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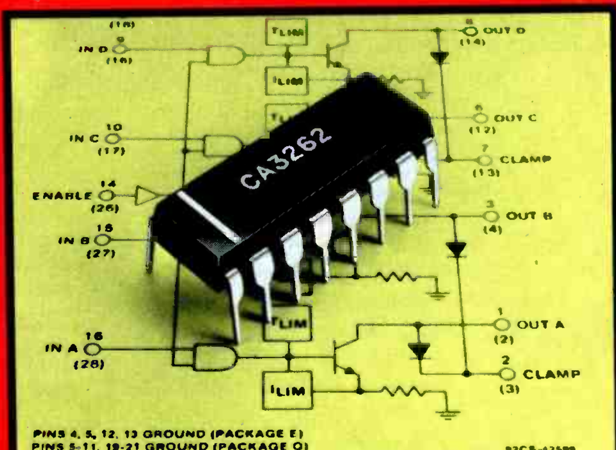
THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

- **Experimenting With Conductive Ink**
- **Portable Altimeter Reads Out To The Foot**



Solid-State Power Switches (p. 62)

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- **Unscrambling NEC's MultiSync Monitor Models**
- **Photo Darkroom Chemical Temperature Controller**

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Plus: Scanners & Scanner Antennas ● Evaluating PC Flight Guide & MacPrint Software ● Power Semiconductors and How *Not* to Mount Them ● Latest Technical Books & Literature ● Electronics & Computer News ● New Electronic Products . . . more.

HARDWARE NEWS

New Dauphin LapPRO-386SX Packs a Powerful Punch for the Price

Dauphin Technology, an aggressive new Midwest-based laptop manufacturer, has come up with a high-performance 386SX-based laptop that offers 386 power at a 286 price. The price alone will turn a lot of heads. But a closer look at the machine itself reveals first-rate engineering, exceptional performance, and loads of standard features that would cost extra on most computers.

With a list price of $4,995 and an introductory price of only $3,695, Dauphin Technology has strategically positioned itself to compete head on with rival 286 models in the same price range. Since 386SX technology provides both present and future applications, the choice between a 286 and a 386SX of comparable cost will be an obvious one for many. Users opting for the LapPRO-386SX will have a laptop with more power, speed, memory and versatility along with the technology to serve them through the next decade and beyond.

Among its many prominent features is a 40 M-byte, 28 millisecond hard drive and 2 M-bytes RAM. Its ability to facilitate DOS, multitasking and multiuser functions, plus all the new 32-bit 80386 software makes it a necessity for anyone who requires the power of a high-end desktop model while away from the office.

Last Fall, Dauphin introduced its first laptop model based on an 80286 microprocessor. Though a late-comer to the market, the LapPRO-286 earned considerable praise for combining the most advanced features with quality engineering and price performance.

Both models from Dauphin Tech offer a 40 M-byte, 28 millisecond hard drive, a 3.5″ floppy drive, two serial ports, one parallel port, a high contrast blue on white CGA/EGA LCD, an internal power supply offering four power options including battery pack, and a dedicated numeric keypad. Options include a 2400 or 4800 BAUD internal modem, math co-processor, 100 M-byte hard disk drive, and external floppy drive and keyboard ports.

The LapPRO-386SX sports a processor speed of 16 and 8 Mhz with zero wait states. It offers 2 M-bytes of Ram on board expandable to 4 M-bytes. Its external monitor port supports CGA, EGA and VGA.

Dauphin Technology has priced its 80386SX laptop to compete head-on with rival 286-based models.

Features include:

- 80386SX Processor, 8 & 16 Mhz, Zero Wait States
- Multitasking Capabilities
- Multiuser Access
- 32-bit Software Compatibility
- 40 M-byte, 28 Millisecond Hard Drive
- 3.5″ Floppy Drive
- 2 M-bytes RAM, Expandable to 4 M-bytes
- Internal Modem Option

The LapPRO-286 provides 1 M-byte RAM which is expandable to 4 M-bytes and an 80286 processor running at 8 or 12 Mhz with zero wait states.

Both models offer the highly acclaimed Digital Research Operating System (a.k.a. DR DOS) which is similar to and compatible with MS DOS. The more distinguishing advantages of DR DOS include on-line help, system utilities such as file retrieval, special security features and an ability to embed software in ROM. Alphaworks integrated software and LapLink file transfer software are also included with each laptop.

Judging by its first two laptop offerings, Dauphin Technology could very well be on its way to becoming a major player in the hardware arena. Though Dauphin Technology is relatively new to the computer industry, Alan Yong, founder, is not. In 1981, Yong incorporated Manufacturing and Maintenance Systems which is now recognized as the leading manufacturer and distributor of industrial alignment systems worldwide. The MMS REACT Alignment Systems, used to align rotating equipment in manufacturing plants, employ a proprietary portable computer and software for alignment calculations and maintenance records.

Given Yong's prior experience in portable computer development, the shift toward developing laptops seemed like a natural move. Yong is determined to build another successful company and his determination shows in the design configurations of these first offerings, a promising start.

Distribution channels for Dauphin Tech products are indeed far reaching and ambitious and include dealers, VARs, OEMs (for private label distribution), along with corporate, educational and government sales. The private label arrangement offered by Dauphin represents an ideal opportunity for OEMs to get into the fast-moving laptop market quickly. And the discounts on corporate quantity purchases are so generous that corporate managers of information systems will undoubtedly regard Dauphin as a serious contender for their business.

In keeping with its aggressive sales approach, Dauphin Technology is currently offering an unbeatable introductory price on both models. End-users would be well advised to invest in a high-performance laptop from Dauphin Tech now.

For more information on Dauphin Tech's laptop line, contact Dauphin Technology in Lombard, Illinois at 312-627-4004. And in the meantime, watch for more surprises from this up-and-coming manufacturer.

CIRCLE 67 ON FREE INFORMATION CARD

MODERN ELECTRONICS

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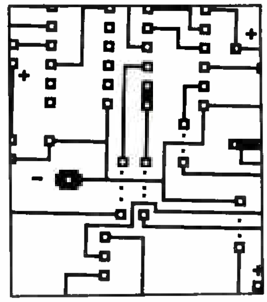

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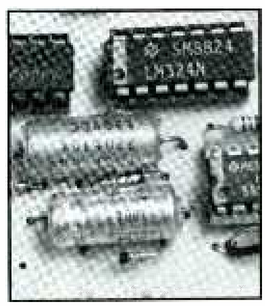

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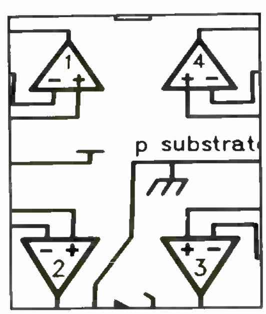

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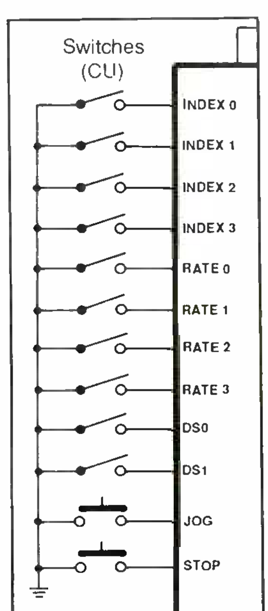

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EDITORIAL

Automotive Electronics

Entertainment electronics such as radios and cassette players have been part of automotive electronics for years. It continues to advance with more sophisticated electronics, even new systems. Now there are AM stereo, CD players, cellular telephones, and fax machines. Soon there will be digital audio tape players.

More importantly, electronics and microcomputers have become major parts of a vehicle's operating systems. Now digital dashboards (I still prefer analog displays) and electronic ignition systems are commonplace. Microcomputer control systems are familiar features, too. Eight-bit/16-bit ones are popular, especially Motorola's MC68GC11 that was designed specially for vehicular use. Even Toyota is using it in some of their automobiles. Electronic fuel injection systems, speed controls, engine management, and computerized diagnostics are all over the place. And electronically controlled anti-lock brakes, active suspension, and four-wheel steering are fast-growing automotive systems.

Electronics in a typical car accounts for nearly $1,000 today. In a few years it's expected to double this amount. Another five years or so should see this figure skyrocket as navigation, collision avoidance, satellite communications, and electronic anti-muffler noise systems take hold in automobiles.

There's a move now toward 16/32-bit computer chips to make automatic control adjustments more refined and to add more sophisticated applications. There are many interesting uses that will evolve for future driving. Many fall under the heading of "peripheral technology." In this area will be smart brake lamps, for example, which use ultrasonic and/or infrared technology to alert the driver when distance between his car's rear and one behind him is unsafe . . . Fiber-optic strips on a window ledge will turn a power window's motor off if your arm is leaning on it so that an injury will not occur . . . . Dashboard displays will not only change their face, but will move to another location—on the upper half of the front window as a virtual image. Using this display system, the driver can read a speedometer or other display without taking his eyes off the road. Stiffer emission requirements will drive use of electronics even deeper.

Designing and producing the integrated circuits needed for the foregoing is more challenging than one can imagine There's a limit to how much wiring can be used in an automobile without raising costs too much, adding considerable weight, and making troubleshooting a circuit a nightmare. To minimize such problems, it's expected that local area networks and multiplexing schemes soon will be used in an automobile.

Beyond this, though, are a host of other difficulties. For instance, all sorts of stresses occur in an automobile's environment. Electrical stresses on electronic components will increase as more and more switching loads are added, each generating high transient voltage spikes throughout a system. Then add extreme heat, cold and dampness, and mechanical vibration and sudden shocks to the mix and you'll better understand how difficult the car's electrical world is to live in for a long time.

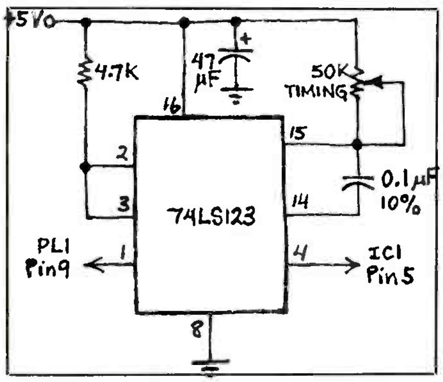
A normal life span for components in an automobile is generally figured as ten years. That's ten years of withstanding ambient temperatures of −40 degrees C to +150 degrees C, as well as all the other stresses. Reliability is ultra important, of course. No one wants conveniences without high reliability, naturally. Nor does anyone want equipment breakdown to take forever to pinpoint and correct; or pay a king's ransom to do so.

With challenges, though, come opportunities. Opportunities for electronics/computer-trained people to get well-paying jobs in this area. It might be work in design and development, servicing, or quality control work. It might be for a manufacturer, dealer or private service shop. Whatever and wherever, smart cars are on the rise. So keep your eyes on the automobile industry for your personal pleasure and for employment possibilities.

Happy 1990!

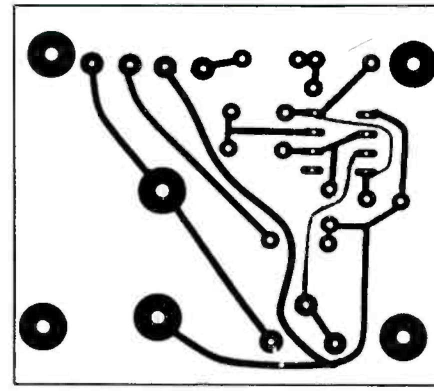
Gremlins at Work

• A few gremlins appear to have gotten loose in my "Car Back-Up Alarm" (October 1989). The first is in Fig. 1, which should have lines drawn from the – and + sides of PB1 to two more terminals on TB1 between the two shown. The terminals should then be lettered I, S, P and H,



left to right, with the – and + lines going to S and P, respectively. Replace Fig. 2 with the pc guide shown here. Install a jumper wire between the pad near the – lead of C1 and the next pad over to the right in Fig. 3. Finally, show two more contacts between those shown for TB1 in Fig. 5 and connect across them PB1.

C.R. Ball, Jr.
Snellville, GA



Author's Update

• A reader who built my "Full-Screen Video Inverter" (September 1989) reported that vertical retrace lines were visible in the upper half of the screen on his Leading Edge Model D computer. This is caused by insufficient width of the vertical pulse, which is normally 0.868 ms. Adding the circuit shown here to the project vertical retrace blanking to be adjusted from insufficient to excessive with the TIMER control.

To install this add-on circuit, remove the connection from pin 5 of *IC1B* in the project and connect this circuit between this IC pin and pin 9 of *PL1* as indicated, and make the +5-volt and ground connections. Be sure to set the TIMER control to maximum resistance before powering up the computer and project.

Boot your computer with *S1* in the project set to NORMAL video. Then set *S1* to INVERSE. If the screen goes black, immediately power down and look for wiring errors. When the circuit is working properly, adjust the TIMING control to a lower resistance until vertical retrace lines just begin to appear at the top of the screen and then back off slightly.

This circuit can be bench tested before installation by connecting it to a 5-volt dc

(Continued on page 81)

IT'S BULL. Zenith Electronics' sale of its computer business (including Heath/Zenith) to France's Groupe Bull has the industry buzzing. Zenith's computer group was the profitable end of its business, while the consumer television side has been in financial doldrums. Consequently, some people thought that the television business would have been on the block. Nevertheless, the pioneer TV maker, the only major one that's owned by a U.S. company, has high hopes for its high-definition television (HDTV) technologies, as well as its other TV segments.

In another bit of TV equipment news with an international flavor, Philips Consumer Electronics Company has begun exporting its U.S.-made TV sets to Japan. Now that's a twist! Philips, which traces ownership to its Netherlands parent company, manufactures and markets TV sets under the Philips, Magnavox and Sylvania brands, as well as private labels.

RESCUING OLD MACS. Early Macintosh computer owners were left in the lurch when their small memory capacity and expansion limitations stifled the machine's functionality. The 128K and 512K models can be upgraded to the equivalent of a Mac Plus, however. Computer Care, Inc. (Minneapolis, MN) makes available a product called "Mac Rescue" to simplify upgrading classic Macs. It's a new daughterboard that snaps on the early-model motherboard...in minutes, it's said. Upgrades are to 1 meg, 2 megs, 2-1/2 megs or 4 megs. An SCSI port in included. For prices, call 1-800-950-CARE (371-0061 in Minnesota).

MORE [COMPUTER] TALK. You'll be hearing a lot more synthesized talk soon, thanks to a new Texas Instruments programmable chip that costs under $2 in high volume (one-million pieces, please!). The TSP50C10 is being touted as the breakthrough that will open up new markets for speech technology, such as ten-buck toys, sales promotion devices, alarms, learning aids, clocks, and so on. The single-chip speech-synthesis system IC stores up to 50 words (40 seconds of speech; 10 minutes more with external memory)....You can hear it in the first "talking advertisement," which appeared in selected editions of the October 20th issue of Business Week.

The integrated circuit is the size of a baby's fingernail, and the whole system in the ad isn't much bigger than a plastic credit card. Three tiny batteries provide power for about 650 plays through a one-inch piezoelectric speaker. A vocal promotional pitch is activated by peeling back a paper flap, which activates the voice. Tearing along a perforation of one of the advertising insert's pages reveals the actual electronic system. A headline blurb under it reads, "Here's what makes this ad talk." The pitchman's voice is realistic, though audio volume is a bit weak.

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.

Compact 8-mm Camcorder

Ricoh claims that its Model R-680 is the smallest, most compact 8-mm camcorder around, the result of a complete redesign of the camcorder configuration and an extremely small 1.5-inch head drum. The handgrip forms a separate element with the camera portion mounted on the front and the tape transport mounted either on the side or back. Features include: 0.5-inch, 270,000-pixel CCD pickup with 4-lux sensitivity; LCD display with real-time tape counter and date/time display that functions with a zero memory indicator (date and time can also be recorded onto the videotape); built-in omnidirectional microphone; tiltable viewfinder; remote-control jack; earphone jack; auxiliary microphone jack; and video/audio jacks for connection to a TV receiver or VCR.

