory & Storage	256 words/channel record memory; nonvolatile memory for saving 9 complete recordings and 1 complete setup for 3 months maximum
Dimensions/Weight	10″ × 4″ × 1.5″/2 lbs.
Other features	Digital multimeter, frequency counter, signal computer; Sony Walkman-based "Audio Tutorial"
Price	$1,995

Leader Model LCD 200

Display	LCD (64 × 192 points)
Bandwidth	dc, to 200 kHz; ac, 10 Hz to 200 kHz
Sampling rate	3 MS/s
Resolution	6 bits vertical, 8 bits horizontal
Accuracy	+4%
Memory & Storage	256 words × 4 waveforms × 2 channels; 6 waveforms can be stored and recalled for later reference/study
Dimensions/Weight	8.875″ × 1.5″ × 5.25″/2.1 lbs.
Other features	Digital multimeter; add, subtract and X-Y manipulation of 2 signals; optional companion printer available
Price	$1,645

Tektronix TEK Model T201/T202

Display	LCD (100 × 128 points; 5.76 × 5.76 cm)
Bandwidth	5 MHz repetitive; 2 MHz single-shot
Sampling rate	20 MS/s
Resolution	7 bits vertical, 7 bits horizontal
Accuracy	1% + 1 LSB
Memory & Storage	Nine 256-word single-channel acquisitions can be saved in Save Reference Memory; nine keyboard setups can be saved in Save Setup Memory
Dimensions/Weight	10.1″ × 4.4″ × 1.9″/1.9 lbs.
Other features	Digital voltmeter/time-counter; two interface options; calculator-like interface (T202); traditional oscilloscope interface; signal processing for differential/ratio measurements
Price	$1,995

Full-Size Digital Storage Oscilloscopes

B&K-Precision Model 2520

Display	CRT (8 × 10 cm)
Bandwidth	dc, to 20 MHz; ac, 2 Hz to 20 MHz
Sampling rate	2 MS/s
Resolution	8 bits vertical, 10 bits horizontal
Accuracy	+3%
Memory & Storage	1,024 words × 8 bits × 2 channels
Dimensions/Weight	5.5″ × 12″ × 18.1″/13.2 lbs.
Other features	Analog plotter output; single-shot & equivalent-time sampling; post storage × 10 expansion of waveform; pre-trigger; refresh; roll mode
Price	$1,990

John Fluke Model PM 3320

Display	CRT (10 × 12 cm)
Bandwidth	200 MS/s
Sampling rate	250 MS/s, 10 GS/s (repetitive)
Resolution	10 bits vertical
Accuracy	N.A.
Memory & Storage	four 4K-byte blocks for signal storage and comparison
Dimensions/Weight	6.9″ × 16.5″ × 22.5″/39.6 lbs.
Other features	Post-processing facilities & mathematical functions; automatic set for amplitude, timebase & trigering; built-in plotter drive
Price	$9,900

Gould Model 4070

Display	CRT (10 × 12 cm)
Bandwidth	100 MHz
Sampling rate	400 MS/s
Resolution	8 bits vertical, 10 bits horizontal
Accuracy	+3%

Memory & Storage	1K word/channel (2- and 4-channel versions); 8 waveform & 4 setup storage facilities; nonvolatile memory for 3 months storage
Dimensions/Weight	17.2″ × 19.9″ × 9.6″/25 lbs.
Other features	Automatic setup & rapid acquisition of repetitive signals; main and delayed timebase; automatic calibration & waveform processor; integral digital plotter for instant hard copy
Price	$8,900

Hameg Model HM 205-2

Display	CRT
Bandwidth	20 MHz
Sampling rate	5 MS/s
Resolution	8 bits vertical, 10 bits horizontal
Accuracy	N.A.
Memory & Storage	1,024 words × 2 channels
Dimensions/Weight	5.7″ × 11.22″ × 15″/17 lbs.
Other features	Optional X-Y plotter output & IEEE-488 bus; built-in graphics printer interface; linear interpolator
Price	$958

Hewlett-Packard Model 54120T

Display	CRT
Bandwidth	20 MHz average mode, 12.4 MHz persistence
Sampling rate	4,500 S/s typical
Resolution	12 bits vertical
Accuracy	+0.4%
Memory & Storage	10 front-panel setups can be saved and 4 waveforms can be stored in nonvolatile memory
Dimensions/Weight	N.A.
Other Features	Automatic pulse-parameter measurements; fully programmable; pushbutton hard copies; time & voltage histograms; mathematical waveform operations
Price	$27,825

Hewlett-Packard Model 54201A/D

Display	CRT
Bandwidth	50 MHz single-shot, 300 MHz repetitive
Sampling rate	200 MS/s
Resolution	6 bits vertical
Accuracy	+2%
Memory & Storage	Four nonvolatile for waveforms & 4 front-panel setups
Dimensions/Weight	7.5″ × 16.75″ × 17.625″/28 lbs.
Other features	Automatic waveform measurements; instant documentation; simplified programming
Price	N.A.

Hewlett-Packard Model 54501A

Display	CRT
Bandwidth	100 MHz repetitive, 1 MHz single-shot
Sampling rate	10 MS/s
Resolution	8 bits vertical
Accuracy	+1.5%
Memory & Storage	501 points/channel (4 channels); 4 instrument setups in nonvolatile memory; 4 nonvolatile & 2 volatile waveform storage memories
Dimensions/Weight	N.A.
Other features	Automatic scaling; fully programmable; automatic measurements; instant hard copy output
Price	$3,465

Hitachi Model VC-6020

Display	6″ CRT
Bandwidth	250 kHz storage, 20 MHz non-storage
Sampling rate	1 MS/s
Resolution	8 bits vertical, 10 bits horizontal
Accuracy	+3%
Memory & Storage	1,024 words/channel × 2 channels
Dimensions/Weight	12.4″ × 5.2″ × 14.8″/19.8 lbs.
Other features	Analog recorder/plotter output
Price	$1,950

Hitachi Model C-6050

Display	6″ CRT
Bandwidth	10 MHz single-shot, 60 MHz repetitive, 60 MHz non-storage
Sampling rate	40 MS/s (20 MS/s/channel)
Resolution	8 bits vertical, 12 bits horizontal
Accuracy	+3%
Memory & Storage	4,000 words/channel × 2 channels; two 4,000-word waveform storage
Dimensions/Weight	13″ × 7.4″ × 18.5″/33 lbs.
Other features	Plotter interface; usable as real-time 60-MHz, 3-channel scope; CRT displays functions and cursor movement
Price	$4,950

Hitachi Model VC-6165

(Also applies to Models VC-6265 & VC-6065)

Display	6″ CRT
Bandwidth	25 MHz single-shot, 100 MHz repetitive, 100 MHz non-storage
Sampling rate	100 MS/s
Resolution	8 bits vertical, 12 bits horizontal
Accuracy	+3%
Memory & Storage	4,000 words/channel × 2 channels; two 4,000-word waveform storage
Dimensions/Weight	13″ × 6.3″ × 17.7″/24.3 lbs.
Other features	Envelope/averaging/roll modes; plotter interface; automatic sweep; trigger lock; operates as real-time scope
Price	$7,700

Iwatsu Model SAS-8130A

Display	7" rectangular CRT
Bandwidth	3.5 GHz (12.4 GHz optional)
Sampling rate	70 kHz
Resolution	10 bits vertical, 10 bits horizontal
Accuracy	+3%
Memory & Storage	1,032-point waveforms (four saved); 127-point waveforms (32 saved); 32 programs can be held in memory; 30 user-specified programs can be executed
Dimensions/Weight	2 11/16" × 1 1/8" × 3 7/8"/43.7 lbs.
Other features	Menu-driven software with automatic measurement routines; optional 3.5" floppy-disk drive; averages up to 4,096 sweeps
Price	$19,500

Leader Model LBO 5825

Display	150-mm rectangular CRT
Bandwidth	dc, to 35 MHz; ac, 10 Hz to 35 MHz
Sampling rate	5 MS/s
Resolution	7 bits vertical, 10 bits horizontal
Accuracy	+3%
Memory & Storage	1,024 words × 2 channels
Dimensions/Weight	12" × 5.25" × 15.75"/21 lbs.
Other features	Memory protect & battery backup storage for up to 5 weeks
Price	$2,950

LeCroy Model 9400A

Display	9" diagonal CRT
Bandwidth	175 MHz
Sampling rate	100 MS/s single-shot, 2 GS/s repetitive
Resolution	8 bits vertical, 8 bits horizontal
Accuracy	2% (1% optional)
Memory & Storage	32K bytes/channel × 2 channels; 192K bytes total
Dimensions/Weight	N.A./33 lbs.
Other features	Cursors for absolute & differential time; voltage & frequency measurements; digital plotter firmware drivers for hard copy of display
Price	$9,400

Nicolet Model NIC-310

Display	5" CRT
Bandwidth	150 kHz maximum sensitivity; 300 kHz minimum sensitivity
Sampling rate	1 MHz
Resolution	12-bit A/D converter
Accuracy	+0.2%
Memory & Storage	4K points/channel × 2 channels; storage options: dual 3.5" floppy disk (176 waveforms can be stored), single 5.25" floppy disk (43 waveforms can be stored)
Dimensions/Weight	15.8" × 5.6" × 17.6"/8.6 lbs.
Other features	Storage for IBM PC file format (PC software provided free); GPIB & RS-232 I/O for plotter
Price	$4,995

Panasonic Model VP-5720A

Display	7" CRT
Bandwidth	100 MHz single shot, 15 MHz effective storage
Sampling rate	40 MS/s
Resolution	8 bits vertical, 8K bits horizontal
Accuracy	+3%
Memory & Storage	8K bytes/channel × 2 channels; 24K bytes for waveform storage & comparison
Dimensions/Weight	5.9" × 12.2" × 19.7"/33 lbs.
Other features	Analog/digital operation; time- & voltage-difference measurement cursors; plotter interface & histogram display; go/no-go screening of automated production lines
Price	$6,000

Panasonic Model VP-5740P

Display	7" CRT
Bandwidth	35 MHz single-shot, 35 MHz effective storage
Sampling rate	100 MS/s
Resolution	8 bits vertical, 10K bits horizontal
Accuracy	+3%
Memory & Storage	Three 10K bytes for transient signal; 10 programs of up to 100 steps each
Dimensions/Weight	5.9" × 12.2" × 19.7"/37 lbs.
Other features	Memory expansion available to 20 10K-byte words and up to 45 100-step programs; built-in computer functions for waveform analysis & processing
Price	$9,900

Tektronix Model TEK 2210

Display	8 × 10-cm CRT
Bandwidth	50 MHz non-storage, 2 MHz single-shot
Sampling rate	20 MS/s
Resolution	8 bits vertical, 4K bits horizontal
Accuracy	+3%
Memory & Storage	4K bytes/channel × 2 channels; reference memory for one screen of information
Dimensions/Weight	5.4" × 15" × 17.2"/16.8 lbs.
Other features	Analog & digital capability
Price	$2,395