A four-head helical-scan video recording system with true RGB color processing is used in the Model R-680 for video, and a rotary four-head audio system is used for hi-fi sound. An f/2.0, 6× power-zoom lens with manual override adjusts from 11 to 66 mm for panoramic shots and close-ups. Shutter speeds range from 1/60 to 1/4000 second.

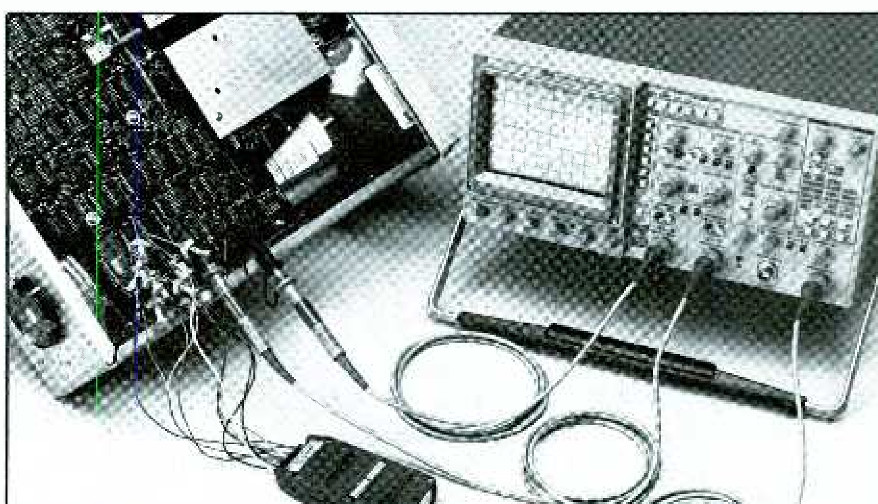
In-camera editing with edit search permits quick location of scenes during recording and playback. A digital titler allows the user to superimpose titles on a recording with a choice of up to eight image or background colors. Titles can scroll and be copied from graphics or original art as well as appear as still images. Through-the-lens focusing and automatic white balance control are provided. Both functions feature manual override. The camcorder measures 4.25 × 4.25 × 7 inches and weighs 1 lb. 12 oz. (without battery). $1,599.

CIRCLE 26 ON FREE INFORMATION CARD

Portable Barcode Readers

The TimeWand II barcode reader from Videx, Inc. (Corvallis, OR) offers portable data collection without connection to a host computer. Smaller than an audio cassette tape box (it measures 4.1 × 2.6 × 0.6 inches), TimeWand II weigh less

Probe Converts Scope Into Logic Analyzer



A new Word Recognizer/Trigger Probe from Tektronix decodes digital words up to 16 bits wide and feeds the result to just about any oscilloscope to convert it into an inexpensive logic analysis tool. The Model P6408 probe permits display of coincident signals on a conventional oscilloscope. It is compatible with most standard logic families and, with its SMG Grabber Tips, provides access to circuitry with lead spacing down to 50 mils. The Grabber Tips are attached to color-coded wires to prevent confusion.

Sixteen manual-set DIP switches in the probe permit selection of user-defined words of up to 16 bits wide. Once the binary word has been decoded, a trigger is delivered to the host oscilloscope to display time-related events. The P6408 operates asynchronously or synchronously, depending on availability of a clock pulse from the device under test. The probe has HI (+2 volts or more) and LOW (+0.07 volt or less) input levels for working on TTL and TTL-compatible logic. Power for the probe is obtained from the +5-volt bus in the device under test.

The probe package includes Tektronix' Model P1609 10× passive probe for coupling the Model P6408 to the scope's 1-megohm trigger input. The passive probe makes it possible for the Model P6408 to extend up to 2 meters from the scope. $350.

CIRCLE 27 ON FREE INFORMATION CARD

No other training—anywhere—shows you service computers

NEW!
Hard drive and voice synthesis training included!

Only NRI walks you through the step-by- step assembly of a powerful XT-compatible computer system you keep—giving you the hands-on experience you need to work with, troubleshoot, and service all of today's most widely used computer systems. With NRI at-home training, you get everything you need to start a money-making career, even a computer service business of your own.

No doubt about it. The best way to learn to service computers is to actually *build* a state-of-the-art computer from the keyboard on up. As you put the machine together, performing key tests and demonstrations at each stage of assembly, you see for yourself how each part of it works, what can go wrong, and how you can fix it.

Only NRI, the leader in career-building electronics training for more than 75 years, gives you such practical, real-world computer servicing experience. Indeed, no other training—in school, on the job, *anywhere*—shows you how to troubleshoot and service computers like NRI.

You get in-demand computer skills as you train with your own XT-compatible system—now with 20 meg hard drive and 640K RAM

With NRI's exclusive hands-on training, you actually build and keep the powerful new Packard Bell VX88 PC/XT compatible computer, complete with 640K RAM and 20 meg hard disk drive.

You start by assembling and testing the "intelligent" keyboard, move on to test the circuitry on the main logic board, install the power supply and 5-¼" floppy disk drive, then interface your high-resolution monitor. But that's not all.

Only NRI gives you a top-rated micro with complete training built into the assembly process

Your NRI hands-on training continues as you install the powerful 20 megabyte hard disk drive—today's most-wanted computer peripheral—included in your course to dramatically increase your computer's data storage capacity while giving you lightning-quick data access.

Having fully assembled your Packard Bell VX88, you take it through a complete series of diagnostic tests, mastering professional computer servicing techniques as you take command of the full power of the VX88's high-speed V40 microprocessor.

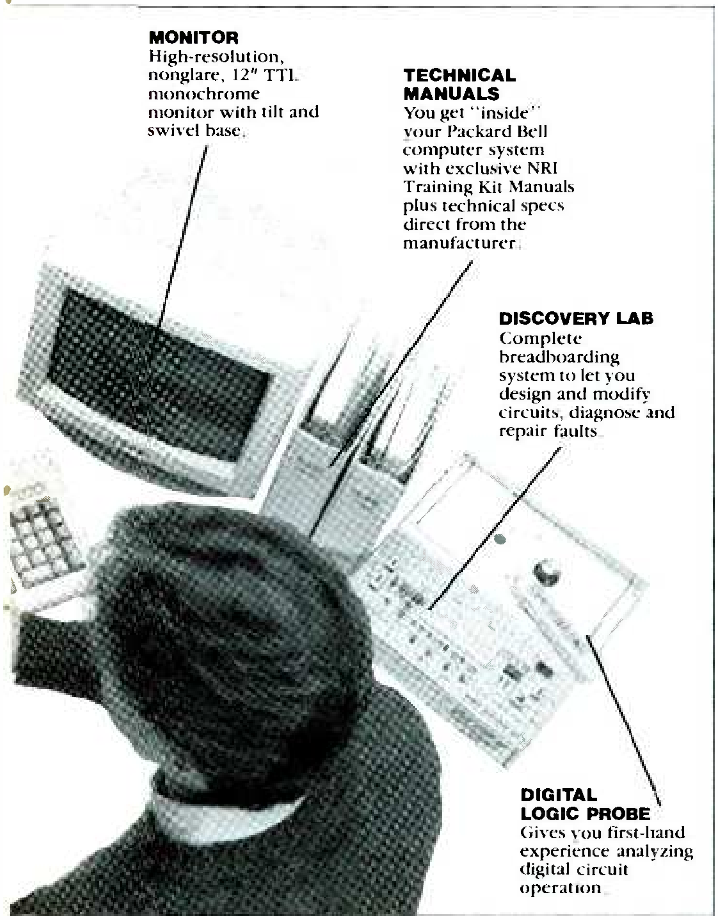
In no time at all, you have the confidence and the know-how to work with, troubleshoot, and service every computer on the market today. Indeed, you have what it takes to step into a full-time, money-making career as an industry technician, even start a computer service business of your own.

New voice synthesis training adds an exciting new dimension to your computer skills

Now NRI even includes innovative hands-on training in voice synthesis, one of today's most exciting and widely applied new developments in computer technology.

You now train with and keep a full-featured 8-bit D/A converter that attaches in-line with your computer's parallel printer port.

in school, on the job, how to troubleshoot and like NRI



Using your D/A converter along with the exclusive text-to-speech software also included, you explore the fascinating technology behind both digitized and synthesized computer speech.

You discover how you can use your computer to access and play back a variety of prerecorded sounds . . . you see how to add speech and sound effects to programs written in BASIC, C, Pascal, and others . . . you even learn how to produce high-quality speech directly from your own original printed text.

NRI's exclusive new hands-on training in voice synthesis is just one more way NRI gives you the confidence-building experience you need to feel at home with the latest advances in computer technology.

No experience needed, NRI builds it in

You need no previous experience in computers or electronics to succeed with NRI. You start with the basics, following easy-to-read instructions and diagrams, moving step by step from the fundamentals of electronics to sophisticated computer servicing techniques.

With NRI's unique Discovery Learning Method, you're sure to get the kind of practical hands-on experience that will make you fully prepared to take advantage of every opportunity in today's top-growth field of computer service.

With NRI, you learn at your own pace in your own home. No classroom pressures, no night school, no need to quit your present job until you're ready to make your move. And all throughout your training, you have the full support of your personal NRI instructor and the NRI technical staff.

Your FREE NRI catalog tells more

Send today for your free full-color catalog describing every aspect of NRI's innovative computer training, as well as hands-on training in robotics, video/audio servicing, telecommunications, electronic music technology, and other growing high-tech career fields.

If the coupon is missing, write to NRI School of Electronics, McGraw-Hill Continuing Education Center, 4401 Connecticut Avenue, NW, Washington, DC 20008.

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Name (Please Print) Age

Address

City/State/Zip

Accredited Member, National Home Study Council 4-010 than 6 ounces. It is said to accomplish a variety of operations that heretofore required cumbersome scanning systems.

Housed in a rugged cast-metal case for use in demanding environments, TimeWand II has a two-line by 32-character liquid-crystal display that shows the scanned barcode, along with scan date and time. TimeWand II can be programmed to prompt the user to scan a pre-described sequence of barcodes. The scanner verifies that the code has been entered correctly, and if not, a delete button erases it and permits re-entry of correct data. The user can scroll and review previously scanned data to verify that each entry has been made in correct sequence.

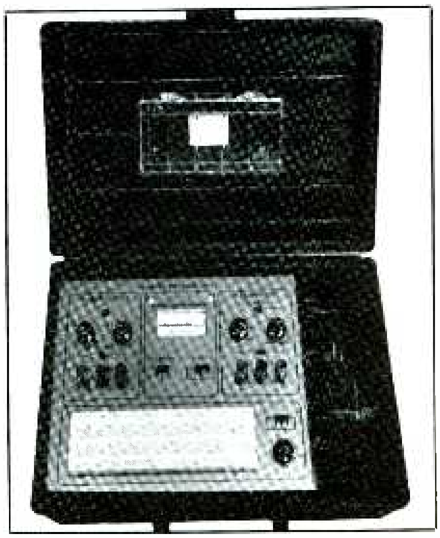
TimeWand II's read head utilizes optics in the visible-light range (an optional infrared read head is available). A variety of barcodes created using thermal, laser, photo-composition and other techniques can be read, including: Code 3 of 9, Interleaved 2 of 5, Codabar, UPC A and E, and EAN/JAN 8 and 13.

A built-in asynchronous RS-232 serial port transmits data at rates from 300 to 19.2K baud. An internal battery charger adjusts charging current as needed. Two basic models are available—32K and 64K capacities. $698 (32K); $789 (64K).

CIRCLE 28 ON FREE INFORMATION CARD

Analog Trainer

Elenco Electronics' (Wheeling, IL) new Model XR-120 analog trainer is specially designed for school proj-



ects. Supplied in a durable black carrying case with a compartment in the lid for holding components, it features easy-to-assemble circuits using the trainer's large 840-point solderless breadboarding socket. Two dc and one ac power supplies are provided, all regulated and short-circuit protected. Also provided is a variable-frequency sine/square/triangular-wave function generator with a 100-kHz range. The trainer is available in both factory-wired and kit versions. $150 factory-wired; $110 kit.

CIRCLE 29 ON FREE INFORMATION CARD

Infrared Headphones

Akron Resources' (Arcadia, CA) Model IR-200 Infrasound infrared headphone system features improved electronics to provide virtually distortion-free reception of the au-

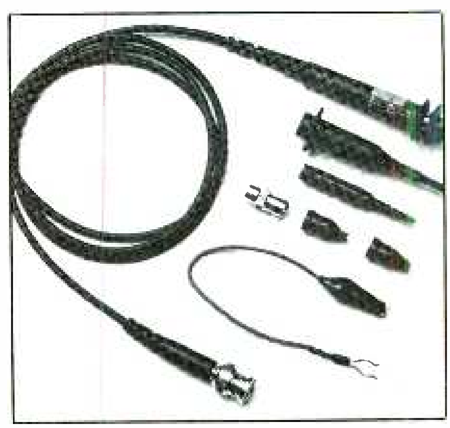
dio output from a TV receiver, VCR, CD player or cassette deck. It works with new TV receivers that have a headphone output and older sets that do not. With newer sets, the ac-powered IR transmitter simply plugs into the jack, while with older sets, a supplied microphone adapter is placed in front of the speaker and is sensitive enough to allow the user to reduce speaker volume almost all the way down for private listening.

Cushioned featherweight ear pads are provided on the headset for comfortable listening. The 4-ounce headset has built-in on/off-volume control and a switch that permits selecting either monaural sound or synthesized stereo sound. The system has a rated frequency range of 30 Hz to 18 kHz. Area coverage is rated at 250 square feet. $79.95.

CIRCLE 30 ON FREE INFORMATION CARD

150-MHz Scope Probe

Test Probes, Inc. (San Diego, CA) has a Model SP150 1×/10× oscilloscope test probe that features a rise-time claimed to be faster than 1.5 nanoseconds. New design and construction techniques are said to eliminate cable microphonics, prevent ex-



ternal interference and seal the probe against moisture. A special strain relief and connector crimp are also said to extend cable life by three times over previous designs. The 1×/10× switch has self-cleaning contacts to further extend useful life. $40.

CIRCLE 31 ON FREE INFORMATION CARD

Laptop Computer

Weighing less than 6.5 pounds and measuring just 12.1 × 9.8 × 2.4 inches, Tandy's Model 1100 FD is one of the lightest-weight PC-compatible portable laptop computers on the market. It comes with MS-DOS 3.3 and DeskMate already programmed into ROM—Tandy's idea of the ideal solution for portable computer users who need PC compatibility but not the heavier weight, higher cost, larger size and shorter battery life of other portables.

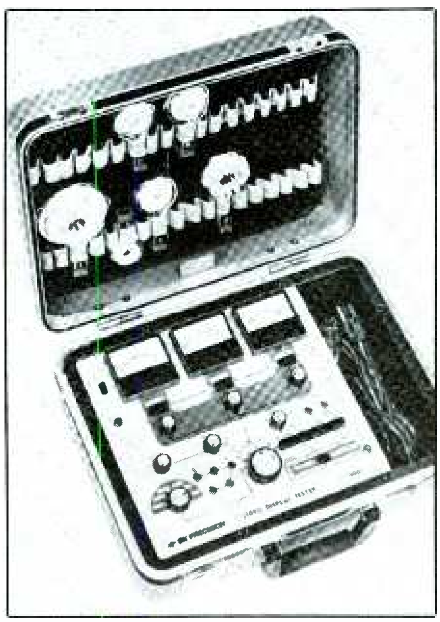
The 1100 FD operates on a removable low-cost rechargeable battery for more than 5 hours and comes with an ac adapter/recharger. Its 80-character by 25-line liquid-crystal display offers a resolution of 640 × 200 pixels. The fold-over display measures approximately 9 inches diagonally and resembles the aspect ratio of conventional video monitors. Other features include: NEC 8-MHz V-20 microprocessor; 640K of RAM; 3.5-inch floppy-disk drive; full-size 84-key keyboard with enhanced keypad emulation; low-battery indicator; battery-saving standby mode; real-time clock; parallel and serial ports; and one dedicated internal modem slot.