Tektronix Models TEK 2220/2221/2230

Display	CRT
Bandwidth	60 MHz (2220/2221), 100 MHz (2230)

Sampling rate	20 MS/s single channel; 2 GS/s repetitive
Resolution	8 bits vertical, 10 bits horizontal
Accuracy	+2%
Memory & Storage	4K or 1K bytes single channel selectable (2230); 4K bytes single channel (2221/2220); one 4K or three 1K bytes for acquisition save (2230); one 4K bytes for acquisition save (2221/2220); nonvolatile memory to save 25 waveforms (2230 option)
Dimensions/Weight	5.4" × 14.2" × 17.3"/18 lbs.
Other features	Analog & digital capability; cursors for time & voltage measurements (2230/2221); GPIB or RS-232 printer/plotter PC interface; peak detection (100-ns glitch capture on all sweep speeds); dual timebase (2230)
Price	$2,995 2220, $3,995 2221, $4,995 2230

Tektronix Models 2430A/2432/2440

Display	CRT
Bandwidth	300 MHz (2432/2440), 150 MHz (2430A)
Sampling rate	500 MS/S (2440), 100 MS/S (2432/2430A)
Resolution	8 bits vertical, 10 bits horizontal
Accuracy	+2%
Memory & Storage	1K word/channel × 2 channels; non-volatile memory with 3-year retention
Dimensions/Weight	13" × 6.3" × 18.9"/23.9 lb.
Other features	Automatic test-program sequencing; automatic single-button scope setups; automatic pass/fail waveform testing; automatic measurements; printer/plotter interface; GPIB programmable
Price	$7,950 (2430A), $9,500 (2432), $11,500 (2440)

Names and Addresses

B&K-Precision/Maxtec International Corp.
6470 W. Cortland St.
Chicago, IL 60635
312-889-1448

Createc
3337 Kifer Rd.
Santa Clara, CA 95051
408-738-3744

John Fluke Mfg. Co., Inc.
P.O. Box C90901
Everett, WA 98206
1-800-426-0361

Gould Inc.
Test & Measurement
3631 Perkins Ave.
Cleveland, OH 44114
216-361-3315

Hameg, Inc.
88-89 Harbor Rd.
Pt. Washington, NY 11050
1-800-247-1241

Hewlett-Packard Co.
P.O. Box 10301
Palo Alto, CA 94303-0890
Call HP Sales Office

Hitachi Denshi America, Ltd.
14169 Proton Rd.
Dallas, TX 75244
214-233-762

Iwatsu Instruments, Inc.
430 Commerce Blvd.
Carlstadt, NJ 07072
201-935-5220

Leader Instruments Corp.
380 Oser Ave.
Hauppauge, NY 11788
1-800-645-5104

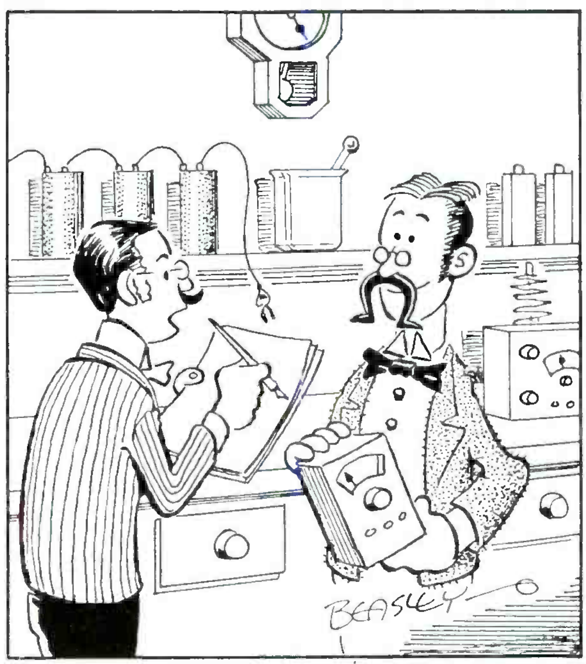
LeCroy Corp.
700 Chestnut Ridge Rd.
Chestnut Ridge, NY 10977-6499
914-578-6046

Nicolet Instruments Corp.
Test Instrument Div.
5225 Verona Rd.
P.O. Box 4288
Madison, WI 53711-0288

Panasonic Factory Automation Co.
50 Meadowlands Pkwy.
Secaucus, NJ 07094
201-392-4050

Tektronix, Inc.
(Hand-held DSOs only)
P.O. Box 1700
Beaverton, OR 97076
1-800-547-1512
1-800-542-1877 in Oregon

Tektronix, Inc.
(Full-size DSOs only)
P.O. Box 500
Beaverton, OR 97077
1-800-426-2200



ALLRIGHT, MR. OHM, WE'LL NAME THE UNIT OF ELECTRICAL RESISTANCE AFTER YOU---NOW WHAT SHALL WE USE FOR A SYMBOL?

ELECTRONICS NOTEBOOK

Experimenting with Super Capacitors

By Forrest M. Mims III

Japan's NEC Electron announced the development of the super capacitor in 1980. This is a new kind of capacitor with considerably more capacitance than conventional capacitors. The farad, the basic unit of capacitance, is so large that conventional capacitors are usually specified in terms of millionths or even trillionths of a farad. Super capacitors have capacitances of up to a farad or more.

NEC's claim to have developed a super capacitor was met with surprise and perhaps a little skepticism. Shortly after its 1980 announcement, NEC flew some of its U.S. staff to Japan for a thorough briefing on the new super capacitors. Details provided by NEC's researchers revealed that the new "supercaps" have 3,000 times the efficiency of a conventional aluminum electrolytic capacitor of the same size. This makes possible a 1-farad capacitor that is less than half the size of a C-size flashlight cell.

While they are commonly used as backup power sources for CMOS RAM, super capacitors have many other uses. They can provide brief periods of backup power for solar-powered equipment. They can power LEDs and LED flasher circuits. They can also be used in simple timer circuits, and they can even serve as short-duration power sources for small lamps and motors.

Later, we'll examine some of these applications for super capacitors in more detail. First, however, let's find out more about how these remarkable components work and how they are made.

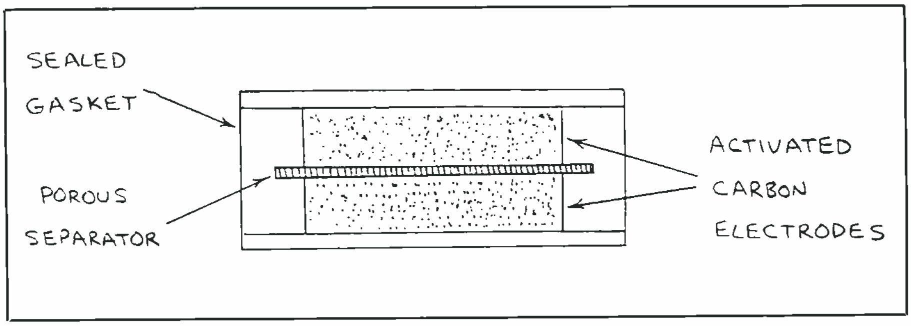


Fig. 1. Internal construction details of a super capacitor.

How They Work

A capacitor is simply two conductors separated by an insulator known as a dielectric. The capacitance of a capacitor is determined primarily by the surface area of the conductors, the distance separating them and the dielectric constant of the insulator between them. The dielectric constant is the ratio of the capacitance of a capacitor with a particular dielectric to that of the same capacitor with air for a dielectric.

You can make a capacitor that has a value of a few picofarads by twisting together two short lengths of insulated wire. For larger values, you can make a "sandwich" of aluminum foil and plastic film.

Prior to the development of super capacitors, electrolytic capacitors provided the highest capacitance of all capacitor varieties. The dielectric of an electrolytic capacitor is formed by depositing a very thin oxide film on an aluminum or tantalum plate. The surface area of the plate is greatly increased by an etching process that leaves a rough, pitted surface. Since the dielectric insulates in only one direction, the terminals of the electrolytic capacitor are polarized.

Super capacitors are not polarized and are projected to have exceptionally long lifetimes. They consist of two conducting surfaces separated by a liquid electrolyte such as sulfuric acid. The key to obtaining exceptionally high capacitance is to use activated charcoal for the conductors. Activated charcoal is a highly porous substance that has an enormous surface area. The total surface area of a few grams of the material is close to an acre!

A super capacitor is made by mixing powdered activated charcoal with an electrolyte such as sulfuric acid to form a thick paste. The capacitance of the paste can range from 200 to 400 farads per gram! Disks of the material are sandwiched on each side of a porous separator to form a capacitor as illustrated in Fig. 1. The porous separator allows charges to move through the electrolyte while separating the plates.

A double layer of charged particles accumulates at the boundary between the electrolyte and the carbon. For this reason, super capacitors are often known as "double-layered capacitors."

Sulfuric acid will decompose into hydrogen and oxygen with an electrical charge in excess of 1.2 volts. Therefore, a single super capacitor element has a maximum working voltage of only 1.2 volts. Capacitors with higher working voltages are made by stacking capacitor elements to form a series array. For example, a 5-volt capacitor is made by stacking up to six capacitors. NEC currently makes 5- and 10-volt super capacitors.

Recall now that the total capacitance of capacitors connected in series is less than the individual capacitance of each capacitor. The total capacitance of two capacitors in series is the product of the two capacitors divided by their sum. The total capacitance of three or more capacitors in series is the reciprocal of the sum of the reciprocals of the capacitance of each capacitor, or $C_{total} = 1/[(1/C1) + (1/C2) + (1/C) + \ldots (1/Cn)]$. This means that each capacitor in a 1-farad series stack if four super capacitors has a capacitance of 4 farads.

Figure 2 illustrates what was inside an NEC double-layer capacitor that I disassembled for this report. Opening the device certainly was *not* easy! In fact, I came away from the experience as impressed by the device's sturdy construction as by its enormous capacitance.

First, I peeled away the capacitor's touch plastic coating. Then, I used a wire cutter to clip away the collar around the edge of the can in which the capacitor was housed. The rim of the can is rolled inward under pressure to form a tight bond between the can and upper terminal. High pressure is required to provide a good electrical connection between the terminals and the relatively high resistance of the conductive plastic that lines each end of the capacitor stack.

After clipping away the collar, I was able to remove the upper terminal and the plastic cylinder that surrounded the capacitor stack. The stack, however, was cemented to the bottom of the aluminum can, presumably with electrically conductive adhesive. To remove it, I had to cut most of the can away and pry the stack from within the metal with a small screwdriver.