In addition to its built-in ROM that features DOS, DeskMate Desktop, DeskMate TEXT application and DeskMate 90,000-word spell checker software, the 1100 FD offers such accessories and utilities as Worksheet, Filer, Telecom, Calendar, Address Book, PC-Link™ and more on floppy disks. Options include a 2,400-bps internal modem, replacement battery and choice of carrying cases. $999.

CIRCLE 32 ON FREE INFORMATION CARD

CRT Restorer/Analyzers

Two new video display restorer/analyzers for servicing computer video terminals and TV CRTs have been announced by B&K-Precision. Both can display the condition of a CRT and then, through an exclusive restore capability, extend its life and improve performance.



The Model 490 features a patented Tri-Dynamic multiplex test method that simultaneously tests all three CRT color guns. Only the beam current actually passing through the G1 aperture to the screen is measured to provide an immediate analysis of cathode-to-cathode leakage. Results are displayed via individual meters. G1-to-cathode and cathode-to-cathode leakage are also analyzed, and a test of focus electrode continuity is performed. Automatic restorative functions include shorts removal, gun cleaning and balancing, and cathode rejuvenation. The Model

(Continued on page 76)

Stepping Motors

This article examines dc stepping motors and provides some applications details

By Stephen J. Bigelow

Dc stepping motors are used by the automation, robotics and industrial-controls industries to achieve a positioning accuracy and precision that regular dc motors simply cannot provide. By delivering a desired sequence of electrical pulses to the windings (or phases) of a stepping motor, the rotor shaft of the motor can be made to rotate a precise amount. Angles of rotation as small as 0.72 degree can be achieved, though 1.8 degrees is more typical.

Stepping motors can develop enough force, up to 3.5 horsepower, to move a fairly large mechanical load with an accuracy of better than 5 percent. In this article, we will examine the construction and characteristics of dc stepping motors in detail and discuss some of its most common applications.

Stepping Motor Assembly

Every dc stepping motor depends for its operation on a combination of strong permanent magnets and electromagnets. The permanent magnets are typically made of iron for its low cost and strong reaction to magnetic fields. They're located on the rotating shaft, or *rotor*. The coil windings are of enameled copper wire that is wrapped around iron cores and mounted to the stationary portion, or *stator*, that surrounds the rotor.

Shown in Fig. 1(A) is an example of a simple two-pole stepping motor. If Phases 1 and 2 in the stator are energized as shown, the north, or N, rotor will be repelled from Phase 1 and attracted to Phase 2. Likewise, the south, or S, rotor will be repelled from Phase 2 and attracted to Phase 1. In magnetics, like poles repel and unlike poles attract.

With only two working poles, as in the Fig. 1(A) example, it's impossible to control the direction of rotor rotation. In this case, the probability of rotation in either the clockwise (CW) or counterclockwise (CCW) direction is 50/50. However, the rotor will align itself firmly with the phases to which it is attracted. If the phases were reversed, the rotor would realign itself in the other direction.

By adding two additional poles to the motor, as in Fig. 1(B), it now becomes possible to control the direction and degree of stepping action. When the motor phases are energized as shown, the N rotor will step 90 degrees CCW toward Phase 4 and remain there.

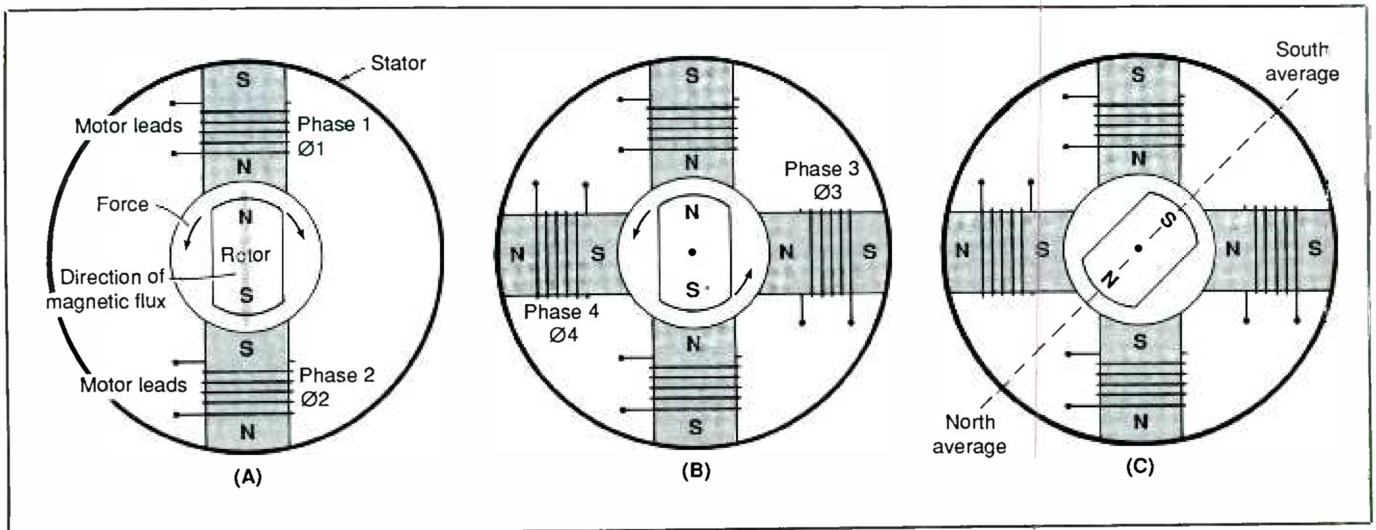


Fig. 1. Examples of (A) a two-phase stepping motor; (B) simple four-phase motor with full-step movement; and (C) four-phase motor with half-step movement.

The amount of force with which the rotor turns depends on the magnitude of the magnetic force generated by the phases. A motor that develops greater phase current or has larger phase windings will usually be able to apply more force. (See the "Electromagnetics" box for a more complete discussion of magnetics and forces in a motor.)

If the phases of Fig. 1(B) were later changed so that Phases 2 and 4 were reversed, the rotor would step again so that its N pole would face Phase 2.

Rotor alignment when two adjacent phases in a motor are energized alike is illustrated in Fig. 1(C). Here, the rotor will turn *between* the two phases to find an "average" phase position. If combinations of motor phases are powered, the rotor can "step" through a known series of movements. It is this kind of control that makes a stepping motor so useful. Keep in mind that it is the *combination* of phase polarities that sets the final position of the rotor, while the *sequence* of those combinations controls the direction of rotation.

Tables 1 and 2 detail the phase combinations used to produce one complete 360-degree rotation for the simple four-phase motor illustrated in Fig. 1(C). Reversing the sequence will reverse the direction of rotation.

Table 2 demonstrates that there are eight possible locations for the for the rotor and that one 360-degree rotation can be completed in eight steps. At eight steps per revolution, the step angle is 360/8, or 45 degrees per step. Because this is not very good resolution for most applications, additional phases are often added to improve resolution. Increasing the number of phases in a motor permits 12 steps per revolution, with a step angle of 30 degrees. An eight-phase motor supports 16 steps per revolution, with a step angle of 22.5 degrees.

To increase resolution even further, "teeth" are employed on both the rotor and the stator to create a

Electromagnetics

When current is made to flow through a conductor, a magnetic field is produced around the circumference of the conductor. The strength of the field at some distance from the surface of the wire is directly proportional to the amount of current moving in the conductor (Fig. A). This relationship is known as "Ampere's Circuital Law." It is expressed as $B = (\mu o \times I)/(2\pi r)$, where B is magnetic field strength in Teslas, μo is the permeability in free space ($4\pi \times 10^{-7}$), I is the current flowing through the conductor in amperes, and r is the radius from the surface of the conductor in meters. "Permeability" refers to the ease with which a magnetic field penetrates a medium like air, plastic or iron.

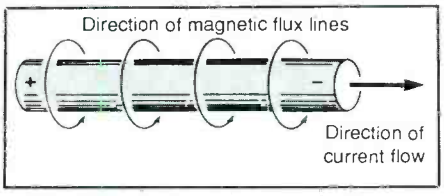


Fig. A. A current-carrying conductor generates a magnetic field around its circumference.

If the conductor is wrapped in the shape of a coil, the magnetic field is concentrated along the core of the coil (Fig. B). This coil is also known as a *solenoid*; it will assume a north pole at the negative (–) terminal and a south pole at the positive (+) terminal. This is now a basic electromagnet.

The concentrated field of the electromagnet can be calculated using a variation of the above formula: $B = \mu o \times n \times I$, where n is the number of turns in the coil and all other factors in the formula are as in the first formula.

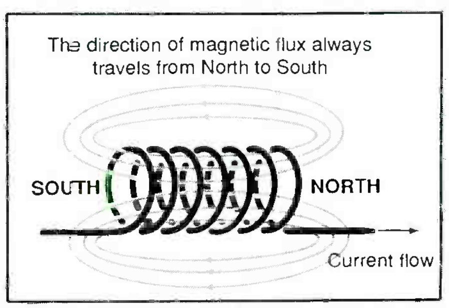


Fig. B. Drawing shows the magnetic field that develops around a solenoid when the coil is powered.

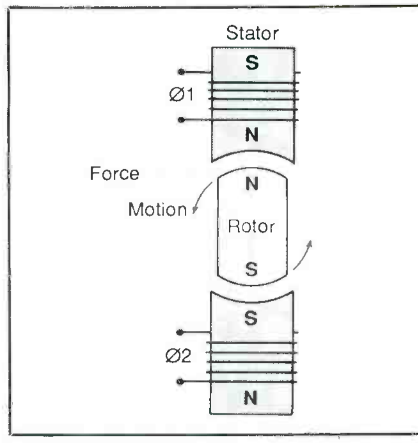


Fig. C. This is a simplified diagram of a simple motor.

As you might see from this second formula, if the value of μ increases, the strength of the magnetic field also increases. By adding metal—such as iron, nickel or cobalt—in the core of the coil, which is easily permeable, the value of μ would be much greater, and the magnetic field would be concentrated substantially. The μ for iron is roughly 2.5×10^{-4}, which is three orders of magnitude *more* easily magnetized than air. When a combination of electromagnets and a permanent magnet on a pivot are arranged along the same axis (Fig. C), a simple motor is formed. If the phases of this motor are energized, they generate magnetic fields, as discussed above. A permanent magnet placed in the presence of those fields will be subjected to forces of attraction and repulsion. Since the permanent magnet is on a pivot, it is free to rotate to realign itself with the magnetic forces.

The force with which the rotor turns is called *torque*. As a general rule, larger stators have stronger magnetic fields to exert greater force to turn the rotor, resulting in more torque.

The above is a summary of some of the principles that govern the operation of all motors. If you wish to learn more on this subject, you can refer to any number of good books about motors in the technical section of a public library.

Table 1. Full-Step Movement for Motor Depicted in Fig. 1(C)

Step	Phase 1	Phase 2	Phase 3	Phase 4	Rotor Pos.*	Direction
1	on	off	off	off	↑	CW
2	off	off	off	off	←	↕
3	off	on	off	off	↓	
4	off	off	on	on	→	CCW

*This column indicates rotor position for phase conditions in each row of table. Arrow points to north pole of rotor.

series of "mini-poles" and "mini-phases." A typical conventional stepping motor is built with 48 teeth on the rotor and 50 teeth on the stator, as well as four sets of stator windings. This effectively gives the motor 200 steps per revolution (50 teeth × 4 pole sets), for a step angle of 1.8 degrees (360°/rev/200 steps/rev) in full-step mode, which is much better for everyday use.

Shown in Fig. 2 is a cutaway drawing of a 48/50-tooth pitch stepping motor. A 50/50-tooth pitch will work exactly the same way, but the slight offset of the 48/50-tooth pitch motor yields much smoother running and more stability at slow speeds.

Various printed materials on stepping motors use the terms "full-step" and "half-step" operation. These phrases refer to the sequence in which the phases are driven.

When only one motor phase is driven at a time, as in Table 1, the motor is said to be full-stepped. When two phases are activated simultaneously, as in Table 2, resolution is doubled and the step angle is cut in half—or half-stepped.

As an example of the foregoing, in Fig. 1(C) a simple rotor and four simple stator phases are used ("simple" in this context means that there are no teeth in the motor). If only one phase is energized at any one time (Table 1), the rotor can rotate to one of only four poles since there are only the four places that the magnetic forces will permit the motor to go to in full-step mode.

If the stator phases are driven in combination (Table 2), four new locations become available to the rotor. Hence, the rotor can now move to any one of eight positions. These extra positions double the resolution of the motor in half-step mode.

Both modes of operation are viable for a stepping motor. However, choice of full-step or half-step mode is made by the choice of the driver system used to control the motor.

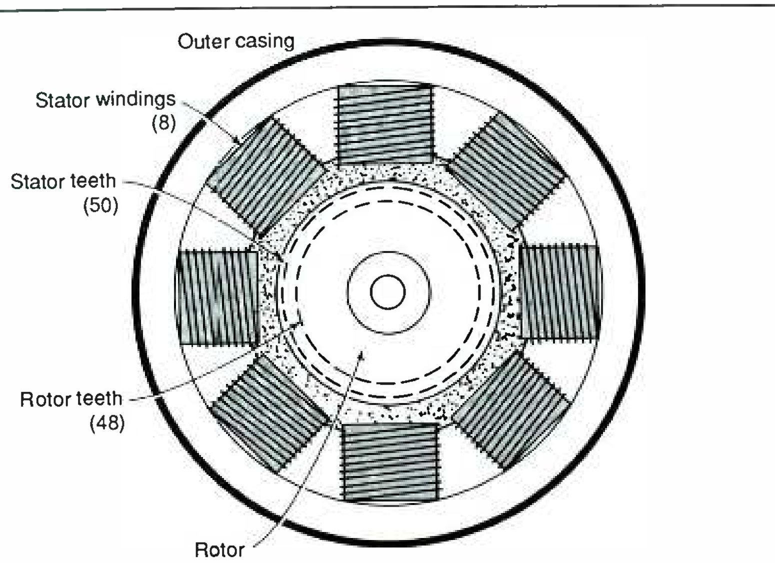


Fig. 2. Cross-sectional view of a typical stepping motor shows phase windings and a 48/50-tooth pitch.

Motor Specifications

On the rear of stepping motors are usually plates or labels that give their ratings and specifications, as shown in Fig. 3. This label lists all of the important information needed to use a particular motor. The major ratings are as follows:

• *Type*. This is nothing more than a part number the manufacturer has assigned to the motor. It usually has nothing to do with the rating or performance of the stepping motor.

• *Oz-in*. This is the amount of torque in once-inches the motor can develop and hold against a mechanical load. This is an important rating since the greater the torque, the more force the motor can deliver to a load.

• *Steps/rev*. This steps per revolution figure is the number of increments the rotor must turn to complete one full shaft rotation. This number is usually expressed in full-step mode; it would be double the stated number for half-step operation.

• *V* and *A*. These are voltage and current conditions, respectively, that must be present on the phase winding to properly energize the motor. Remember that in half-step mode two phases must be energized simultaneously. Hence, it is a good idea to select a motor power supply that can provide more than twice the current

Fig. 3. An example of specifications plate that is typically affixed to stepping motors.

as needed for a one-phase motor.