Though the super capacitor I disassembled was rated at 5.5 volts, it contained only four individual capacitors. This gives a maximum working potential per capacitor of 1.375 volts, which is higher than the 1.2-volt peak permitted for capacitors with a sulfuric-acid electrolyte. Therefore, it's possible that an electrolyte that has a higher disassociation voltage was used in the capacitor I disassembled.

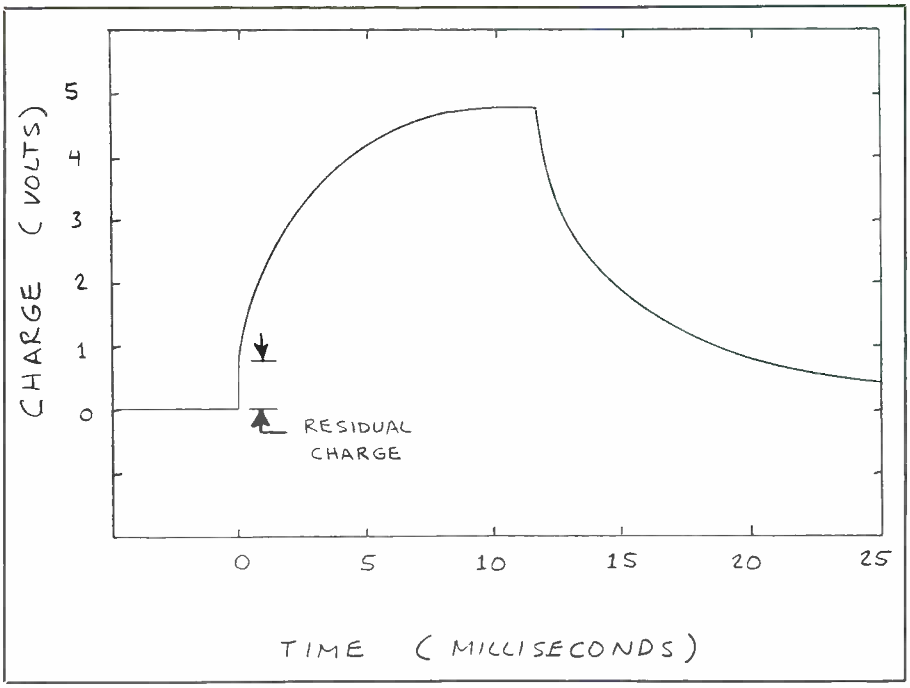


Fig. 3. The charge/discharge cycle of a 0.1-farad super capacitor.

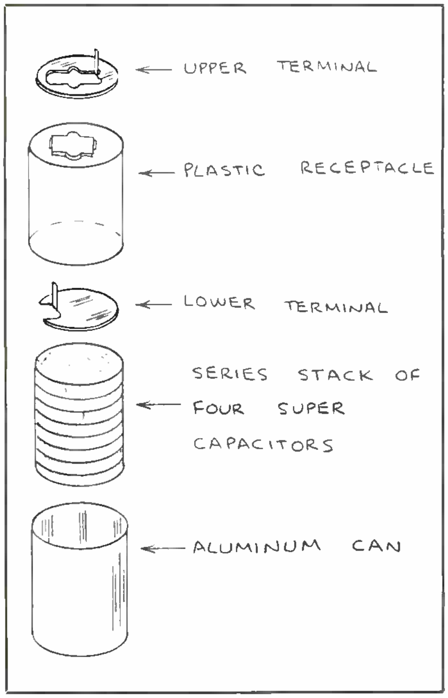


Fig. 2. Internal construction details of a NEC super capacitor.

Super Capacitors Versus Storage Batteries

The first time you experiment with a super capacitor, you may be tempted to think of it as a rechargeable battery. I did. But a super capacitor is *not* a battery. The shape of its charge/discharge curve is identical to that of any other capacitor.

Figure 3 is an oscillogram of a complete charge/discharge cycle of a 0.1-Farad double-layer capacitor. To make this oscillogram, I first connected an oscilloscope to the capacitor's terminals. The sweep speed was set to 2 seconds per division. Next, I placed a sheet of tracing paper over the scope's screen. I then triggered the sweep and connected a 5-volt supply to the capacitor through a 68-ohm series resistor. As the moving dot traversed the screen, I traced its course with a pencil.

Incidentally, note the portion of the charging curve labeled "residual charge" in Fig. 3. This is an allowance for the nearly 1 volt of change that remained on the capacitor even after I shorted together the two terminals of the device for a few minutes.

To capture the discharge cycle, I allowed the moving dot to move across the screen until it reached the peak of the charge cycle traced on the paper. I then connected a 68-ohm resistor across the capacitor's terminals and traced the descending path of the moving dot.

Now that we agree that a super capacitor is not a battery, let's look at some advantages of super capacitors over batteries. As a backup power source, double-layered capacitors can compete with storage batteries only when the current drain is very low. Nevertheless, they do have some important advantages over conventional storage batteries.

Since internal impedance is relatively high, the terminals of a double-layer capacitor can be safely shorted together. The capacitor will discharge under this condition, but at much too slow a rate to

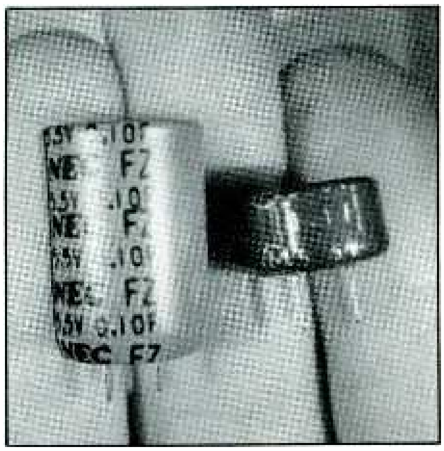


Fig. 4. Double-layer capacitors made by NEC (left) and Murata. Both capacitors have a rated capacitance of 0.1 farad.

cause heat build-up. Try this with a nickel-cadmium storage cell, lithium cell an most other electrochemical supplies, and you will quickly find yourself with an extremely hot power source. Some chemical power cells will even explode when their terminals are shorted together. Some batteries have an internal thermal fuse that automatically disconnects a battery when its temperature rises to an unsafe point.

Another important advantage is that double-layer capacitors can be charged and recharged indefinitely. And they don't exhibit the undesired "memory" effect that is common to Ni-Cd cells.

Still another advantage is that double-layer capacitors can be operated over a wider temperature range than batteries. For example, NEC's capacitors can be operated over a range of from −25 degrees C to +70 degrees C. They can be stored over a range from −40 degrees C to +85 degrees C.

Finally, double-layer capacitors can be soldered into a circuit and be forgotten. Lithium, Ni-Cd and other backup batteries may eventually need to be replaced as their charges become depleted or their ability to be recharged has declined.

Super Capacitor Sources

You can obtain double-layer capacitors from electronics parts suppliers and mail-order companies. For example, Mouser Electronics (P.O. Box 699, Mansfield, TX 76063) catalog lists more than a dozen NEC "supercaps" in both 5- and 10-volt ratings. The values of these capacitors ranges from 0.022 to 1 farad. Digi-Key Corp. (P.O. Box 677, Thief River Falls, MN 56701) lists a family of Panasonic (registered trademark) double-layer capacitors, including a 3.3-farad device. Both cylindrical and cubic package shapes are available.

MuRata (2200 Lake Park Dr., Smyrna, GE 30080) makes a line of super capacitors called ACE-CAP™. These range in value from 0.018 to 0.1 farad. The 0.1-farad ACE-CAP is apparently identical to Radio Shack's Cat. No. 272-1440 unit.

I've experimented with super capacitors made by NEC and MuRata. As Fig. 4 reveals, the most striking difference between capacitors made by the two companies is their physical size. NEC's 0.1-farad capacitor measures 0.55 inch wide and 0.80 inch high. MuRata's 0.1-farad ACE-CAP is considerably smaller, measuring only 0.5 inch wide and 0.30 inch high. These are nearly the same dimensions for Panasonic's 0.1-farad capacitor.

If you don't have any double-layer capacitors on hand, the fastest way to begin experimenting with the circuits that follow is to use Radio Shack's 0.1-farad unit. You can achieve higher operating voltages by connecting capacitors in series with each other, and you can obtain higher capacitance by connecting capacitors in parallel with each other.

Some Applications

Now that you know what super capacitors are, how they're made and from where they can be obtained, let's look at some applications for these devices.

• *Battery-Backup Applications.* The most common application for double-layer capacitors is to provide backup power for CMOS RAMs, microprocessors and other circuits. Depending on the capacitor used and the CMOS circuit's current consumption, backup times can range from as little as a second to as much as a month or more.

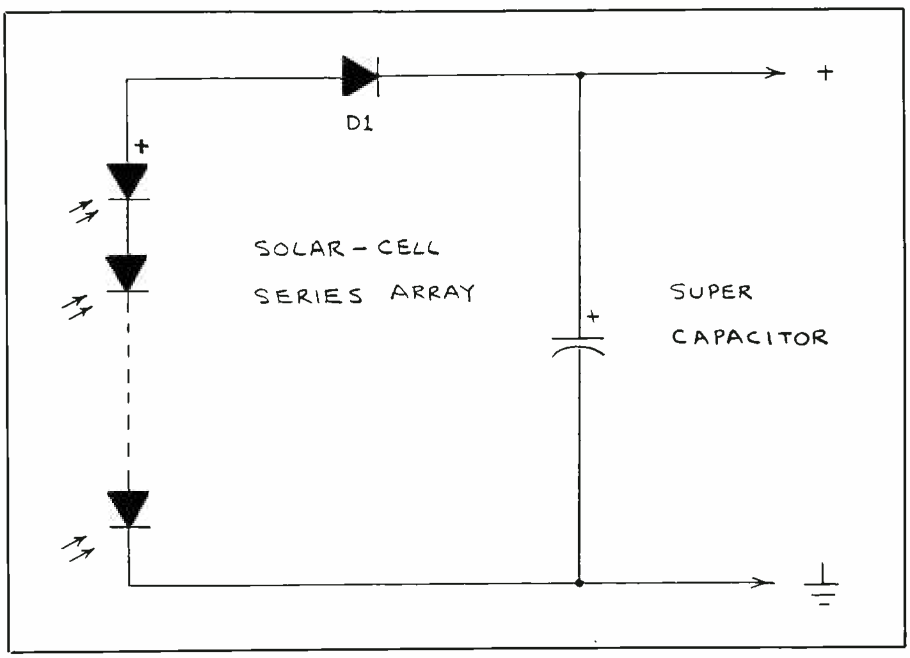


Fig. 5. Charging a super capacitor with a solar-cell array.

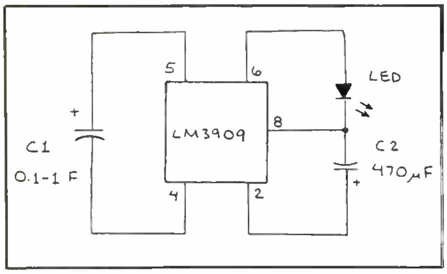


Fig. 6. Super-capacitor-powered LED flasher circuit.

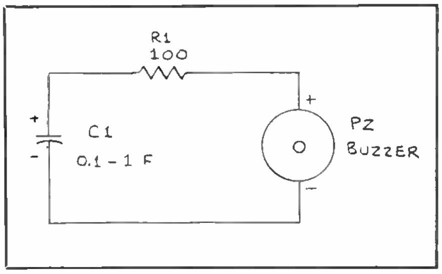


Fig. 7. Using a super capacitor to power a piezoelectric buzzer.

In a typical application, the super capacitor can simply be connected directly across the power-supply pins of the chip to be backed up. The capacitor will be charged to the power supply's potential. When the power supply is disconnected or disabled, the super capacitor then provides backup power.

In many cases, a double-layer capacitor can power an operating CMOS circuit. You can, however, increase backup times by powering only the CMOS RAM portion of a circuit. In any event, you must avoid subjecting the capacitor to more than its rated voltage.

MuRata's 0.1-farad ACE-CAP will typically deliver a linear current of 10 microamperes for 1,000 minutes, 100 microamperes for 100 minutes, and so forth. This capacitor can be fully charged in about an hour. It will self-discharge from 5 to 3.2 volts in 240 hours.

While these specifications are impressive enough on paper, they become even more interesting when you experiment with actual devices. Consider the charging time. While a full charge may require an hour, a double-layer capacitor can be charged reasonably close to full capacity in a minute or so. No charging resistor is necessary.

As for the self-discharge time, I charged a 1-farad NEC double-layer capacitor to 4.5 volts in a minute or so. A week later, the capacitor retained a charge of 3.05 volts.

• *Solar-Cell Charger.* A series of solar cells can easily be used to charge a double-layer capacitor to any point between 0.5 volt (one cell) to 5 volts (10 cells). Figure 5 shows how to insert a protective diode between a solar-cell array and a super capacitor to prevent the latter from discharging through the solar cells when they are not activated by light.

I connected a miniature solar-cell array to a super capacitor. When the cells were placed under a small desk lamp, the capacitor was charged to about 4.5 volts in a few minutes. The capacitor was then

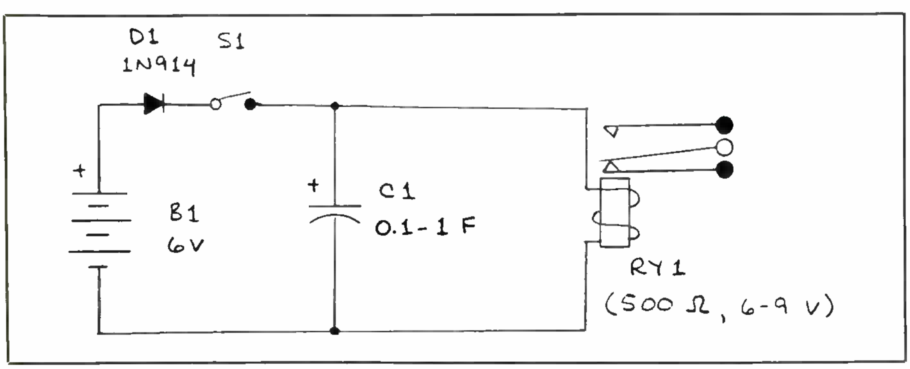


Fig. 8. An ultra-simple super-capacitor timer circuit.

able to drive a super-bright light-emitting diode through a series resistor.

A practical application for a solar-cell-charged super capacitor is as a backup source for brief intervals when the sun is obscured by clouds. A product ideally suited for this application is the solar-powered radio.

• *Capacitor-Powered LED Flasher.* A super capacitor will directly power a LED with a built-in flasher chip. However, this variety of LED draws so much current that the capacitor will be rapidly discharged.

The LM3909 LED flasher chip is much better suited for this application. This chip will reliably operate over a power-supply range of from 1 to 5 volts and consumes little current. The very brief pulses it applies to the LED keep average current consumption very low.

Shown in Fig. 6 is the method used to power a simple LM3909 LED flasher circuit with a double-layer capacitor. When *C2* has a value of 470 microfarads, this circuit will flash about once per second. Upgrading *C1*'s value to 1 farad and charging it to 5 volts will operate the circuit for at least 10 minutes. When the capacitor is discharged, it can quickly be recharged by connecting a 5-volt dc supply across its terminals.

If a 5-volt power supply is not available, you can use a 6-volt battery to recharge the double-layer capacitor. To do so, first insert a silicon diode (1N914 or similar) between the battery and capacitor to drop the battery's potential to a maximum of 5.4 volts. This method works when the capacitor is rated at 5.5 volts. Use two diodes in series if the capacitor is rated at 5 volts.

• *Capacitor-Powered Buzzer.* A piezoelectric buzzer can easily be powered for several minutes or more by a super capacitor to provide a fail-safe alarm that will operate even when power has been interrupted to the buzzer's driving circuitry.

Shown in Fig. 7 is a typical circuit for powering a piezoelectric buzzer with a super capacitor. In this circuit, *R1* is used to increase the discharge time of the capacitor, even though it reduces somewhat the volume level of the sound emitted by the buzzer. You can experiment with different resistances to determine the optimum tradeoff between sound level and discharge time.

• *Super-Capacitor Timer.* For very long timing cycles, I prefer to use a crystal-controlled programmable timer or a computer. This provides a much more precise timing period than when using a capacitor alone as a timing element. However, is you are willing to trade a bit of accuracy for economy and simplicity, you can use super capacitors in the RC circuits of many timers. Based on my preliminary experiments, timing cycles of a week or more can easily be achieved.

You can even use a super capacitor alone as a timer. Figure 8 illustrates one method for doing this. Here, double-layer capacitor *C1* is connected directly across the terminals of a small relay. The relay's contact arm will be pulled in as long as the charge on the capacitor is adequate. When the charge falls below the minimum holding value, the relay will deenergize. A new timing cycle can be begun by closing *S1* for a minute or so. Larger values of capacitance will give longer timing cycles. Longer timing cycles can also be realized by keeping *S1* closed long enough to fully charge *C1*.

Going Further

I've used double-layer super capacitors to power small motors, incandescent lamps and a transistor radio. No doubt you'll think of other applications for super capacitors as you experiment with them in actual circuits. **ME**

Music Hast Charms

By Ted Needleman

Most readers of *Modern Electronics* enjoy experimenting with electronic circuits and devices. One of the areas that seems to be perennially popular is electronic music. Various magazines (including this one, of course) have published music-oriented construction projects such as fuzz boxes, phase shifters, etc. The emergence of the personal computer changed the electronic generation of music from analog devices into a predominantly digital process.

Making music with a computer, whether that computer is contained within a keyboard, or resides in a PC, is now commonplace. There are a bewildering amount of products, both hardware and software, available at prices reasonable enough to justify their purchase by the hobbyist/musician. We'll take a look at some of these products in this and upcoming columns. Don't worry if you're at the level of proficiency where they *still* laugh when you sit down at the keyboard. I've played guitar for almost 25 years and I'm not much beyond that stage myself. The appeal of many of the products we'll be taking a look at is that they permit someone with little or even no musical background to create surprisingly good music.

Of course, if you're an accomplished musician, rather than just a doodler or listener, the process becomes an order of magnitude easier. If you do happen to fall into this category, just keep in mind that the reviews in next month's (and future) columns are being performed by someone who is interested in music, but not all that musically proficient. A professional or accomplished musician would almost certainly have a different opinion of the products I looked at.

A Little Bit of Background

Music has existed in one form or another almost has been around as long as mankind itself. The first musical instrument was the human voice, followed by percussion instruments such as rocks banged against various materials. Electronic music, while a comparatively recent development, has existed for longer than you likely imagine. Simple electrical and electro-mechanical instruments were developed during the late 1800s, though it wasn't until the early 1930s that the first well-known totally electronic musical instrument appeared.

This instrument, called the Theremin (after its inventor, Leo Theremin), provided an eerie sound, somewhere between a violin and a hand saw being played as a musical instrument. It was used on the sound tracks of numerous movies, the most notable being Hitchcock's "Spellbound," and myriad science-fiction and horror movies.

The Theremin was also a very striking instrument to watch being played, though physically it was just a large console with two antennas, one mounted vertically at the top of the console, the other sticking out horizontally from the side. The musician playing the instrument moved his hands near the antennas and, hopefully, an almost pure sine wave was generated. In most configurations of the Theremin, the vertical antenna controlled the pitch (that is, the frequency), while the side-mounted horizontal antenna controlled volume.

Aside from the fact that the Theremin was the first well-known electronic instrument, it is of importance because it employed several electronic techniques that are still being used today.

Compared to some of today's instruments, the Theremin was not very sophisticated. The sound source consisted of two simple oscillators, tuned 180 degrees out of phase. When properly tuned, this resulted in a phase cancellation and no output was produced. The pitch antenna consisted of a capacitive element of one of the oscillators. When a player's hand approached the antenna, it was capacitively coupled to the oscillator, changing the frequency. This resulted in a beat frequency being produced by the oscillator pair, and this beat frequency was the resultant output.

The same capacitive coupling was used for the volume antenna, except in this case it was used to control a voltage controlled amplifier (VCA). VCAs and VCOs (voltage controlled oscillators) were major components in analog synthesizers, and are still emulated in the digital versions of these instruments.

The Theremin is still a popular construction project. In fact, one of the many Theremin construction projects which appeared in the 1960s was authored by a graduate student whose name was to become even better known in the music industry than Theremin's—Robert Moog.

As technology progressed in the period of the '30s through the '60s, so did electronic music technology. Most of the instruments developed during the 1940s, '50s, and early '60s were electro-mechanical in nature. Perhaps the two best known of these are the Hammond organ and Rhodes electronic piano. The Hammond uses a rotating magnetic tone wheel for each key to induce a fluctuating voltage (that is, tone) in a coil. The tones are further modified by electronic filters controlled by switches (voicing keys) and linear potentiometers (drawbars). The Rhodes piano functions in a similar manner, except that the tones are generated by a vibrating magnetic reed which is struck by a key-activated hammer. As a piano works mechanically in the same manner, with a hammer striking a tuned string, characteristics of the generated sound can be made fairly similar to that of an acoustic piano.

There are four major waveform characteristics produced by a musical instrument which give each instrument its unique sound or identity. These are harmonic content, attack, duration, and decay. To a large extent, with acoustic instruments, the method used to generate the sound will determine the waveform characteristics. For example, percussion, string, and wind instruments all have similar characteristics within each individual class, even though the actual sound may be quite different (which is why a guitar doesn't sound like a piano, even though they are both string instruments).