• *Rpm.* This rotations-per-minute specification is a deceptive rating in stepping motors because the direction and speed of stepping can be changed at any time, depending on the data sent to the driving system. An rpm number may be averaged by dividing the total number of pulses applied to the motor in 1 minute by the number of steps required to complete a rotation. For example, if a motor with 200 steps per revolution receives 1,000 pulses in 1 minute (in the same direction, of course), the rpm can be calculated as 1,000 steps/min./200 steps/rev., which factors out to 5 rpm.

Motor Driver

A stepping motor is strictly an electromechanical device that has no means of controlling itself. For a motor to function properly, each phase must be driven separately from an external driving circuit. Such driving systems can vary greatly in power delivery, cost and complexity. Even so, each shares the same four major sections: the Control Unit, the Indexer Unit, the Output Unit and the Power Supply. Figure 4 shows how each of these Units interrelate with each other, and each has a function as follows:

• *Control Unit (CU).* This is a user interface that provides the means by which the operator tells the motor what to do. The interface can be as simple as a series of switches (see Fig. 5) or as complex as a microcomputer running sophisticated software. No matter how simple, each CU must be able to send instructions to the rest of the driver system. Using a CU, an operator can tell a motor how many steps to take, the direction in which to take them, when to step and how fast to step. A CU will also tell the system whether it is in half-step or full-step mode.

• *Indexer Unit (IU).* This element stores the sequence of information sent by the Control Unit and translates that data on command to form

Table 2. Half-Step Movement for Motor Depicted in Fig. 1(C).

Step	Phase 1	Phase 2	Phase 3	Phase 4	Rotor Pos.*	Direction
1	on	off	off	off	↑	CW
2	on	off	off	on	↖	↑
3	off	off	off	on	←	
4	off	on	off	on	↙	
5	off	on	off	off	↓	
6	off	on	on	off	↘	
7	off	off	on	off	→	↓
8	on	off	on	off	↗	CCW

*This column indicates rotor position for phase conditions in each row of table. Arrow points to north pole of rotor.

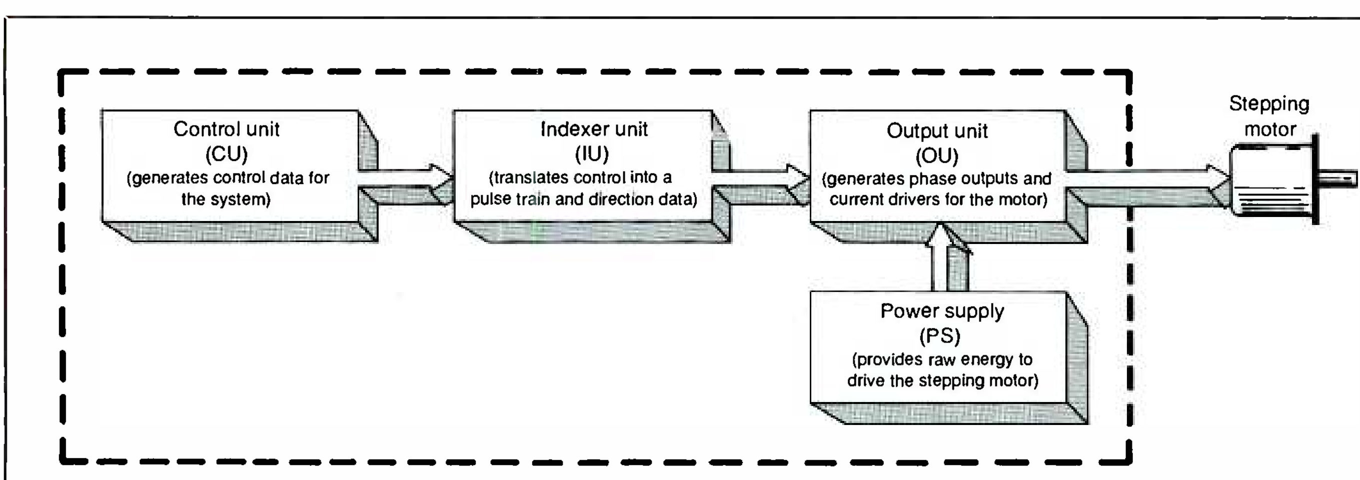


Fig. 4. Block diagram of a generic stepping-motor system showing the various elements used for motor control.

Fig. 5. A simple Control Unit for stepping motors.

Table 3. Index and Rate Operations for the SMC 10

DS1	DS0	Index 0	Index 1	Index 2	Index 3
0	0	100 steps	200 steps	300 steps	400 steps
0	1	500 steps	1,000 steps	1,500 steps	2,000 steps
1	0	2,000 steps	4,000 steps	8,000 steps	16,000 steps
1	1	1,000 steps	2,000 steps	3,000 steps	4,000 steps
		Rate 0	Rate 1	Rate 2	Rate 3
X	X	1,000 pps	1,000 pps	500 pps	250 pps

If no rate is selected when motor is indexed, rate will default to 800 pps (pulses/second). DS0 and DS1 are "don't care" conditions for rate control.

the proper series of pulses and directional data that will be required to drive the motor. The Indexer also sets the step rate (steps per second) in the system.

- *Output Unit (OU).* This unit counts the incoming step pulses, as well as the data rate, and activates the appropriate combinations of outputs that will drive the motor. Power transistors are usually used as current amplifiers with open-collector outputs to buffer the Output Unit from the high currents required by the motor, as illustrated in Fig. 6.
- *Power Supply (PS).* This unit provides the energy required to run the stepping motor. It is chosen to provide the voltage and current levels required for a particular motor (a different type of motor may need a different power supply).

For industrial purposes, the Indexer Unit, Output Unit and Power Supply may be combined into a single self-contained unit. For computer-based Control Units, the CU may

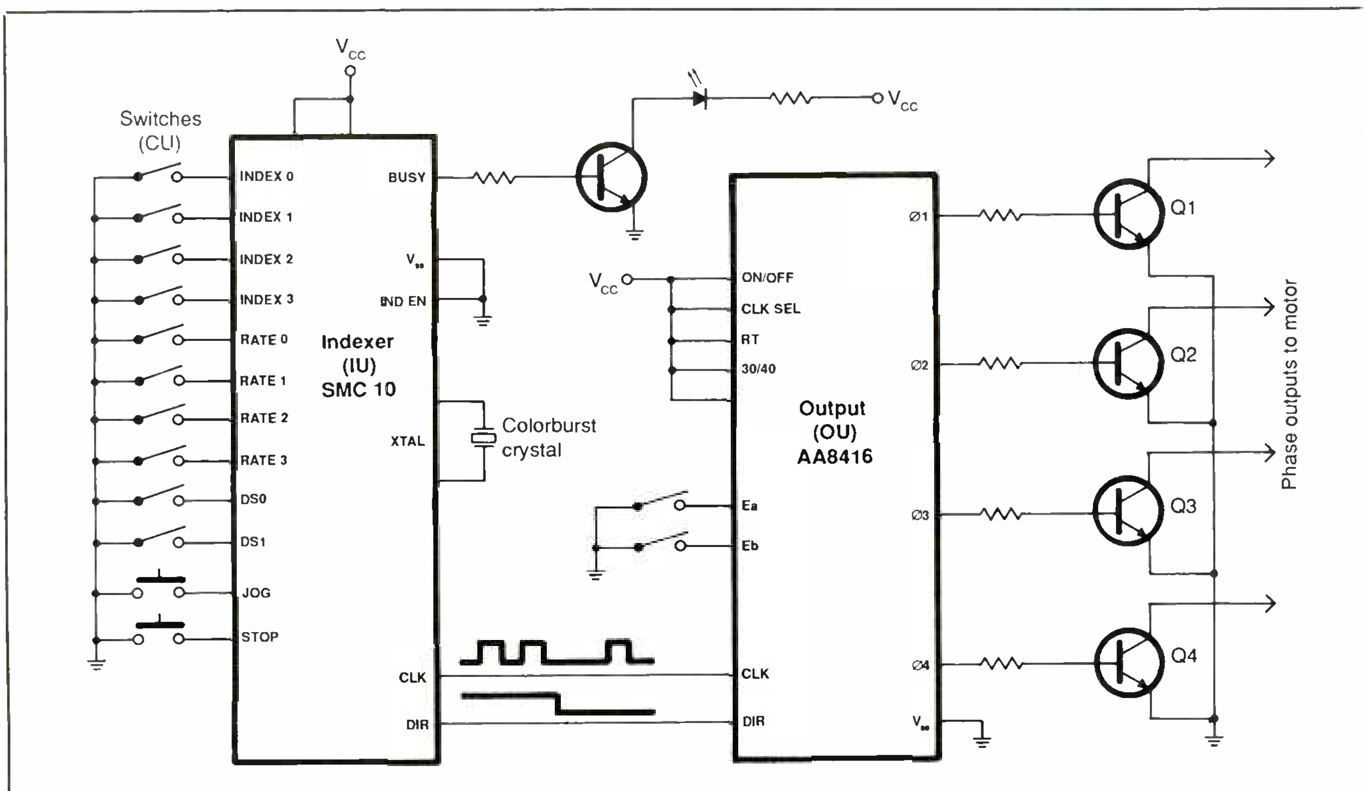


Fig. 6. Schematic diagram of a simple motor drive-current amplifier array.

have an RS-232 serial interface. Simpler switching-type controllers may have a parallel I/O interface. A single 117-volt ac source is supplied to the module. The appropriate stepping motor can be directly cabled to the motor on the face of the module.

Applications

Due to their small size and relatively high power, stepping motors are rapidly finding applications in new industrial and commercial areas. This is especially so in automation, where their high precision and reliability make them a superior choice when items must be manipulated through a series of complex repetitive motions. Other applications include pick-and-place machines, grinding, metal punching, welding and laser-beam steering, to name just a few.

One of the simplest uses for a stepping motor is driving a linear-motion table. In a typical such application, the table uses a motor to turn a large lead screw that, in turn, moves a fixed bar mounted on a very-low-friction table. By using a lead-screw assembly, the precise rotations of the stepping motor are translated into precise back-and-forth linear motion on the table.

As an example of the above, a stepping motor with 200 full-step steps per revolution drives an 8.5-inch lead screw that has five threads per inch, yielding a total of 40 full turns. One turn of the lead screw moves the bar 1 inch/5, or 0.2 inch. The step angle of the motor is 360°/200, or 1.8 degrees. Consequently, when the motor makes one step, it turns the lead screw 1/200 turn.

With a linear movement distance of 0.2 inch per revolution of the lead screw and a 1/200 turn per step, a linear motion of 0.2 inch/200, or 0.001 inch per step is obtained. Thus, total resolution of the linear-motion table is 0.001 inch.

Stepping-motor accuracy is typically 3 percent "non-cumulative," which means that the maximum error is for the entire distance traveled, *not* per step. Hence, if the linear-motion table is moved 5,000 steps at 0.001 inch per step, the table will travel 5 inches with an accuracy of ±3 percent, or within 0.15 inch. This means that the table can travel as much as 5.15 inches or as little as 4.85 inches.

When two stepping-motor/lead-screw assemblies are operated perpendicular to each other, the result is an X-Y table that can position a part both left-to-right and up-and-down. In Fig. 7 is shown an automated process that uses an X-Y table to position two sets of parts under cutting lasers. The system is controlled by the computer shown at the right in the photo, which is required to support the various cutting patterns used.

Commercially available integrated circuits can provide the indexing and output functions required by stepping motors. The Anaheim Automation SMC 10 is a fully programmable simple single-chip indexer with jog, step and limit switch inputs as well as 16 preset index distances and 20 preset rate combinations. A companion chip, the AA8416, is a three- and four-phase motor driver device that can operate in full-step or half-step mode. Pinouts for both chips are illustrated in Fig. 8.

The AA8416 driver accepts clock and direction inputs, as well as a "phase-idle" input that can turn off all motor phases to conserve power and reduce motor heating. This chip

Motor Safety

Even though most stepping motors are designed and manufactured to conform to recognized safety standards—particularly those supported by N.E.M.A. (National Electrical Manufacturers Association), U.L. (Underwriters Laboratories) and A.N.S.I. (American National Standards Institute)—well-built components can still become hazardous if they are operated in an unsafe manner. There are several important safety points to consider when using stepping motors and driving circuits.

Always make certain that every motor and control circuit is properly grounded to eliminate shock hazards in the event of a breakdown. Never apply a current greater than that for which it is rated to the windings of a motor. High currents cause excessive motor heating, which can result in thermal breakdown of the winding insulation.

Phase wiring between the output of the driver system and motor terminals should be carefully shielded to reduce the effect of motor noise in the rest of the circuit. Also, use wiring of the proper gauge to accommodate the phase current with a minimum of voltage drop.

Unless a motor or control circuit is specifically designed to operate at high temperatures, make sure the ambient air temperature around a motor system does not exceed 40 degrees Centigrade (104 degrees Fahrenheit). Plenty of free air should be made to circulate around the motor.

Keep in mind that moisture in a motor or control circuit can create a short circuit and a shock hazard. Exposure to moisture for a long time will break down winding insulation and corrode contacts, seriously shortening a motor's life. An enclosed motor can be used in damp environments but only if *all* openings are sealed.

If a motor burns out, it is a potential fire hazard. Hence, be sure to prevent the motor from coming into contact with any combustible material.

For a more detailed dissertation on motor and generator safety, obtain Standards Publication No. ANSI C51-1/NEMA MG-2 titled "Safety Standard for Construction and Guide for Selection, Installation and Use of Electrical Motors and Generators" by writing to the National Electrical Manufacturers Association, 2101 L Street N.W., Washington, DC 20037.

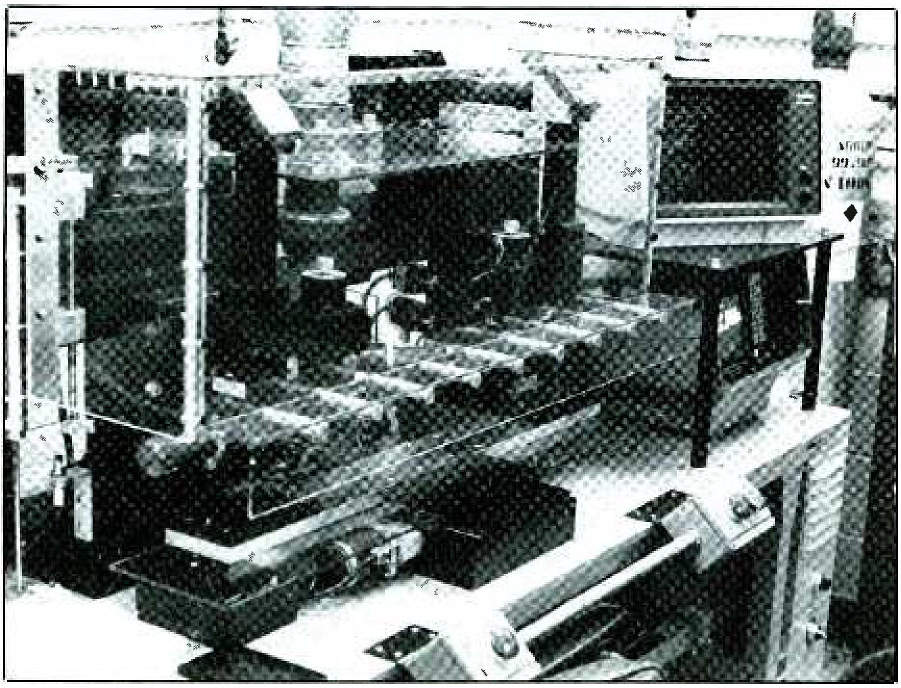


Fig. 7. System view of an industrial process using an X-Y table to position parts under a laser beam.