A percussion instrument, such as a drum or blocks, features a very short attack; the volume reaches its maximum very quickly. The duration of the sound varies, depending on the particular instrument, from a short time period to almost instantaneous. The decay, which is the period the amplitude drops off, is often sharp. Some percussion instruments, though, such as cymbals, bells, gongs, and vibes are designed to have both rich harmonics and long decay times because the sound-producing materials continue to vibrate for some time.

String instruments, on the other hand, have very different characteristics. A guitar or piano has a very fast attack and, unless they are muted (the string is dampened), a slow decay and long duration. Because a string is freely vibrating between two points, and other strings are acoustically coupled through the body of the instrument, they also tend to be rich in harmonics. The instrument's body and soundboard, which amplifies the sound, also contributes to both the duration (sustain) and tonal qualities.

Wind instruments, which use a resonating column of air that produces a sound, have waveform characteristics different from the two preceding classes. As the initial sound is produced by a vibrating reed, the attack can be either fast or gradual. The duration lasts for as long as the player holds a note, and the decay, once the note is released, is rapid.

While the foregoing is a bit basic, and just begins to touch upon the physics of musical sound production, it does provide a quick look at how the major factors determine what an instrument sounds like. These are all important considerations in any discussion of electronic musical instruments.

Music & Computers

The totally electronic production of music really started to come into its own during the 1960s. The mid 60s saw the introduction and widespread adoption of electronic organs such as the Vox and Farfisa. Using transistorized oscillators and pre-set filters, these organs generated a variety of sounds ranging from mellow flute-like tones (with near sine wave output) to sharp biting notes (saw wave characteristics). Also popular during this period were guitar fuzz boxes, which introduced deliberate overdriven clipping and distortion, mechanical reverbs which used spring driven delay lines, and echo boxes, such as the Echoplex, which used a tape loop and movable tape heads. With the Echoplex, output from a guitar or other instrument was recorded by a standard record head, then played back by one or more play heads located along the tape loop. By varying the position of the playback head(s) or on some units, the tape speed, you could shorten or lengthen the delay of the echo.

By the late sixties, the first modular synthesizers began to appear. Perhaps the best known of these was the Moog, from Robert Moog's Moog Music. These modular units consisted of oscillators, white-noise generators, filters, ring modulators, phase shifting circuits, bandpass filters, and other waveform modifying circuitry as well as a keyboard. A particular sound was achieved by applying a control voltage from the keyboard into a voltage controlled oscillator (VCO), then routing the signal from this into other waveform modifying modules. This routing was accomplished by manually plugging audio cables into jacks to connect one module to another. As these were similar to the old style telephone switchboard patch cords, the process of setting up the modules for a specific sound quickly became known as a "patch." The term patch is still used to represent a specific sound setup on a synthesizer, even though switches or programming codes are now used.

By setting up the correct patch, tailoring the waveform (attack, sustain and decay), as well as the harmonic content of the waveform, it became possible to approximate the characteristics of many instruments. It also was possible to create musical sounds and tones which had never been produced before (such as those obnoxious bleeps and bloops that were tremendously over-used when synthesizers first became available).

Changing a sound could take quite a while with these patch cords, depending on how elaborate a patch was to be set up. Another major problem, at least as far as using one of these early synthesizers in live performances, was that they were monophonic instruments, capable of sounding only a single note at a time. Multi-note chords had to wait until more sophisticated technology (and instruments) became available. Multi-track recording techniques did much to alleviate this problem when recordings were made in a studio. For a vivid demonstration of this, take a listen to Wendy Carlos' classic "Switched on Bach" recording.

Today's Technology

The synthesizers available today are a whole different breed. The Casio MT-520 that will be discussed next month (as part of the CMS-1 MIDI Studio) has features and capabilities that Robert Moog could only dream about when he was assembling his early systems. And you can buy these capabilities for about $150, a small fraction of what the original synthesizers were priced at.

To a large extent, you can thank the advances in computer technology and integrated circuitry for this. Inexpensive RAM and ROM memory mean that synthesizers can store sounds, patches, and even record songs as you play them. Complex sound generating capabilities provide multiple note polyphony, with up to 10 or more notes sounding at once, or the sounds of several instruments simultaneously being generated.

Instrument synthesis is accomplished through one (or more) of three techniques. The oldest method, still used on many synthesizers today, is subtractive synthesis. A complex waveform is generated by a noise generator or oscillator, then "pared down" to the desired form by filters and other waveform modifiers. Other synthesizers use stored "images" of a particular instrument's waveform, which is shifted up or down in frequency to produce the desired note. Sampling keyboards are designed to digitally record and store samples of a desired sound or tone. Depending on the available memory, up to 40,000 samples per second can be taken and stored. Sampled sounds and notes are usually played back with a digital technique called Pulse Code Modulation (PCM).

The third technique, just starting to become widely used, is additive or resynthesis. With resynthesis, a sound, such as a piano note, is analyzed using a basic mathematical technique Fourier Analysis. The waveform can then be mathematically described, and it is this description which is stored, rather than the note itself. When a player wishes to play a note, say, middle C, the description is retrieved and used to generate a waveform which corresponds to the original (allowing, of course, for the degradation induced by mathematical approximation of the original).

The available technology also means that synthesizers have gone way beyond the familiar keyboard. Rack-mounted synthesizers, driven by computer are common, as are controllers (that select which notes and instruments will sound) in the form of drums, guitars, and even saxophones. Some of the products we'll look at in coming months allow you to generate music strictly through keyboard and mouse input, with the sound generation being accomplished by a peripheral card installed in one of your PC's expansion slots.

One of the greatest advances in electronic music, though, does not concern itself directly with the generation of sound. MIDI, an acronym for Musical Instrument Digital Interface, is a simple serial network which permits the control of one instrument (suitably equipped) by another instrument or computer. Most mid and high range electronic instruments available today are equipped with MIDI capability. These MIDI in and out ports serve two purposes. The MIDI in port allows the instrument to be controlled by any other MIDI controller. This can be another instrument, or a computer equipped with a MIDI interface and a program called a sequencer.

The sequencer, which can be either a computer software package or a standalone box containing the program and memory, can be thought of as being similar to a multitrack tape recorder. Each "track" in the sequencer represents one instrument. Most computer-based sequencer programs have at least 16 tracks or more, though the exact number of individual instruments that can be "played" depends upon both the number of MIDI channels the particular computer MIDI interface card offers and the specific MIDI instrument the signals are being sent to. For example, the Casio MT-520 has 10-note polyphony. This means that the keyboard can generate up to 10 individual notes or sounds (such as individual drum strikes) at the same time. If you have two instruments playing 3-note chords, such as a piano and guitar, this uses 6 of the 10 notes. Add another note for the bass line, an eighth note for the drum, and you are left with 2 notes that can be used for the lead melody.

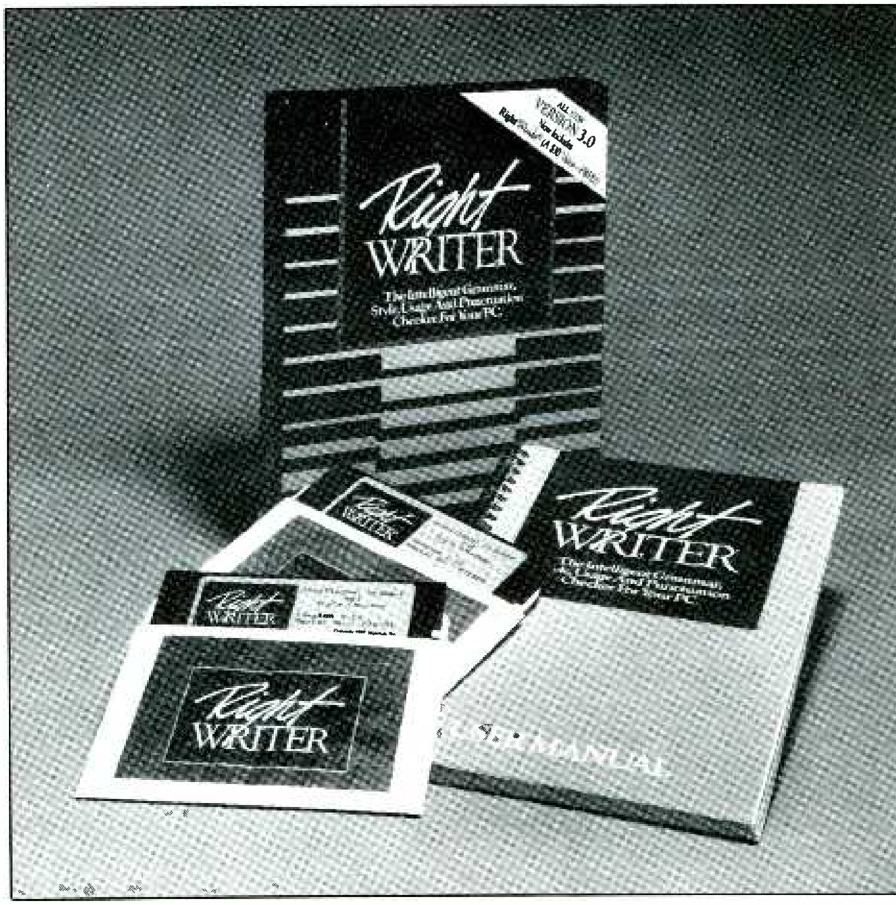
With a sequencer program, each "track" contains certain information besides the note that is to be played. From the musical side, the sequencer must also specify which octave the note falls in, as well as the duration of the note. A track must also be able to tell the instrument which musical instrument, or voice, it represents. Some MIDI instruments also have thru ports, which pass the MIDI messages on to other instruments. If a particular track is to be played on a different instrument, "down stream" of the first, the sequencer must also transmit that information. These, and other "System Exclusive" messages, are passed into the MIDI network and are recognized by the receiving instrument.

MIDI, like most networks, is a two way street. The MIDI out port allows an instrument to transmit. This transmission can be used to control another MIDI instrument, or it can be directed to the MIDI interface card in the PC. Regardless of the destination, the messages are the same. They consist of the same type of information (note, duration, voice, MIDI channel, etc.) that the sequencer sends out to the instrument. This allows the keyboard (or other MIDI instrument) to "record" tracks within the sequencer. These tracks can then be modified and edited, then played back.

As with any network, MIDI is a fairly complex subject, made even more difficult since many of the messages are stored in binary, rather than the mnemonics used in low level programming languages like assembler. If you intend to do much with electronic music and MIDI, you'd be best off getting a good book or two on the subject. Craig Anderton's *MIDI for Musicians* is one good book, Michael Boom's *Music Through MIDI* is another. These books are available at many bookstores, music shops, and computer stores. Be prepared, though, to spend some time experimenting. After all, that's still the best way to learn. Next month we'll take a look at several MIDI products for the PC and Mac, including a complete MIDI package (synthesizer, interface board, and sequencer software) for under $400. See you then. **ME**

RightWriter Style/Grammar Checker

By Art Salsberg



People use word processors to make writing more efficient. However, they use supplementary programs to make writing *better*. Some of these add-on programs became so popular that they were embedded into the word processors themselves for quick call up. These are spell-checking and synonym-listing programs.

Another important writing aid—the style and grammar checker—is not as elemental. Nevertheless, it provides a writer with a convenient method to check the way he uses words and sentences—grammar, punctuation, clarity, etc. RightWriter from RightSoft, Inc. (4545 Samuel St., Sarasota, FL 34233) is among the leading software packages in this category, with some 90,000 current users claimed for it. Its newest version, 3.0, priced at $95 (plus $4.50 S&H), is examined here. It's available on either two 5.25" floppy disks or on a single 3.5-inch disk, and is said to be compatible with most word processors.

Inside RightWriter

The new Version 3.0 of RightWriter features a handful of major improvements over earlier ones. It also upped the minimum computer memory requirement from 256K to 384K. RightWriter runs on IBM and compatible PC, AT, PS/2 computers having a diskette drive and hard disk or two diskette drives.

RightWriter is designed to guide the writer by indicating possible problems on a *duplicate* of the original document file chosen for such analysis. Comments relating to grammar, style and word use are inserted into the text to form a marked-up copy. The overall document is critiqued at the end with indexes of the writer's strengths and weaknesses, as well as a list of words that might be questionable for one reason or another.

The writer can then review the suggestions, accepting or rejecting them. With most popular word processors, such editing can be done directly on the file copy. When finished, you can command the program to delete its inserted comments and summary to give you a finished, edited file. The file with comments is also saved, as is your original document file. We'll examine the utility of the comments and summary later on.

RightWriter's operation can be activated from a DOS prompt or from a menu, the latter being one of the major changes in this newest version. The main menu gives the user a host of easy-to-choose operating options for the document to be analyzed, assuming that settings are to be changed. Otherwise, RightWriter can be put to work directly from the prompt. Among settings that can be quickly changed is the writing style that RightWriter should adjust for. Options include educational level (no change, general public, high school, college and uncommon) or writing type (business, technical, report/article, manual, proposal or fiction.) Then there are choices that can be made among a variety of grammar, style and punctuation rules; sentence structure suggestions, review word listing, computer system defaults, indexes (readability, strength, jargon, etc.), document statistics (number of words, number of sentences, percentage of prepositions, etc.).

The foregoing changes can be saved for automatic future use, if one wishes to do so. The menu also lists a bevy of word processors. RightWriter, however, automatically identifies the file format of most popular ones, memorizing which one it is. You can edit directly on the copy of the original file with these "fully compatible" word processors. Other word processors, though, may only allow you to view or print out the marked-up copy.

Among the fully compatible ones are Bank Street Writer, IBM Writing Assistant, Microsoft Word, Multimate, PC Write, Volkswriter, WordPerfect, WordStar Professional, and XyWrite, to name a few. Some that cannot be used to edit directly on the copy file are Leading

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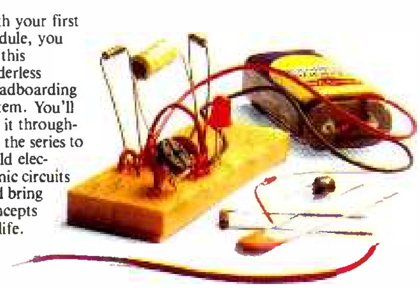

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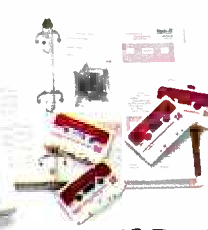

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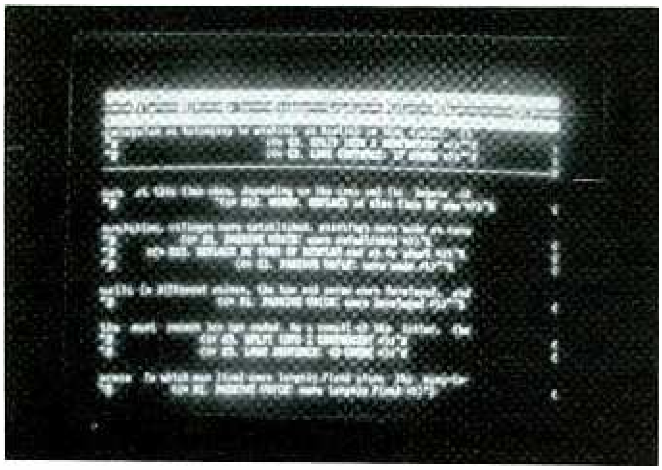

Examples of how RightWriter marks up a copy of a file it analyzes. The top screen photo illustrates how the style/grammar program inserts suggestions on improving written matter. The comments are produced in boldface on-screen and when printed.

At right is a printout of the program's summary of comments for the document pictured above, which happens to be the initially written version of this "Software Focus" review. Note that some of the "Words To Review" at the conclusion of the review are listed with a (J), for jargon. In reality, a few of these words are simply misspellings that remained because the copy was not put through a Spell Checker before it was analyzed.

```
                        <<** SUMMARY **>>

Overall critique for: C:\ws5\files\review1.
Output document name: C:\ws5\files\review1.OUT

READABILITY INDEX: 10.69

     4th       6th       8th       10th      12th      14th
      |****|****|****|****|****|****|***  |    |    |    |
     SIMPLE    | ------ GOOD ----- |                 COMPLEX

     Readers need an  11th grade level of education.

STRENGTH INDEX:  0.54

     0.0                  0.5                         1.0
      |****|****|****|****|****|**  |    |    |    |    |
     WEAK                                           STRONG
     The strength of delivery is good, but can be improved.

DESCRIPTIVE INDEX:  0.56

     0.1             0.5                 0.9         1.1
      |****|****|****|****|**  |    |    |    |    |    |
     TERSE | ------------ NORMAL ------------ |      WORDY
     The use of adjectives and adverbs is normal.

JARGON INDEX:  0.00

SENTENCE STRUCTURE RECOMMENDATIONS:
       1. Most sentences contain multiple clauses.
          Try to use more simple sentences.

                      << WORDS TO REVIEW >>
Review this list for negative words (N), jargon (J),
colloquial words (C), misused words (M), misspellings (?),
or words which your reader may not understand (?).
        activated(M)   1               analyzed(M)   2
           cannot(N)   1              coloquial(J)   1
        elemental(J)   1              foregoing(M)   1
       indicating(M)   1                  isn't(N)   2
           jargon(N)   2                     no(N)   3
              not(N)   4             prepostions(J)   1
      readability(J)   1            sufficiently(M)   1
                << END OF WORDS TO REVIEW LIST >>
                     <<** END OF SUMMARY **>>
```

Edge, Q & A Write, and Samna Word.

An interesting new feature of Version 3.0 is the ability to add words to the program's dictionary. A host of word flags can be chosen for new words, including educational level, jargon, colloquial, misused, negative, user flag. Each option has three settings that can be selected: yes, no, and no change.

RightWriter is accompanied by a hefty spiral-bound user manual that also includes a small plastic-coated quick-reference card that calls out special menu keys, such as F1 function key to display an extended Help screen, and information about Comments inserted into the text.

While the card isn't really necessary, you will definitely need the manual to fully understand what this grammar and style program is all about. In fact, it will give you some special insights to how proofreading is approached, and assist you in making a decision as to whether or not to follow the program's suggestions.

In-Use Comments

RightWriter installs easily, especially if you use the default settings and employ a word processor that's fully compatible with it. Using WordStar Professional, for example, I exited this review's file and called up RightWriter's menu. I then chose to analyze this review, typing its file name and pressing the Enter key. The program then automatically gave the file a marked-up copy name with an ".OUT" extension. (You can provide your own file name if you wish to.).

Pressing function key F10 starts the analysis. The screen then displays file names of the document being analyzed and the marked-up copy being prepared. Below this the name of the word processor is noted, with WordStar being automatically identified without my help. The document's number of words, number of unique words, and the number of words analyzed by the program are displayed progressively on the screen. The first draft of this review had a word count of 1035, with 463 numbered as unique. RightWriter analyzed the full 1035 words.

After this, the program rates the writing with a few indexes. This information can be used as a progress screen as changes are made to successive copies. The summary displayed for this column's draft showed a Readability Index of 10.69. A simple graphics bar at the conclusion of the marked-up copy elaborated on this. It indicated that the copy required readers to have an 11th-grade education level in order to understand it. Next was a strength index of 0.54, which the marked-up summary noted was good, but can be improved. A Descriptive Index of 0.56 was later identified as being normal, while the Jargon Index was nonexistent because I had turned this setting off because there's so much natural jargon in the electronics and computer world. The whole process took about five minutes for this file.

To see the marked-up copy of the original text file, you must return to DOS and use your word processor. With a fully compatible WP, you can edit the marked-up file copy that contains RightWriter's recommendations. When completed, you can direct the program to remove all the inserted comments so that you will have a clean copy.

The program's on-screen remarks are necessarily succinct, of course, but they're sufficiently informative. Inserted comments are called out by wording placed between angle brackets and asterisks, as follows: <<* S16. CLICHE *>>. Comments are generally listed under the end of the phrase or sentence that it pertains to. A small caret is often employed to more pointedly indicate what copy comments refer to.

The letter and number preceding comment word(s) indicate a category (S for style, G for grammar, etc.) and number that simplifies locating the comment reference in the user manual. Here's where you get an explanation of why the word or sentence in question is probably not a good choice. Additionally, you'll also find an example on how to improve what was written.

RightWriter's concluding summary of the text it analyzed is useful and interesting. It is sure to help anyone gain a better sense of his writing quality and show how close he is to matching the target audience's reading level. Weighing the comments strewn throughout the text should enable the writer to tighten up his writing so that it is clearer and more powerful.

RightWriter's recommendations are not to be followed slavishly, of course. Though most comments represent good counsel, some can be wide of the mark too. Naturally, the writer makes the final choice of following a suggestion or not. I found the program to be very helpful. Sure I ignored some suggestions about splitting a sentence into two sentences. But some comments were thoughtful, even for a machine.

I can recommend this useful program to anyone who's intent on improving his writing. In essence, RightWriter can serve as a home-study improvement course in writing structure. It's certainly worth its moderate price if you'll be using it with a fully compatible word processor.

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61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132
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Multi-Line Home Phones

By Curt Phillips

Panasonic's Model KX-T3155 multi-line, multi-function telephone instrument.

Not too long ago, few people would have considered the need for a multi-line telephone in the home environment. But now it's not unusual for homes to have two or more lines. Some call their second line the "children's phone" and for some it's a quasi-business line. Many of us spend enough time with our computers on-line via modems that a second phone line becomes a necessity, lest we continually hear, "I tried to call you all last night, but your line was always busy."