Stepping Motor Glossary

Accuracy. The percentage of error between estimated motor movement and actual movement. Stepping-motor accuracy is typically 3% or 5%.

Drive. This general term describes the circuitry used to control a stepping motor.

Ramping. By varying the frequency at which a motor is stepped (varying the steps per second), the motor can be accelerated and decelerated. This is very useful in controlling large motor loads.

Step Angle. The number of degrees a rotor (motor shaft) turns each time the motor's phases (windings) are energized.

Steps Per Revolution. The number of steps a rotor must turn to complete one full 360° rotation.

Steps Per Second. The maximum number of steps a motor can produce in one second. When dealing with dc stepping motors, steps per second replaces revolutions per minute (rpm).

keeps track of motor position and outputs the correct signals to each motor phase. All that is required to complete a simple stepping-motor control circuit using the SMC 10 and AA8416 are a stepping motor and some power power transistors, as shown in Fig. 9.

The Indexer Unit in Fig. 9 is the SMC 10 chip. Default switches DS0 and DS1 set the range of index steps. The INDEX 0, 1, 2 and 3 switches set the speed at which the selected index will be carried out.

Table 3 details the switch settings for default select, index and rate. When an INDEX input is at logic low, the BUSY output lights the LED while

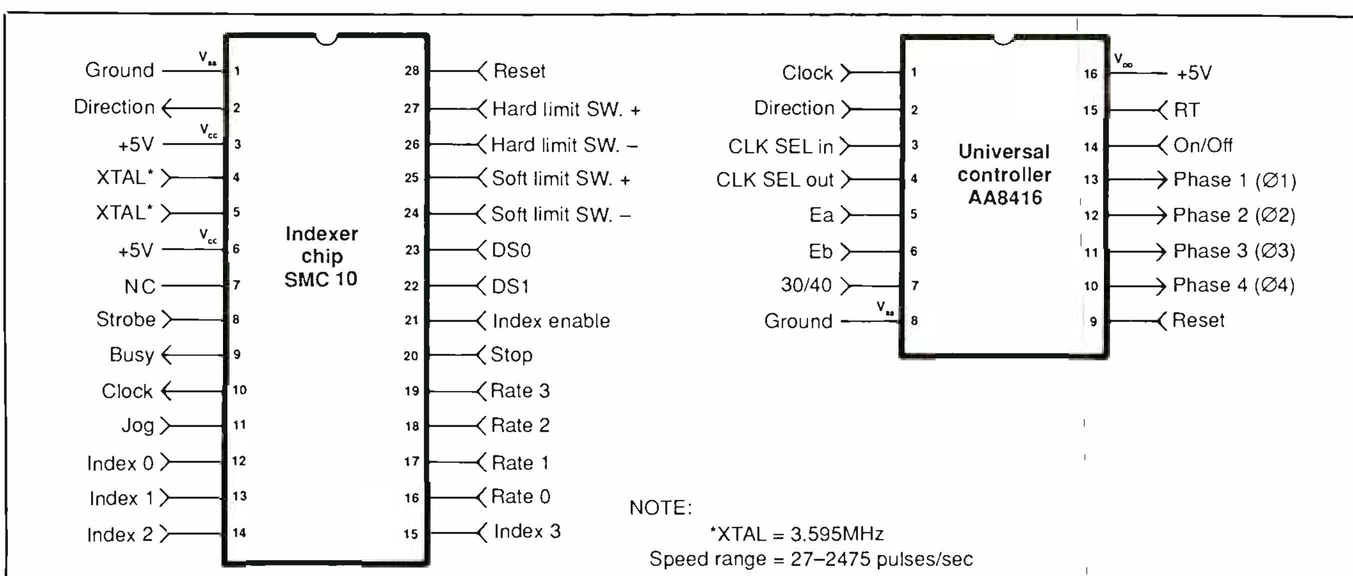


Fig. 8. Pinouts and data for (A) SMC 10 fully programmable single-chip indexer and (B) AA8416 three- and four-phase driving device, both made by Anaheim Automation.

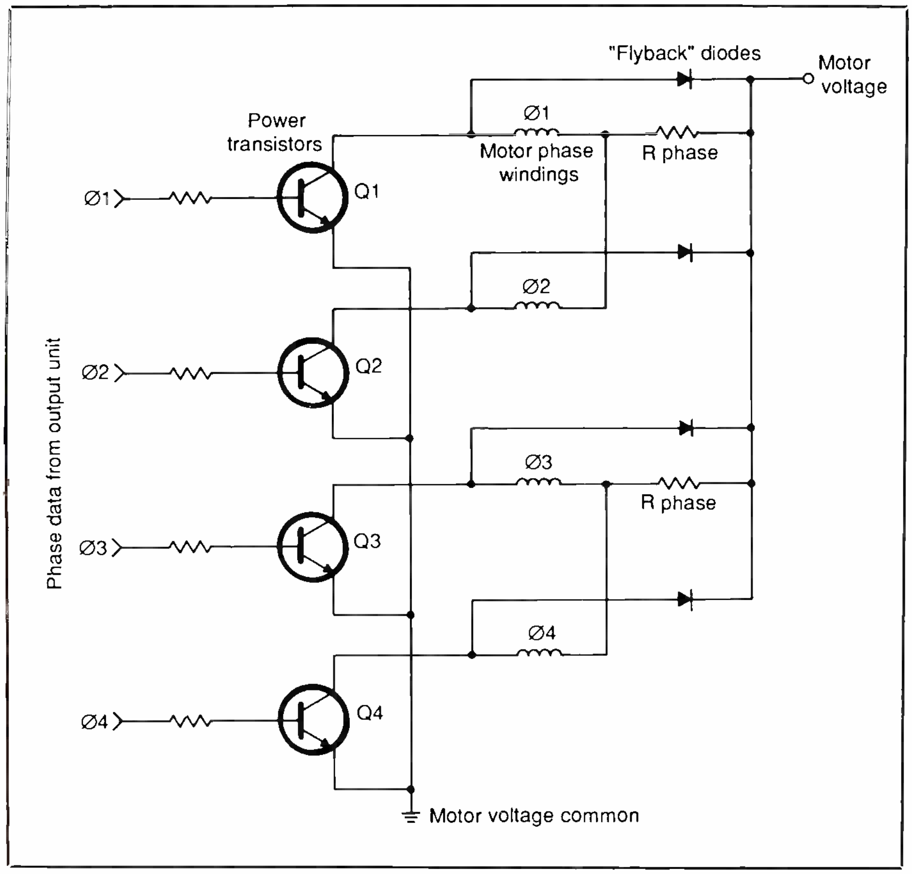


Fig. 9. Example of a schematic diagram of a two-chip stepping-motor control system based on the SMC 10 and AA8416 chips.

the motor is indexing. Closing the STOP switch at any time immediately stops the motor. Closing the JOG switch and holding it that way for longer than 0.5 second causes the SMC 10 to output a stream of clock pulses until the JOG switch is released.

The Control Unit (CU) in the Fig. 9 circuit consists of all the control switches in the system: INDEX 0 through INDEX 3, RATE 0 through RATE 3, STOP, JOG, DS0, DS1, Ea and Eb. In this system, no direct microcomputer control is used. It would be a simple matter to group the switches by function and mount them to the front panel of an enclosure.

The Output Unit (OU) in Fig. 9 is the AA8416 universal controller chip. The mode of motor stepping, full-step or half-step, is controlled by the Ea and Eb switches. The AA8416 chip accepts clock and direction information from the SMC 10 and converts that data into four phase output signals that are used to drive a network consisting of four current-amplifying transistors.

"Flyback" diodes in the Fig. 6 drive circuit prevent current spikes from being generated in the system when a phase is shut off. The R_{phase} resistors in this circuit act as current limiters that set the peak operating parameters for a stepping motor for a particular power supply.

Microstepping Motors

Stepping motors and their driving systems are always improving as the demand for their use increases. The need for greater stepping resolution has resulted in the emergence of a technique called "microstepping." The principles of microstepping have been around for many years, but only recently with the advent of inexpensive control integrated circuits and switching circuits has microstepping become the preferred tool for intricate applications.

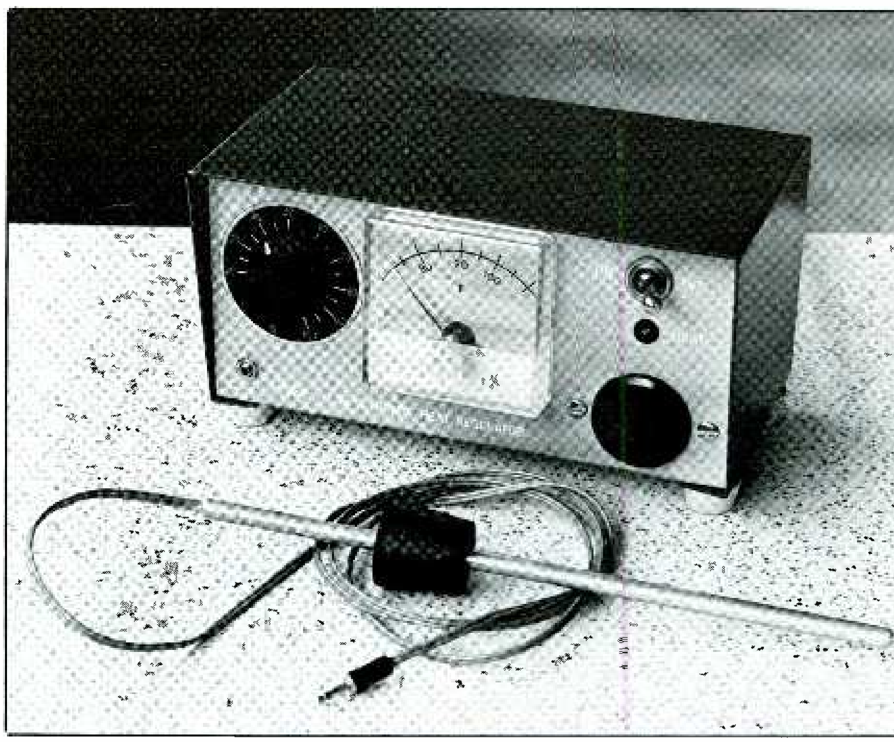
Microstepping uses additional control circuitry to phase-balance the current sent to the phases of a stepping motor. This approach can allow a normal 1.8-degree-per-step motor to step as little as 0.015 degree per step and less. As more efforts are put into research and development, it is almost a certainty that microstepping will become more widely used in a wide variety of applications.

Stepping motors have found uses in many areas of automation and control, including grinding, cutting, positioning and welding, to name just a very few. Wherever reliable, precise motion is desired, stepping motors are coming to the fore.

Darkroom Chemical Temperature Controller

Maintains processing temperatures to within a fraction of a degree

By Maurice P. Johnson, W3TRR



Most serious amateur photographers eventually put together a darkroom in which they can perform their own processing. Working under "safelight" conditions on black-and-white materials provides visual inspection and a degree of "error correction" during development. However, color prints are usually processed in a light-tight drum or tube under strict time and temperature conditions, with the result visible only at the end of the procedure. Exposure and filtration (color balance) must be correct at the very start and throughout color processing. Temperature variations of just a degree or two can have a marked effect on the color balance of the finished print.

Precise timing can be accomplished with any number of inexpensive timers on the market. But few, if any, inexpensive temperature controllers suitable for color-photography work are on the market. This article discusses a practical means of regulating processing temperatures to within a fraction of a degree using a simple electronic system that is ideal for the amateur darkroom.

Controlling Temperature

A degree of latitude is inherent in black-and-white photo printing. Because processing is performed at or near room temperature, temperature control is seldom a formidable problem. Also, because only a few short steps are involved, elapsed time is minimal. On the other hand, color printing generally involves longer processing times.

To reduce the time, chemical actions are accelerated by raising solution temperatures. Recommended temperature is 100° F for many processes. Thus, solutions are used some 30° warmer than ambient room temperature—which is the reason why temperature control is required. In keeping with the laws of thermodynamics, solution temperatures will attempt to drift to the lower "heat-sink" temperature of the ambient air unless, of course, the heat loss is stopped or replaced.

One technique of elevating temperatures for processing purposes is the "drift-by" method in which the processing tube is manipulated without a tempering bath so that the heat sink is simply the ambient air. Solutions are preheated to somewhat higher than 100° F before the start of processing. The liquid is then poured into the processing tube and cools down inside the tube during processing. The intent of the drift-by method is to strive for an average temperature of 100° F as a mean value as the solution cools—hence the origin of the term "drift-by."

Obviously, the drift rate depends on the thermal time constant of the tube, temperature differentials and starting temperatures, insulation factors and duration of the processing steps. Room ambient temperature may change from time to time; so some experimentation and on-going correction is required to arrive at satisfactory results.

An inherent limitation in the drift-by technique is that fact that the entire "system" wants to drift toward a heat sink that is *not* at the desired processing temperature. An obviously more-satisfactory concept would be to supply a heat sink *at* the desired processing temperature. Any drifting then would be toward rather than away from the "bogey" temperature.

It is usually impractical to raise the temperature of the room air to a 100° ambient. Hence, a different form of heat sink is required. This can readily be supplied in the form of a water bath. Containers for solutions and the processing tube are partially immersed in this water bath so that, with the passage of time, any drift is toward the water-bath temperature. Thus, the bath can be used to bring the processing tube and chemicals to the desired temperature before initiating a process.

Implementation now requires that a satisfactory method be devised to keep the tempering water bath stabilized at the correct temperature. It is possible to use mixing valves on sources of hot and cold water, but this requires constant water flow for satisfactory results. Such heat and water wastage can be circumvented by supplying controlled amounts of heat to a fixed-volume water bath. This is the method exploited in the project to be described.

Since the temperature of the water

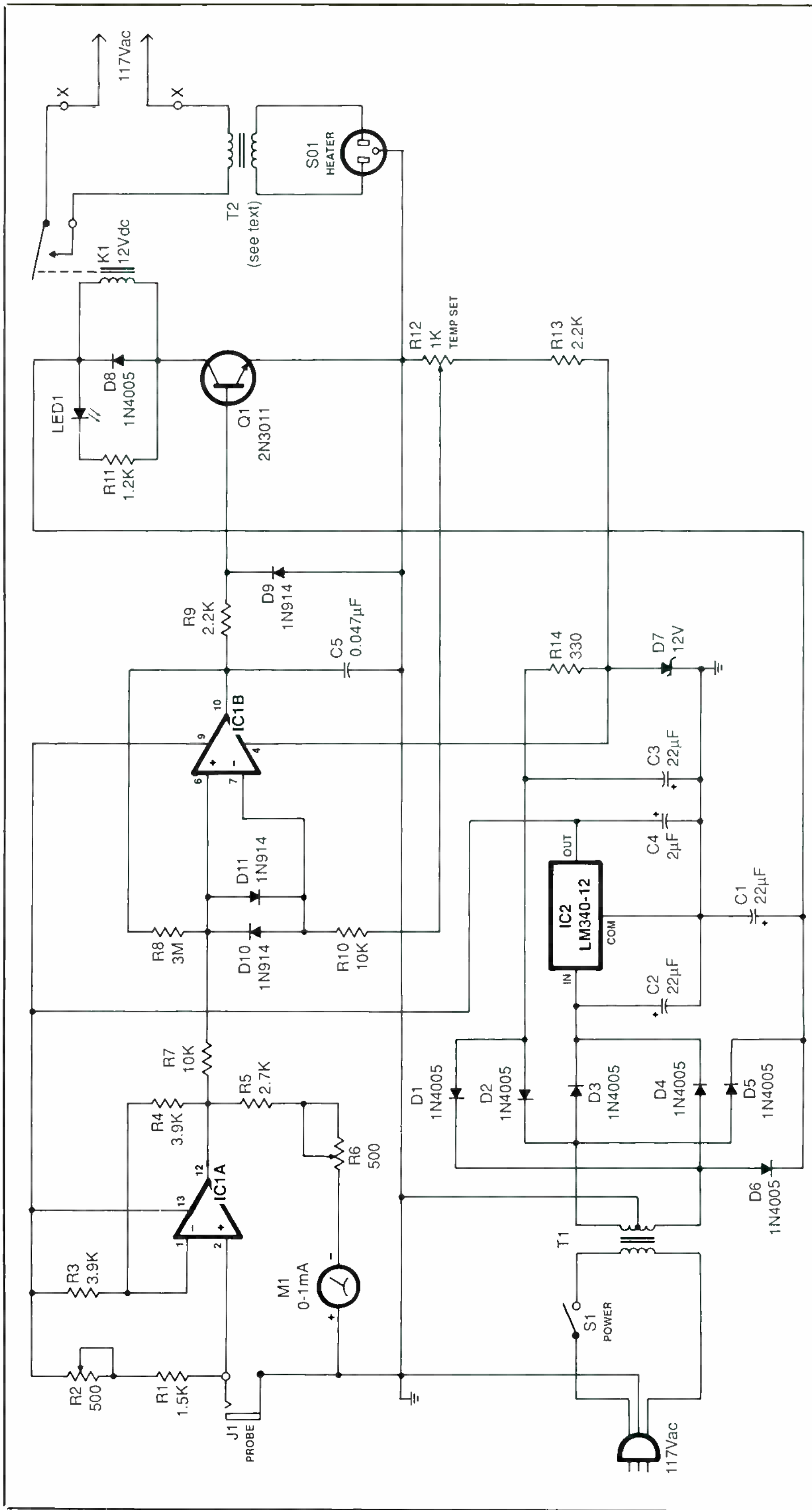


Fig. 1. Complete schematic diagram of Temperature Controller's circuitry.