Here at "Gadget Central," I have *three* phone lines; the original, a second for modem/business and a third for the computer bulletin board (BBS) I'm setting up. Having one phone for each line took up too much space on my desk; so I decided to look for a multi-line phone.

One feature I've become "addicted to" from the several other phones that I own is memory dialing, which is the ability to store for recall 20 or so of my most-used phone numbers and to dial them with a couple of keystrokes. I was determined that the multi-line phone should incorporate this feature. Of course, the local phone company offers a "speed dialing" service, but it charges about $4 per month *per line* for this privilege, while single-line memory phones are available in the $25 price range (which is less than seven months of amortization on the speed dialing costs alone).

Panasonic's Multi-Line

The Panasonic Model KX-T3155 "Easa-Phone" offered the features I wanted and more. It's a two-line telephone with 48-number memory capability. In addition, it serves as a speaker-phone, allows for conference calls between the two lines, will automatically redial a busy number for up to 15 times within a 10-minute period, and has tone or pulse capability and a true "hold" feature.

To use the phone, first you press the button to select which of the two lines you want. A LED over the line buttons shows if the line is in use by another extension or is on hold. If you have placed a line on hold with the T3155, any other extension can release it simply by taking the handset (or receiver) off the hook.

With two phone lines, you don't really need the call-waiting feature offered by many local phone companies for about $2 per month. Using the phone company's call-forwarding feature, a $2-per-month item that two lines do not alleviate the need for, I have all calls forwarded to my "main" number and place my outgoing calls on the second line. If I receive another call, the T3155 allows me to put the first call on hold and take the second call, just like call waiting. (It will not help the possibly frazzled nerves or insulted feelings of the first caller, however!)

In addition, if I want the two calling parties to join in a conference call, pressing one button on this Panasonic phone allows me to do it. Thus, I don't need the phone company's conference calling feature, saving me about $3 per month.

Thanks For the Memories

The 48-number memory is accessed in two different ways. The Panasonic offers 20 "speed dialing" numbers that work by pressing the AUTO button, then the two digits (01 to 20) corresponding to the number you want dialed. This is consistent with the way several other types of memory phones work; so I can set "01" on all these phones to the same number, making the key assignments easy to remember. To aid in remembering these assignments, the T3155 has a pull-out card under the phone.

The second group of 28 memories are called "One-Touch Dialing." This group uses the buttons located above the dialing keypad, but the name is a misnomer since half of these memories are accessed by pressing two buttons. Fourteen of the buttons dial a number at one touch, but the other 14 memories require that you push the LOWER button first, then one of the other buttons. I don't know about Japan, but in the United States we call that "two touches."

I'm quibbling, of course, since all of the memories are very easy to use. The 28 "One-Touch Dialing" memories have a card overlay where the button assignments can be written. Each of the 48 memories can store up to 16 digits. I have yet to fill all 48 memories.

For use with "third-party" long-distance services or business PBXes, this phone has a PAUSE function that can be programmed into the memories. Also, the T3155 can be switched from pulse to tone automatically within a memory location.

In normal operation, the number being dialed, whether punched in manually or recalled from a memory location, is visible on an LCD display at the top of the phone. The T3155 allows the user the choice of defeating this display function for "secret" numbers. Once a connection has been made, the LCD displays the amount of time spent on the call, which is quite useful for monitoring the length of long-distance calls.

The speaker-phone function allows you to dial with the handset on the hook. Once the called party has answered, you can either talk to them using the speaker and microphone or pick up the handset. As soon as the handset is picked up, the speaker-phone function is disabled.

The speaker-phone function also affects the redial function. When the handset is off-hook pressing the REDIAL button will cause the last number dialed to be redialed once. Engage the speaker-phone function and hit REDIAL, and the phone will continue to redial the number for up to 15 times, pausing approximately 30 seconds between redials.

Muting & Flashing

As with many modern phones, the T3155 has a MUTE button that disconnects the mike to allow the user to talk with others in the room without the connected party hearing (a feat often not well accomplished by simply placing a hand over the mike). But on most phones, this button is momentary-contact, so that it must be pressed for the entire time you want the phone muted. On the T3155, the MUTE button is a toggle function, so that you press once to turn off the mike and it stays off until you press the MUTE button again to turn it back on.

Many of the phone company's "Custom Calling Service" features (the ones you don't need when you get this phone) require a quick tap of the switch hook to engage them. This quick tap is called a "flash." Although it isn't hard to do, some people seem to have much difficulty doing it. To aid them, the T3155 has a FLASH button that will do it correctly, automatically. The FLASH function can also be programmed into the memory locations.

As mentioned previously, the phone has an LCD display; so the designer could not let it go without designing a clock and alarm function into the phone. I don't need this since I already have so many items with clock functions that by the time I've set all my clocks forward for Daylight Savings Time, it's time to set them all back again (remember, we'll be "springing" forward soon). Therefore, this feature doesn't particularly endear itself to me, but I don't really object to it.

The T3155 requires three AA cells; I've heard of complaints of short battery life with several brands of these multi-function phones. Although I haven't encountered this situation since using the T3155, a jack for an external ac adapter is located on the back of the phone should this become a problem.

The retail price of the Panasonic KX-T3155 is about $125, but depending on how carefully you shop, you should be able to find it in the $75 to $90 range. I've shown where it can save you approximately $9 per month in "Custom Calling" charges, but I'm not really suggesting that it alone will justify the cost of a second line.

In my case, I had already determined the need for a second line. The KX-T3155 saves me about $9 per month, with a simple payback in about 10 months. From that point on, the $9-per-month savings can be applied to the cost of the second line, about $19 per month from Southern Bell in Raleigh, NC (including fall forwarding), making the effective cost of installing a second line about $10 per month. I haven't included the cost of installing a second line, and it still won't single-handedly justify it, but it does help in making the decision.

A certain big telephone provider runs ads telling how much better its phones are constructed than the competition. I haven't tried bouncing the T3155 off a concrete floor, but in several months of not-very-gentle use, it has proven reliable, with many easy-to-use and useful features. **ME**

Your comments and suggestions are welcome. You can contact me through The Source (BDK887), Delphi (CURTPHIL), CompuServe (73167,2050) or at P.O. Box 678, Garner, NC 27529.

that has a value of about 10 times the specified value for the single resistor to bring the circuit into spec.

If it is necessary to troubleshoot the project, set the power supply for an output of 14 volts and check the potential across *D2* to ascertain that it is 6.4 volts. If you obtain this indication on the meter, measure the potentials at pins 4, 7, 8 and 10 of *IC1* for the presence of this zener voltage. Assuming that you do obtain the proper indications at each IC pin, set the power supply to each of the specified voltage-detection levels (9.0, 12.8, 13.4 and 15.1 volts for *LED1* through *LED4*, respectively) and measure the corresponding comparator input terminals at pins 5, 6, 9 and 11 for a dc potential that should be 6.4 volts. Ascertain in each case that this potential rises and falls when the supply's output is raised and lowered.

Check the LEDs to make sure that they are not wired backward into the circuit. Also check the orientation of the LM339 chip in the IC socket and that all its pins are plugged firmly into their respective receptacles in the socket. If you still do not obtain the proper indications from the circuit, try another LM339.

Once you have ascertained that the project is operating as it should, you can proceed to installing it in your vehicle, if that was the reason why you built the Analyzer. Locate the project somewhere within easy view of the driver but where it will not obstruct other instrumentation or road visibility. Then route the input leads as needed.

Connect the black-insulated negative lead to any convenient nearby chassis ground point. This can be under the head of an existing screw in your vehicle's chassis or in a separate hole you drill and fill with a sheet metal screw. Whatever the case, terminate this lead in a spade or ring lug, sand or file the metal around the screw hole down to bright metal and use a toothed lockwasher on both sides of the lug.

After routing the red-insulated positive input lead behind the dashboard and through the firewall into the engine compartment of the vehicle, it is best to connect it directly to the vehicle's battery through a dashboard-mounted slide or toggle switch that allows you to manually enable and disable the project when the ignition is turned on and off. If you prefer to avoid the risk of forgetting to turn off the project when the ignition is switched off, you can route power to it through the contacts of a relay that is energized and deenergized when the ignition is turned on and off. Both options are illustrated schematically in Fig. 4.

Though it is not absolutely necessary to disable the project when the vehicle's ignition is switched off since the circuit draws only about 12 milliamperes (it will have no discernible effect on battery performance in a vehicle that is operated at least once every week or two), it is always a good idea to avoid unnecessary battery discharge in any case.

It is not recommended that you connect the positive lead of the instrument to any part of the vehicle's electrical system other than the positive battery terminal or cable. To do so will induce a voltage-drop error and may cause the Analyzer to give erroneous indications.

Using the Analyzer

The following steps should be performed in sequence when checking out an automotive battery and charging system. Before starting the vehicle's engine, connect the input leads of the Analyzer directly to the vehicle's battery terminals, making sure you observe proper polarity. Also, before switching on the ignition, check the alternator belt for proper tension.

Now do the following:

(1) Before starting the engine, the NOT CHARGING LED or INSUFFICIENT CHARGING LED will be on, which one depending upon how long the vehicle has been sitting idle. Have an assistant start the engine as you observe the Analyzer's LED display. If the LOW BATTERY LED comes on during cranking, battery terminal potential has fallen to less than 9 volts. This indicates that the battery is in a low state of charge or is near the terminal point of its life cycle. Recharge the battery and repeat the test. (Note: For sustained cranking time to observe the Analyzer's LED display, you can disable the vehicle's ignition system by removing the center lead of the ignition coil—or any other approved method of doing so—to prevent the engine from starting. Do *not* crank the engine for more than 15 seconds at a time.)

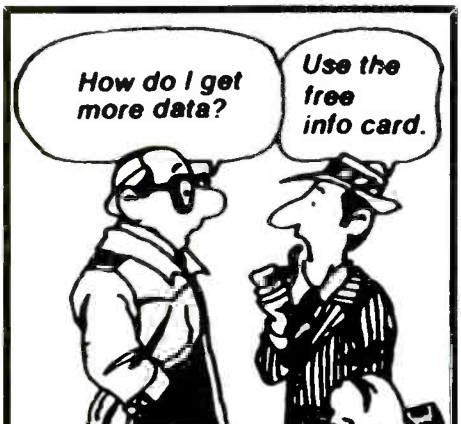
(2) With the engine idling, all LEDs should be off, indicating that everything is normal with the vehicle's electrical system. However, some vehicles will cause the INSUFFICIENT CHARGING LED to light because their battery terminal voltage does not exceed 13.3 volts during idling. This will be checked in step (3) below. If the NOT CHARGING LED lights, the vehicle's charging system is totally not operating, which can be caused by a defective regulator circuit, open alternator or bad connection somewhere in the electrical harness between alternator and battery.