PARTS LIST

Semiconductors
D1 thru D6,D8—1N4005 or similar 1-ampere, 400-PIV silicon rectifier diode
D7—1N759 or equivalent 12-volt zener diode
D9,D10,D11—1N914 or similar small-signal silicon diode
IC1—747 dual operational amplifier
IC2—LM340-12 or 7812 fixed +12-volt regulator
LED1—Red light-emitting diode
Q1—2N3011 or similar npn silicon switching transistor
Capacitors
C1,C2,C3—22-µF, 35-volt miniature electrolytic
C4—2-µF, 25-volt miniature electrolytic
C5—0.047-µF, 25-volt Mylar
Resistors (5% tolerance)
R1—1,500 ohms, ½-watt (see text)
R3,R4—3,900 ohms, ½-watt
R5—2,700 ohms, ¼-watt
R7,R10—10,000 ohms, ¼-watt
R8—3 megohms, ¼-watt
R9—2,200 ohms, ¼-watt
R11—1,200 ohms, ½-watt
R13—2,200 ohms, ½-watt
R14—330 ohms, ½-watt
R2,R6—500-ohm, pc-mount multi-turn trimmer potentiometer with 0.1" pin spacing
R12—1,000-ohm, panel-mount wire-wound, linear-taper potentiometer
Miscellaneous
J1—Miniature phone jack (Radio Shack Cat. No. 274-252 or similar)
K1—12-volt dc (150-ohm coil) relay with spst normally-open contacts
M1—0-to-1-mA meter movement with 2¼" square face (optional—see text)
S1—Spst slide or toggle switch
SO1—Panel-mount 3-conductor ac receptacle
T1—25-volt, center-tapped, 300-mA power miniature power transformer (Stancor No. P-8395 or similar)
T2—117-volt isolation transformer (optional—see text)
Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware (see text); sockets for ICs; Fenwal No. GB32P2 thermistor and other materials for probe assembly (see text); suitable enclosure (7"W × 3½"H × 3½"D); ac line cord with plug; miniature phone plug (Radio Shack Cat. No. 274-286 or similar) for probe cable; terminal strip; dial plate; control knob; lettering kit; spray acrylic; cardboard for dial-plate; staking pins; machine hardware; hookup wire; solder; etc.

bath is usually greater than that of the ambient air, only heat need be supplied. This is fortunate because the mechanics of cooling below ambient are more involved than the use of a simple immersion device that adds heat to the system.

An effective water-bath system includes a pan or tray of temperature-controlled water. The processing tube is then supported partially immersed in the bath so that it can be rotated by hand or a motor drive. Rim or axial drive can be arranged to turn the drum or tube at 30 to 60 rpm for satisfactory chemical action. Only an ounce or two of each chemical is then needed to process a print.

Tempering a water-bath system is straightforward. It consists of a pan or tray that holds a gallon or two of water, a heater to warm the water, a pump or impeller to circulate the water to maintain a uniform temperature throughout and a sensor to sample water temperature are interrelated to each other to form a feedback control loop that senses drops in water temperature and pumps heat into it to compensate. The control system stops pumping heat into the water when the desired temperature is reached.

A first approach to such a control system could utilize a snap-action thermostat to switch power to a heating element. The thermostat serves as both sensor and switch, which makes the circuitry very simple. Disadvantages of this system are: a considerable differential between on and off temperatures, the result of the hysteresis of the snap action; a tendency for contacts to arc when breaking the heater current path; touchy, time-consuming adjustments (which must be repeated every time temperature is changed; and an inability to maintain a temperature to within closer than a few degrees.

Accuracy and tightness of control can be considerably improved with an electronic regulator in which the heating element is separate from the sensor. Hence, the sensing element does not have to directly switch the heater current. This arrangement permits use of a sensitive semiconductor or thermistor as the sensor. Amplification can be added between sensor and heater to enhance sensitivity. The desired operating temperature is then selected or adjusted by the electronics package. This brings us to the project that is the subject of this article.

About the Circuit

Sensitivity to minute temperature changes is important in color-print processing. Therefore, a suitable sensing element is required at the "front end" of the project. Though thermocouples, resistance wire, carbon resistors, diodes, transistors and other elements are candidates for the sensor in this project, an inexpensive glass-encapsulated non-linearized thermistor is virtually ideal.

The temperature coefficient of the typical thermistor is negative. That is, its resistance decreases with increasing temperature. It is the ease with which a thermistor can be used in a simple resistive bridge circuit that makes the thermistor very suitable for our purpose here.

For this project, I chose a Fenwal No. GB32P2 thermistor as the sensor. This thermistor is enclosed in a glass envelope and has a resistance of 2,000 ohms at 25° C (77° F) that drops to 1,200 ohms at 100° F. Its

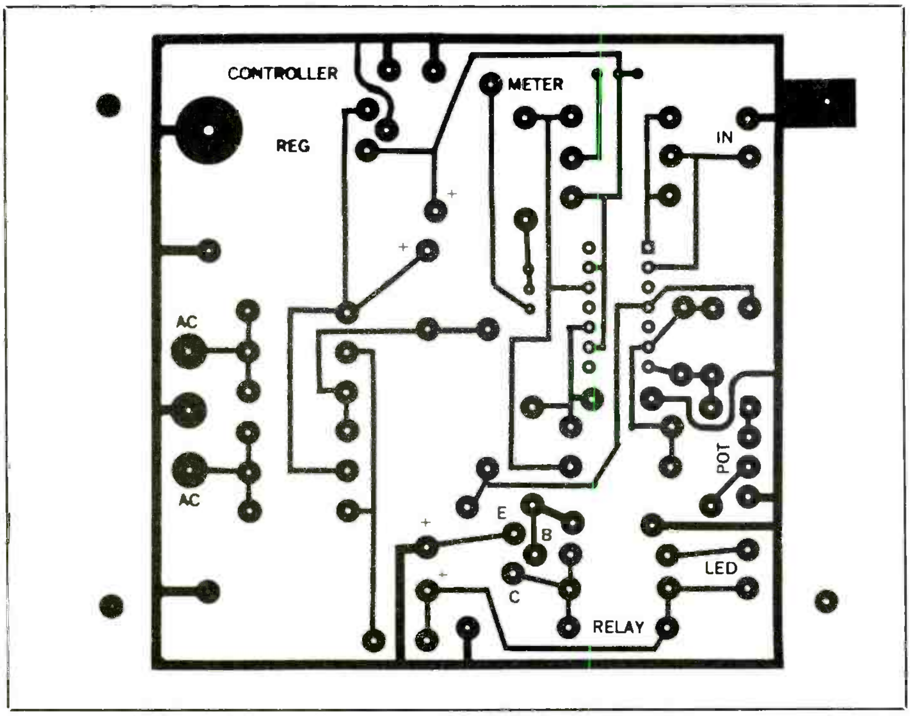


Fig. 2. Actual-size etching-and-drilling guide for project's printed-circuit board.

characteristic curve is exponential to beyond 300° C.

In this project, operation is confined to a limited range of temperatures between 20° and 50° C. Over this range, the performance of the Fenwal thermistor is nearly linear. The thermistor has a negative temperature coefficient of 3.9%/°C, which is slightly more than 2%/°F.

Shown in Fig. 1 is the complete schematic diagram of the electronic controlling circuitry for the regulator circuitry. Note that the thermistor connects, via INPUT jack *J1*, between the noninverting (+) input of operational amplifier *IC1A* at pin 1 and circuit ground. This first op amp is used as a bridge in conjunction with the thermistor. The thermistor and series resistor *R2* and potentiometer *R3* form one arm of the bridge. The other arm is made up of *R4* and *R5*. The differential voltage across the bridge is applied to the inverting (−) and noninverting (+) inputs of *IC1A* at pins 1 and 2, respectively.

With this configuration, the thermistor can work with circuit ground. The output of *IC1A* at pin 12 is 0 volt with reference to ground at a room temperature of 70° F. With the resistance of the thermistor dropping as heat increases, the resultant unbalanced bridge voltage causes the output voltage of *IC1A* to swing in the negative direction.

Meter *M1* is an option. With it connected to output pin 12 of *IC1A* as shown (and with proper scale calibration), the meter can display the temperature that corresponds to the voltage at pin 12 of the op amp. Note that because the output of the op amp is negative-going, the meter ties into the circuit with its positive (+) terminal connected to ground. This way, as temperature goes up and the resulting voltage at pin 12 of *IC1A* goes more negative, the swing of the meter's pointer will be up-scale.

Whatever voltage appears at pin 12 of *IC1A* is coupled through *R7* to the non-inverting input of *IC1B* at pin 6. This second op amp is wired to provide Schmitt-trigger action. Resistors *R8* and *R9* establish positive feedback from output pin 10 and + input pin 6 of *IC1B*. The ratio of the values of these two resistors determines the amount of hysteresis in the Schmitt trigger. (Separating the trip points via hysteresis improves on/off switching action and prevents relay "chatter" at the switching threshold.)

The output voltage from *IC1A* is applied to the inverting (−) input at pin 7 of the *IC1B* Schmitt trigger. This voltage becomes increasingly more negative as the sensed temperature rises. To permit adjustment of the voltage (and temperature) at which *IC1B* triggers or switches, a variable negative bias is connected to the − input of the op amp from the negative bus in the power supply via TEMP SET control *R12*. This bias can be adjusted over a range from 0 to −4 volts by means of the control to permit the temperature of the water bath to be varied from 75° to 110° F as needed for different chemicals.

The pin 10 output of *IC1B* connects to the base of relay driver transistor *Q1*, which has as its collector load the coil of relay *K1*. The transistor is operated in a switching mode to limit turn-on dissipation. Ac line power to the heater, plugged into receptacle *SO1*, is switched by the contacts of the relay.

Visual indication that power is being supplied to the heater is provided by light-emitting diode *LED1*. As you can see, a power transformer, *T2*, is shown connected between *SO1*. This transformer is an optional step-down unit that must inserted into the circuit as shown if you use a heater that requires a lower voltage than the 117 volts of the ac line.

If you plan on using a low-voltage heater exclusively, you can mount it inside the enclosure that houses the project and wire *SO1* into its secondary circuit as shown. Alternatively, if you want the flexibility of using a variety of heaters, wire *SO1* between the points marked "X" and use an external transformer as needed between the receptacle and heater.

Shown at the bottom in Fig. 1 is the

ac-line-operated power supply circuitry for the project. This is a conventional full-wave 12-volt design with regulation via fixed +12-volt regulator *IC2*. In addition to the +12-volt output, the supply also has a negative output via the *D1/D2* rectifiers for bias set via TEMP SET control *R12*. Zener diode *D7* makes this output nominally −12 volts, before it is divided down via *R12* and *R13* and applied to pin 7 of *IC1B*.

Because of the potential shock hazard, extreme caution is advised when contemplating use of an immersion heater to warm a water bath, which may involve occasional body contact with the water. The circuitry for the electronic portion of the project has been carefully designed to maximize safety. As you can see, a three-conductor line cord brings ac power into the project so that all metal is returned to ac ground. A relay isolates the controller circuitry from the 117-volt ac line power for the heater. Consequently, care should be exercised in selecting a heater for use with this project.

Imported immersion heaters intended to heat a cup of water for tea or coffee may have an adequate rating of 250 watts or so—sufficient power to heat the water bath. However, they are hardly shining examples of safe devices to use for this application. For a few dollars more in cost, an industrial immersion heater fitted with a three-conductor power cord would be a much wiser choice.

Another approach to safety can be considered if you are unable to find suitable high-grade 117-volt ac heaters. This is to operate the heater at a low voltage to reduce the danger of electrical leakage into the water bath. As described above, a step-down transformer would be used.

Ceramic-coated wire-wound power resistors wired together and powered by 6- to 24-volt transformers are another example of a heater that can be used. Obviously, current requirements will have to be tailored to the voltage applied so that 150 to 300 watts can be dissipated into the water bath. Because the power will be dissipated directly into the water bath, the physical sizes of the resistors can be smaller than they would have to be if dissipation is into the surrounding air. Connections for this arrangement can be coated with silicone adhesive for waterproofing and electrical insulation.

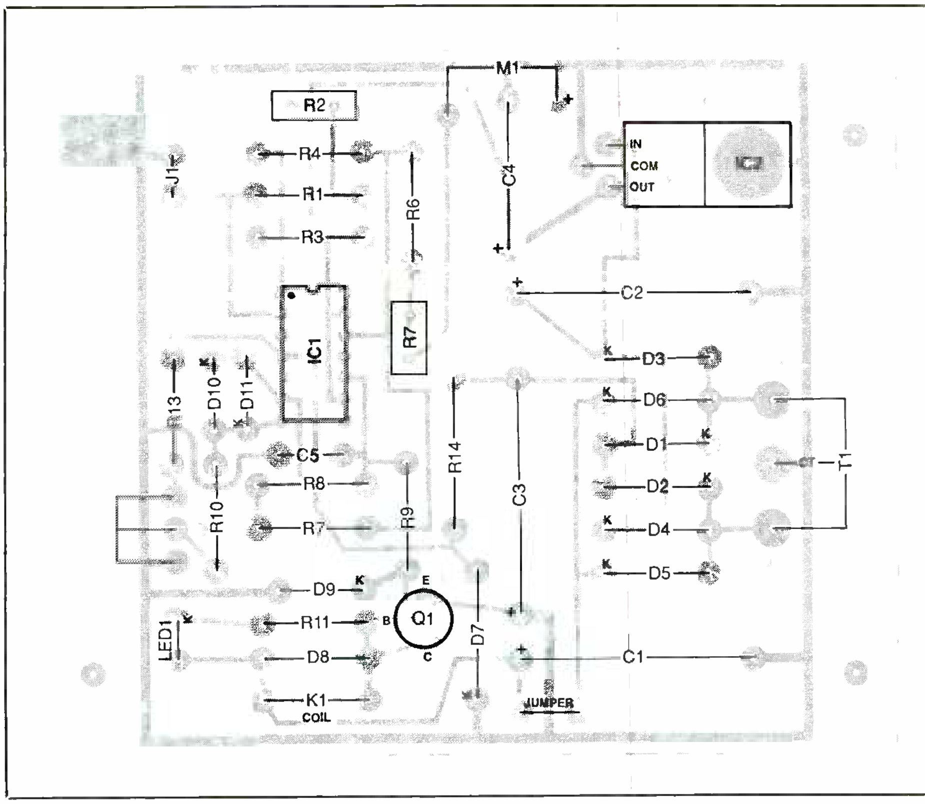


Fig. 3. Wiring diagram for pc board.