(3) To check the charging capacity of the alternator, turn on the heater/air-conditioner blower at full speed, rear-window defogger/defroster, windshield wipers at full speed and headlights on high beams. Now race the vehicle's engine to 1,500 or 2,000 rpm (moderate speed). All LEDs on the Analyzer should be off. If the INSUFFICIENT CHARGING LED comes on, the alternator cannot deliver enough current to handle the accessory load, which may be caused by a shorted or open diode or a shorted winding in the alternator itself. Since the alternator is a three-phase machine that employs a six-di-

ode bridge circuit, it will be able to deliver some output even though one phase might be defective.

(4) To check the regulator, turn off all accessories and race the vehicle's engine to about 2,000 rpm. If the OVERCHARGING LED turns on, the regulator is defective. A defective regulator will cause the battery to consume excessive water, which will shorten its life. In many vehicles, the regulator is not adjustable; so the only cure for such a problem is to replace it.

Once you install the Automotive/Battery-Charging System Analyzer in your vehicle or use it as a stand-alone instrument with a variety of vehicles, you will come to appreciate how easy it is to perform diagnoses (and repairs) of electrical systems. Just one problem you diagnose and repair yourself can easily save you more than the project costs you to build. **ME**



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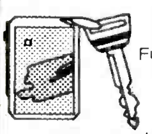

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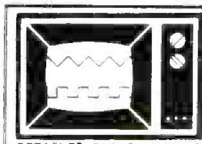

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NICKEL-CAD BATTERIES (RECHARGEABLE)

SPECIAL!! AAA SIZE
Panasonic# P-16AAA
1.2 volt @ 180 MAh
CAT# NCB-AAAX $1.50 each
10 for $13.50 • 100 for $125.00

AA SIZE $2.00 each
1.25 volts 500 mAh
CAT# NCB-AA

AA SIZE $2.20 each
WITH SOLDER TABS
CAT# NCB-SAA

C SIZE $4.25 EACH
1.2 volts 1200 mAh
CAT# NCB-C

D SIZE $4.50 each
1.2 volts 1200 mAh
CAT# NCB-D

TRANSISTORS

CAT#	TYPE	CASE	PRICE
PN2222	NPN	TO-92	5 for 75¢
2N2904	PNP	TO-5	3 for $1.00
2N2906	PNP	TO-18	3 for $1.00
PN2907	PNP	TO-92	5 for 75¢
2N3055	NPN	TO-3	$1.00 each
PN3569	NPN	TO-92	5 for 50¢
2N3904	NPN	TO-92	5 for 75¢
2N3906	PNP	TO-92	5 for 75¢
2N4400	NPN	TO-92	5 for 75¢
2N4402	PNP	TO-92	5 for 75¢
2N5400	PNP	TO-92	4 for $1.00
2N5880	PNP	TO-3	$2.00 each
2N5882	NPN	TO-3	$2.00 each
MJ2956	PNP	TO-3	$1.50 each
MJE2955T	PNP	TO-220	75¢ each
MJE3055T	NPN	TO-220	75¢ each
TIP30	PNP	TO-220	75¢ each
TIP31	NPN	TO-220	75¢ each
TIP32	PNP	TO-220	75¢ each
TIP41	NPN	TO-220	75¢ each
TIP42	PNP	TO-220	75¢ each
TIP121	NPN	TO-220	75¢ each
TIP126	PNP	TO-220	75¢ each

WIDE BAND AMPLIFIER

NEC# UPC1651G. 1200 Mhz @ 3 db
Gain: 19db @ 1-500 hz. 5 volt operation.
Small package 4mm dia. X 2.6 mm thick.
CAT# UPC-1651 2 for $1.00
10 for $4.50 • 100 for $35.00

N-CHANNEL MOSFET

IRF-511 TO-220 case
CAT# IRF 511
$1.00 each • 10 for $9.00
LARGE QUANTITY AVAILABLE

OPTO SENSOR

U shaped package with mounting ears. 1/8" opening. 3/4" mounting holes. CAT# OSU-6 50¢ each
10 for $4.50 • 100 for $40.00

WALL TRANSFORMERS

ALL PLUG DIRECTLY INTO 120 VAC OUTLET

6 Vdc @ 200 ma.	CAT# DCTX-620	$2.25
6 Vdc @ 750 ma.	CAT# DCTX-675	$3.50
9 Vdc @ 250 ma.	CAT# DCTX-925	$2.50
12 Vac @ 930 ma.	CAT# ACTX-1293	$3.50
18 Vac @ 1 amp.	CAT# ACTX-1888	$3.50

SWITCHES

ITT PUSH BUTTON
ITT MDPL series 3/4" X 1/2" gray rectangular key cap. S.P.S.T. N.O.
Push to close. RATED: 0.1 amp switching, 0.25 amp carry current. P.C. mount. CAT# PB-8
65¢ each • 10 for $6.00 • 100 for $50.00

10 POSITION MINI-ROTARY
Grayhill# 56P36-01-1-10N-C
Mini rotary switch. Non-shorting 1 deck, 10 positions. .125" dia. shaft X .375" long. .377" behind the panel depth. P.C. pins.
CAT# MRS-10 $2.50 each

HALL EFFECT SWITCH
MICROSWITCH# 4BE3
Slanted keyboard switch with hall effect sensor. Snaps into 5/8" square chassis hole. Hall effect sensor slides easily from switch and can be used in other applications.
CAT# HESW 4 for $1.00
10 for $2.00 • 100 for $15.00

SPDT PUSHBUTTON
Marquardt# 1843
Rated 6 amps @ 125/250 Vac
Black plastic pushbutton
Switch body .92" X .94" X .65".
CAT# PB-18 $1.65 each • 10 for $1.50 each

LED'S

STANDARD JUMBO
DIFFUSED T 1-3/4 size
RED CAT# LED-1
10 for $1.50 • 100 for $13.00
GREEN CAT# LED-2
10 for $2.00 • 100 for $17.00
YELLOW CAT# LED-3
10 for $2.00 • 100 for $17.00

FLASHING LED
with built in flashing circuit operates on 5 volts.
RED $1.00 each
CAT# LED-4 10 for $9.50
GREEN $1.00 each
CAT# LED-4G 10 for $9.50

BI-POLAR LED
Lights RED one direction, GREEN the other. Two leads.
CAT# LED-6 2 for $1.70

LED HOLDER
Two piece holder.
CAT# HLED 10 for 65¢

RELAYS

12 VOLT D.C. COIL S.P.D.T.
Omron# G2E-184P
4 Amp contacts
335 ohm coil
Sugar cube size.
.81" X .42" X .44" high
P.C. mount with pins on DIP spacing
CAT# RLY-787 $1.50 each

120 VOLT A.C. - D.P.D.T.
GUARDIAN# 1220U-04
10 Amp contacts.
1,100 ohm coil
1.703" X 1.578" X 1.687". Clear polycarbonate cover. Gold plated solder or socket mount terminals.
CAT# RLY-228 $3.50 each

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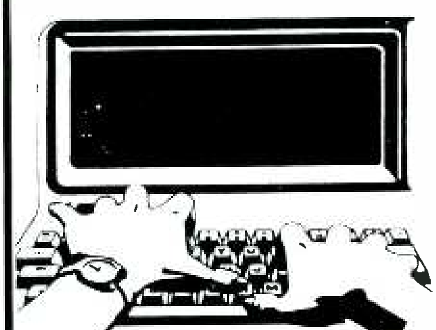

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NEW PRODUCTS . . . *(from page 14)*

each day (randomly) to give your home a lived-in appearance when you are away. Included is battery backup to prevent loss of programmed-in data during a power outage lasting up to 48 hours.

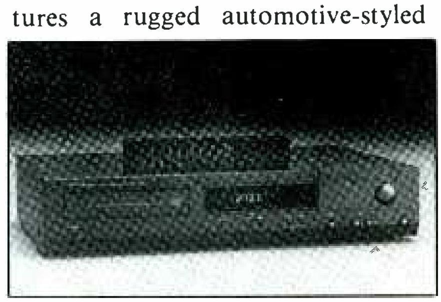
The clock radio timer/controller plugs into any ac outlet and sends digitally-coded signals over existing house wiring to the X-10 modules. The devices to be controlled (lamps, appliances, etc.) plug into the modules that, in turn, plug into other ac outlets. The CR512 works with any X-10 Powerhouse-brand modules and compatible modules it privately brands, including those sold by Heath, Leviton, Radio Shack, Sears and Stanley.

You can program the radio to wake you up at a preset time, and there is a button to allow you a 10-minute snooze period. Also, you can turn on the radio with a sleep key, and there is a headphone jack for private listening. $49.99.

CIRCLE 47 ON FREE INFORMATION CARD

Economy CD Player

A new remote-controlled compact-disc player from Audio Dynamics (San Bruno, CA), Model CD-1000E, that retails at only $249, features a three-beam laser pickup and 16-track programmability. Housed inside a Eurostyle matte-black case, it features a rugged automotive-styled



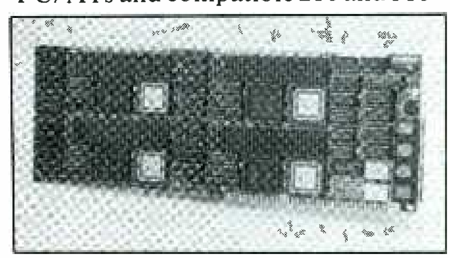
transport that will also play the new smaller-size CD "singles" without the need for an adapter.

Technical specifications include: 20-Hz to 20-kHz ±0.5 dB frequency response; 96-dB dynamic range; 90-dB channel separation; unmeasurably low wow and flutter; 96-dB S/N (IHF-A weighted); and 2-volt rms output signal level. The unit measures 17″W × 11⅞″D × 2½″H and weighs 10 lbs. 9 ozs.

CIRCLE 93 ON FREE INFORMATION CARD

Four-User Network Board

New from InterContinental Micro (Anaheim, CA) is an add-in card that provides complete four-user networking on a single board for IBM PC/ATs and compatible 286 and 386



file servers. The QuickLink-IV card adds four independent diskless workstations to the file server's bus.

QuickLink-IV is claimed to significantly reduce support and installation costs of building a PC network. With four complete PCs on one card, simple addition of a terminal with serial cable makes a complete PC. QuickLink cards plug into the file server's bus or an external expansion chassis. To add another user, another QuickLink or QuickLink-IV is added. User interface is via RS-232 (or RS-422 for distances up to 4,000 feet) to the "dumb" terminal or to a modem. According to ICM, QuickLink-IV gives an AT true mainframe multi-user power with the ability to share among all users files and peripherals attached to the computer.

Built into QuickLink-IV are four NEC V40 processors operating at 8 MHz. Each processor comes with 768K of no-wait-state user RAM. Power drain is rated at 2.5 amperes for four users.

ICM provides complete documentation, installation utilities and technical support with each QuickLink-IV. $2,295.

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