Construction

Begin construction by wiring together the electronics package. There is nothing critical with regard to component layout or conductor runs. Therefore, any traditional method of wiring can be used. You can wire together the components on a home-fabricated printed-circuit board or on perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware. In either case, use a socket for the dual op-amp integrated circuit.

If you decide to use printed-circuit construction, use the actual-size etching-and-drilling guide shown in Fig. 2 to fabricate one. When the board is ready, orient it in front of you as shown in Fig. 3 and begin populating it by installing and soldering into place the IC socket. Do *not* plug the IC into the socket until after you have conducted voltage tests and are satisfied that the circuit is properly wired. (If you are using perforated board, use the same general layout shown in Fig. 3, but refer to Fig. 1 for wiring details.)

Next, install and solder into place the resistors, trimmer potentiometers, capacitors and diodes. Make sure the electrolytic capacitors and all diodes are properly oriented before soldering their leads to the pads on the bottom of the board. As you now install the transistor in the Q1 location, make certain its leads go into the proper holes before soldering them into place.

Bend the pins of the voltage regulator back toward the metal tab on the case to form a triangular arrangement that conforms with the hole spacing for *IC2* on the board. When properly done, the pins should drop into the holes and the hole in the regulator's tab should line up with the hole in the circuit board. Secure the regulator in place with a 4-40 × ¼-inch machine screw, nut and lockwasher. Then solder its pins into place.

Strip ¼ inch of insulation from both ends of nine 6-inch-long hookup wires. If you are using stranded wire, tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. Plug one end of these wires into the holes labeled M1 (two wires), R13 (three wires), LED1 (two wires) and K1 COIL (two wires) and solder into place.

Install and solder into place a short length of bare solid hookup wire or cut-off resistor lead in the location near the bottom of the board indicated for the jumper. Then plug staking pins into both J1 holes and solder these into place. Temporarily set aside the circuit-board assembly and proceed to machining the chassis.

You can use any type of enclosure that will accommodate all components without crowding or interference with each other. Begin machining by drilling the mounting holes for the circuit-board assembly and power transformer through the floor panel. Then drill mounting holes for the POWER switch, light-emitting diode, input jack, potentiometer, meter movement (if used) and chassis-mount ac receptacle through the front panel. Then drill holes through the rear panel for mounting the relay and a four-lug terminal strip and to provide entry for the ac line cord as shown in Fig. 4.

Ideally, the relay coil and meter movement should be isolated from each other so that their magnetic fields do not interact. The particular inexpensive movement shown in the prototype in the lead photo and Fig. 4 has a steel shielding back panel that helps in this regard. However, any standard 1-milliampere full-scale movement may do as well or better in this project.

The plastic front of my meter was easy to remove to allow me to add a temperature scale, but this is not essential. A chart can be made relating temperature to meter pointer deflections if desired. Alternatively, the circuit can be aligned to give a center-scale indication at the desired operating temperature (say, 100° F), with greater and lesser temperatures being indicated by up- and down-scale pointer deflections. Surplus meter movements for FM receiver tuning have such calibration and are well-suited to this type of display.

In actuality, the meter movement is a convenience that can be eliminated altogether without sacrificing proper operation of the project, since the relation between temperature and control dial markings can be accurately determined. The control's range is such that temperatures between 75° and 110° F can be dialed in and maintained.

To conform to accepted human engineering principles, the TEMP SET control should be wired so that clockwise rotation of the shaft gives increases in temperature and vice-versa. This requires that the negative bias be increased to raise the trigger threshold. Hence, the wiper should move away from ground as the control's knob is rotated clockwise.

When you are finished machining the enclosure, deburr all holes and cutouts to remove sharp edges if any were drilled or cut through metal. Line the entry hole for the ac line cord with a rubber grommet. Then use a dry-transfer lettering kit to label the front panel as shown in the lead photo. (The calibration marks around the potentiometer control will be left for later during calibration and will be done on thin cardboard stock—like the blank side of an index card—that will be cemented into place on the panel.) When you finish the lettering, spray the entire panel with two or more light coats of

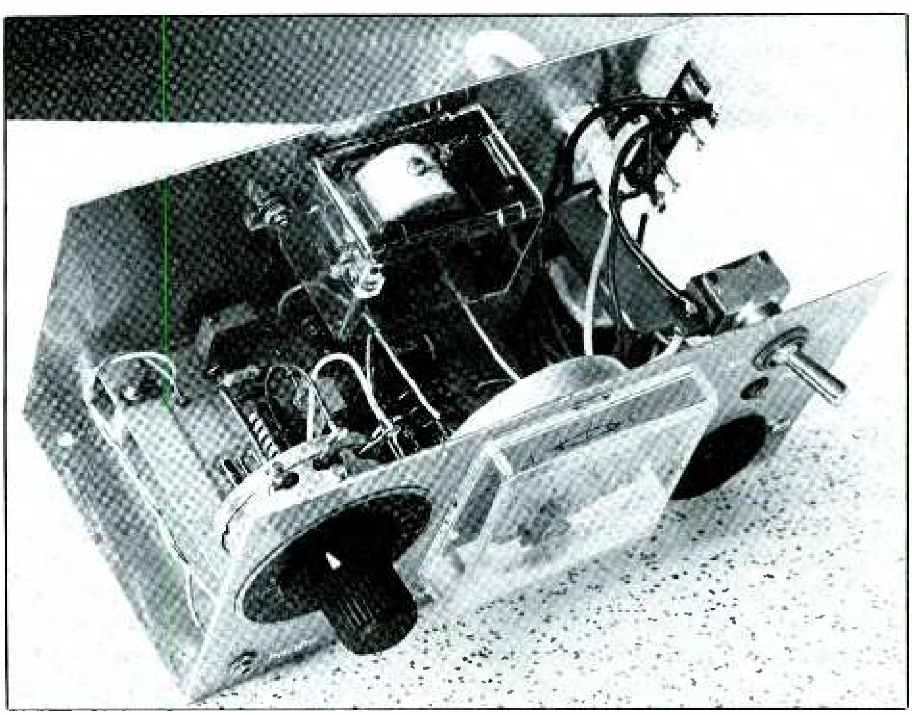


Fig. 4. Interior view of assembled project built on pc board.

clear acrylic to protect the legends. Allow each coat to dry before spraying on the next.

When the acrylic has thoroughly dried, plug the secondary leads of the power transformer into the T1 SECONDARY holes in the circuit-board assembly and solder them into place. Make certain that the center-tap lead goes into the center hole in the board.

Now mount the circuit-board assembly into place with ½-inch spacers and 4-40 × ¾-inch machine screws, lockwashers and nuts. Place an additional lockwasher between the ground trace hole near the J1 hole and top of the spacer at that location to assure a solid electrical connection between board and metal enclosure. Then mount the power transformer into place with suitable hardware.

Except for the LED, mount the various items that go on the front panel in their respective holes or cutouts. Position the potentiometer so that its lugs are pointing away from the floor of the enclosure. Locate the wires coming from the J1 holes and identify the one that is tied to *R1* via the circuit-board trace (lower of the two holes when viewing the board as shown in Fig. 3). Make a small hook in the end of this wire. Then loosely twist together both wires. Crimp and solder the free end of the wire with the hook in it to the "signal" lug of the jack. Then crimp and solder the free end of the other wire to the other lug on the jack.

Locate the wires coming from the R13 holes in the board. Crimp and solder the free end of the middle wire to the center lug of the potentiometer. Viewing the potentiometer from the front, crimp and solder the free end of the upper R13 wire in Fig. 3 to the left lug and the free end of the remaining wire to the right lug.

Crimp and solder the free ends of the wires coming from the M1 hole to the lugs of the meter (if used). Make sure the connections are properly polarized before soldering them.

Locate the two wires coming from the LED1 holes and identify the one for the cathode (labeled with a K in Fig. 3) by forming a small hook in the end. Clip the cathode lead of the LED to ½ inch long and form a small hook in the stub. Slip a 1-inch length of small-diameter heat-shrinkable tubing over the ends of both wires. Crimp together the cathode connection and solder it. Clip the anode lead of the LED to ½ inch long and connect and solder it to the free end of the remaining wire. Slide the tubing up over the connections until it is flush with the bottom of the LED's case and shrink into place. Use a standard panel clip or small rubber grommet to mount the LED in its hole in the front panel.

Strip ¼ inch of insulation from both ends of three 5-inch-long 16- or 14-gauge stranded hookup wires. Tightly twist together the fine conductors at both ends of all three wires and sparingly tin with solder. Crimp and solder one end of these wires to the three lugs on the ac receptacle mounted on the front panel.

Feed the unfinished end of the ac line cord through the hole you drilled for it into the enclosure. Tightly twist together the fine wires in all three conductors and sparingly tin with solder. Terminate the neutral conductor (the one that goes to the half-round pin on the line cord plug) in a No. 6 chassis lug. Secure this lug between the mounting lug of the terminal strip and chassis to provide a solid electrical and mechanical connection.

Now, using the terminal strip, wire together the ac line cord, POWER switch, primary side of the power transformer, relay contacts and chassis-mounted ac receptacle, as shown in Fig. 1. Make absolutely certain that you wire this circuit together properly. When you are finished with your wiring, double-check it against the schematic diagram to make sure it is correct.

The bare wires that connect to the thermistor must not come into contact with the water bath. Otherwise, leakage current through the water could reduce the apparent resistance of the thermistor and cause an apparent temperature display of greater than the true temperature of the water. In addition, the thermistor must be handled with care. So you must enclose the thermistor inside some form of probe housing.

A closed-end stainless-steel tube, such as used for Weston immersible thermometers, would be an ideal choice for the housing. However, more readily available is an 8-inch length of metal tubing that has inner and outer diameters of 0.25 and 0.13 inch. Two-conductor miniature speaker cable can be used to connect the thermistor to the circuitry.

A 3-foot length of cable is about right, but you can increase this if need be (cable length is not a critical factor). A miniature phone plug that matches the input jack on the front panel of the electronics package serves as the means for connecting the probe to the controller circuitry.

For proper operation of the project, the probe housing must be watertight yet provide good thermal coupling between thermistor and water bath. To achieve this aim, the lower end of the tubing must be tapped to accept a screw that acts as a plug that closes the end. The wire leads of the thermistor must be cut to different lengths, mated by soldering them to staggered ends of the miniature speaker cable. Lengths of insulating sleeving must be used to cover the thermistor joints to prevent them from touching the metal of the tubing and shorting out.

Slide the thermistor connected to its cable into the tubing and verify that the fit is okay and that neither lead comes into electrical contact with the metal tubing. Once verification is complete, remove the thermistor and paint the tubing to improve its appearance and help prevent corrosion while in use.

A heat-conductive epoxy is re-

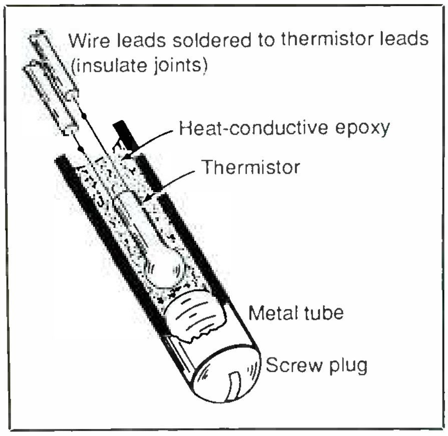


Fig. 5. Fabrication details for thermistor probe.

quired for final assembly. Wakefield Delta Bond 152 was used for the probe in the prototype. However, any other material that gives similar results will do fine.

Mix a small amount of the the two-part epoxy, enough to coat the threads of the screw used to plug the probe tip. After coating its threads with the epoxy mixture, drive the screw into the prepared end of the tubing and wipe away any excess epoxy on the outside of the assembly.

Next, coat the shank of the thermistor and tip with some more of the epoxy and slide the thermistor into the probe tube until its tip touches the screw. (Details of how the "action" end of the probe assembly is put together are shown in Fig. 5.) Then support the probe assembly vertically, tip end down, so that the viscous epoxy mixture firmly embeds the thermistor to the metal surround as it sets. Allow the probe assembly to set for a day at room temperature without further handling.

Cover the upper end of the probe housing with sleeving or heat-shrinkable tubing or caulking to prevent water from entering the tube from that end should the probe be accidentally dropped into the water bath. As a convenience for supporting the probe, you can slip onto the tubing a rubber bottle stopper, positioning it as shown in the lead photo.

When current flows through the thermistor, a certain amount of self-heating occurs. The thermistor should operate into a heat sink that absorbs this self-heat. The metal probe housing acts as this heat sink so that very little drift occurs even in air. With the probe immersed in the water bath, the thermistor "sees" a nearly infinite sink, and self-heating effects are eliminated. Hence, the thermal coupling between water bath and thermistor via the probe functions in both directions. Good thermal coupling is obviously required to reduce the thermal time constant by which the thermistor responds to the temperature of the bath.

Checkout & Use

With *IC1* still not installed in its socket, connect the common lead of a dc voltmeter or multimeter set to the dc-volts function to the negative (−) lead of *C2* or *C3*. Plug the line cord of the project into an ac outlet and set the POWER switch to "on."

Touching the "hot" probe of the meter to pin 4 of the *IC1* socket should yield a reading of −12 volts. Touching it to pins 9 and 13 of the same socket should yield a reading of +12 volts. Touching the probe to the positive (+) lead of *C1* should yield a reading of approximately +12 volts (this unregulated line goes to only the relay circuit and does not require tight voltage control).

If you do not obtain any of the above readings or one or more reading is the reverse polarity, the power-supply section is mis-wired, and this situation must be corrected. Power down the project by pulling its line cord from the ac outlet, and rectify the situation.

When you are certain that the project has been properly wired, power it down and allow the charges to bleed off the electrolytic capacitors in the power supply. Then install *IC1* in its socket. Make sure the IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

When using the project, the probe should be plugged into the INPUT jack at all times power is applied. Some current flows through the thermistor, resulting in a small amount of self-heating. With the probe held in the air, the temperature indication may "creep" slightly because (as mentioned above) the probe housing is a limited-area heat sink. With the probe tip properly immersed in water, however, this effect is negated by the volume of the water and readings will be stable.

Calibration of the circuit consists merely of adjusting the two trimmer controls on the circuit-board assembly to establish the control range. It may be possible to reduce the value of *R6* and increase that of *R7* to 1,000 or even 5,000 ohms if you wish different meter indications. However, keep in mind that the meter circuit shunts the output of *IC1A*, which should not be heavily loaded.

The meter movement described above, or one similar to it, can be calibrated as follows:

- Immerse the probe in a jar of water, along with a reference thermometer but do not plug an immersion heater into the project's chassis-mounted ac receptacle.
- Adjust the water temperature manually to 75° F by adding hot water and turn on power. (Note: As you add warm or cool water, stir the water in the jar to obtain a uniform temperature throughout as you proceed with the calibration steps.)
- Adjust trimmer *R3* until the meter's pointer rests at the left index on the scale. Label this index 75°.
- Add warm water to the jar to bring the temperature up to 90° F and adjust trimmer *R7* until the pointer is at mid-scale. Mark and label this position 90°.
- Raise the water temperature to 100° and lower it to 80° and mark and label these points on meter scale.
- Continue raising the temperature

to 110° and lowering it in 5° increments and label the scale accordingly. If you wish, you can then put minor divisions on the scale at each 1° increment. These should prove sufficient for most purposes.

If you omitted the meter movement, calibrate a dial plate for the TEMP SET control on the front panel. Use the heater to raise the water temperature to 75°F on the thermometer and make a mark at this point on the dial plate, labeling it 75°. Continue doing this in 5° intervals, as indicated on the thermometer. After calibrating the dial plate in 5° intervals, calibrate it in 1° intervals.

As you do the above, allow the probe sufficient time to stabilize in temperature at each calibration point. If you fabricated the probe as described above, stabilization should occur in only a few seconds.

Once the project is calibrated, use the TEMP SET control on the front panel to set the trigger threshold that sets the temperature at which the heat is cycled on and off at a duty cycle that will maintain the water bath at the temperature selected.

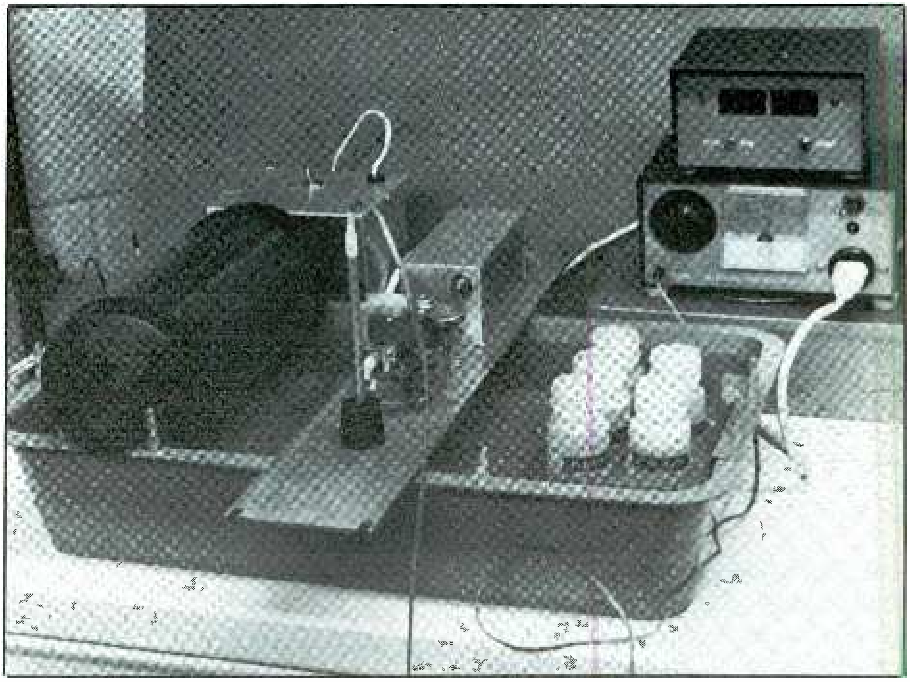


Fig. 6. Typical processing arrangement shows drum at left, project with probe, immersion heater and stirrer at center, and bottles of chemicals in water bath at right. Motor constantly turns drum and stirrer assures uniform bath temperature.

Figure 6 shows a typical print-processing arrangement using the DEV TEC drum and a water bath. The immersion heater, probe and circulator to stir the water to maintain a uniform bath temperature are all mounted on a metal support strip that lies across the bath. The drum rests across support pins and freely rotates, partially submerged in the water bath.

The drum is conveniently rotated by a 30-rpm motor that axially drives the tube from one end. This motor alleviates the tedium of manually rotating the tube at a uniform rate during processing and is a worthwhile embellishment to the processing arrangement.

A typical thermistor may have a 20-percent tolerance in exact resistance-versus-temperature characteristics. Initially, bridge balance is made by making the differential potential at pins 1 and 2 of *IC1* equal to 0 volt so that the output at pin 12 is also 0 volt. Although the differential input to the 747 is 0 volt, each input may be +6 volts in itself.

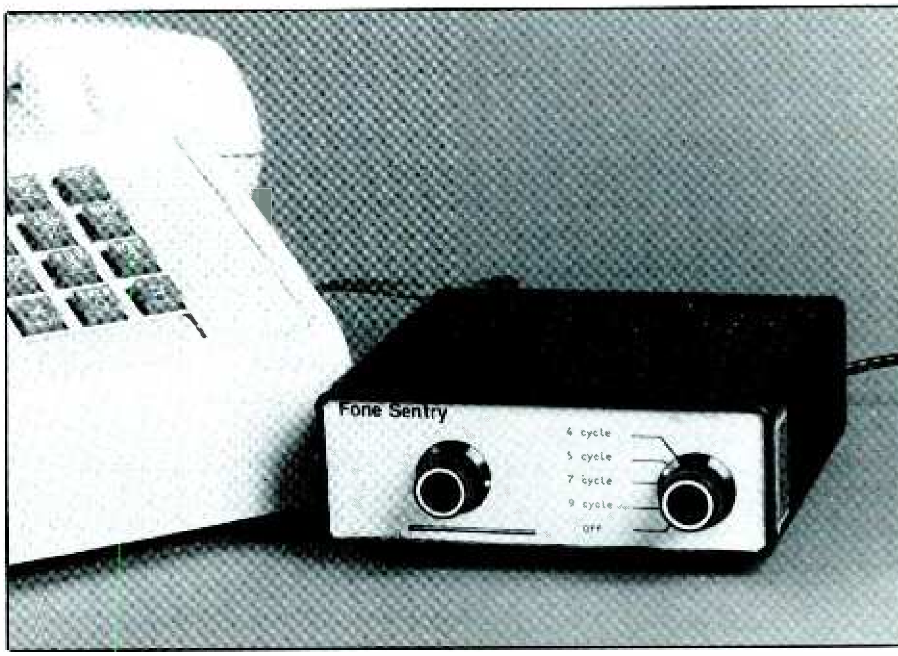
Should the thermistor resistance be such that initial balance cannot be obtained, the value of *R2* can be changed so that 75° balance is obtained with the TEMP SET control on the front panel set to maximum counterclockwise. Should higher temperatures be desired at the upper end of the control range, the value of *R14* can be slightly reduced.

With the arrangement described earlier, the project will regulate temperatures over a 75° to 110°F range, which adequately covers most present-day processing requirements. Of course, this assumes that the ambient temperature in the processing area is *lower* than the desired processing temperature. **ME**

The Fone Sentry

Prevents your telephone from ringing for a preselected number of times so that you will not be disturbed while sleeping

By Steve Sokolowski



Have you ever been disturbed from a sound sleep by the shrill ring of your telephone only to answer a wrong number? If so, you will really appreciate our Phone Sentry. This handy telephone accessory can be set to intercept the ring signal for a preset number of pulses before your telephone actually does ring. By preventing your telephone from ringing until the preset count is reached, unwanted callers will simply assume no one is home and hang up. For those people to whom you wish to talk, just inform them to let the phone ring for more than the predetermined number of times, which can be in the range of four to ten.

When your phone finally does ring and you answer it, operation of the system is unaffected from normal. Upon completion of the call and you hang up, Fone Sentry automatically returns to monitoring your telephone line until the next call comes in.

About the Circuit

Fone Sentry is basically a counting circuit. Instead of counting digital pulses, it counts the number of times the telephone company places the ring signal across the red- and green-insulated wires of the line. When the ring signal count corresponds with that selected by you with a rotary switch on the project, Fone Sentry enables an electronic switch. At this point, an internally generated ringer sounds to alert you to the fact that someone who has the get-through "code" is on the line. You then pick up the telephone instrument's handset and conduct your conversation.

The complete schematic diagram of the Fone Sentry's circuitry is shown in Fig. 1. Power for the circuit is supplied by a commonly available 12-volt dc plug-in power supply, which connects between the +12-volt bus and circuit ground.

When power is applied to the circuit, *IC1* goes into oscillation and generates three different audio tones. Individual inverters in hex inverter *IC1* then perform separate functions. For example, *IC1A* and *IC1B* make up a low-frequency generator that oscillates 12 times per second. Similarly, the *IC1C* and *IC1D* combination generates a 287-Hz tone and the *IC1E* and *IC1F* combination generates a 335-Hz tone. Whether or not the Fone Sentry is active, *IC1* continuously develops these tones.

The secret of producing the pleasant-sounding audio tones generated by expensive AT&T, NEC and Toshiba instruments is the way the basic frequencies are mixed by *IC2*. This 4093 quad two-input NAND Schmitt trigger combines the three input tones from the *IC1* oscillators at pins 4, 8 and 10 at pins 1 and 2 of *IC2A* and pins 5 and 6 of *IC2B* appears at output pin 11 of *IC1C*.

Control of the time Fone Sentry signals an incoming call and the on/off sequence of the tone generator is determined by 4066 bilateral switch *IC3*. To better understand how this unique switching arrangement works, turn to Fig. 2. Here you can see that two of the four switches inside the 4066 chip are connected in series with each other. For an output to appear at pin 11 of the chip, Switch #1 and Switch #2 must be closed. To close these switches, control voltages are introduced at pins 12 and 13, respectively, of the chip. It is the task of these control voltages to mold and shape the tone signal as needed.

To close switch #1, a positive voltage must be provided at pin 13 of the 4066. If an IC that counts the number of 110-volt, 30-Hz ring-signal pulses are applied across the telephone line and these pulses go from ground to a positive voltage every time the predetermined ring count is reached, a logic 1 can be placed on pin 13 of the 4066 to control the first half of the internal tone generator.

If Switch #2 were not used, the audio tone produced by *IC1* in Fig. 1 would be heard from crystal transducer *XTL1*. A signaling tone of this type can quickly become annoying. To compensate for this, Switch #2 inside the 4066 is used to shape the audio into the normal 2 seconds on/4 seconds off ring cycle.

Conditioning the incoming ring signal with *IC5* and *IC2D* provides the makings for the second needed pulse. Now, every time the ring signal across the telephone line is detected, these two chips develop a pulse that has a 2-second on period and 4-second off period. It is this pulse that synthetically creates the standard telephone company ring signal.

To see how these control pulses are created, turn your attention to 4N33 optical isolator *IC5* in Fig. 1. This device connects across the incoming telephone line through resistor *R1* and capacitor *C1*. Connected internally between pins 1 and 2 of the optoisolator is a light-emitting diode, which flashes when a ring voltage on the telephone line is detected.

When the LED inside *IC5* flashes, a light-activated photo-Darlington transistor array inside the chip conducts. In turn, the transistor allows the + 12 volts applied through *R10* to pin 5 of *IC5* to be grounded. To convert this pulse into a positive-going signal, *IC2D* is used as an inverter. Not only does *IC2D* invert the signal,

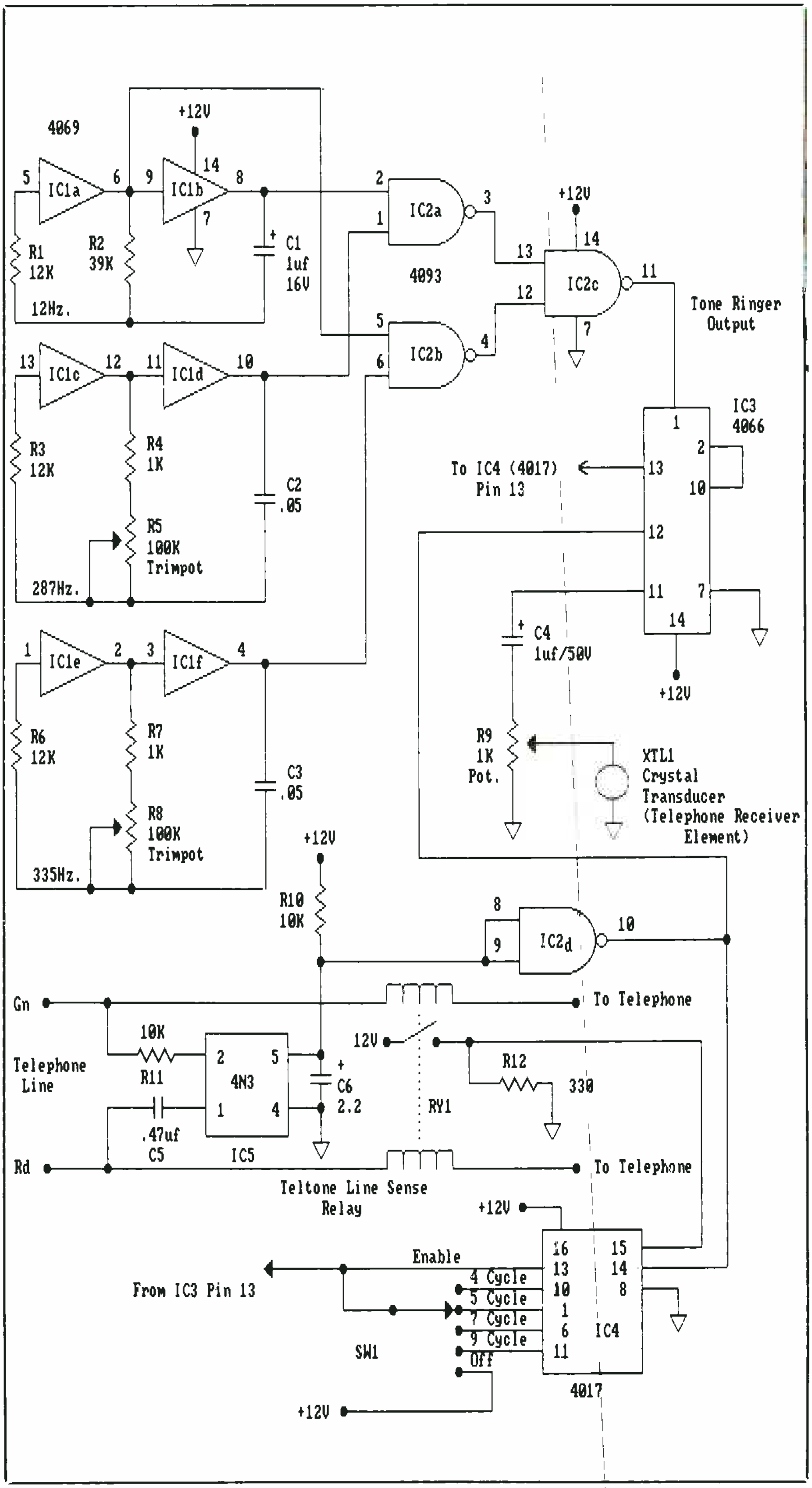


Fig. 1. Complete schematic diagram of the Fone Sentry circuitry.

PARTS LIST

Semiconductors
IC1—4069 hex inverter
IC2—4093 quad 2-input NAND Schmitt trigger
IC3—4066 bilateral switch
IC4—4017 divide-by-10 counter
IC5—4N33 optical isolator
Capacitors
C1—1-μF, 50-volt axial-lead electrolytic
C2,C3—0.05-μF ceramic disc
C4—1-μF, 50-volt radial-lead electrolytic
C5—0.47-μF, 250-volt axial-lead tubular
C6—2.2-μF, 16-volt axial-lead electrolytic
Resistors (¼-watt, 5% tolerance)
R1,R3,R6—12,000 ohms
R2—39,000 ohms
R4,R7—1,000 ohms
R12—330 ohms
R5,R8—100,000-ohm trimmer potentiometer (Digi-Key Cat. No. KOA15 or similar)
R9—1,000-ohm linear-taper potentiometer

Miscellaneous
RY1—Line-sense relay (see text)
SW1—1-pole, 6-position nonshorting rotary switch
XTL1—Crystal transducer (or telephone receiver element—see text)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure; 12-volt, 200-mA dc plug-in power supply; telephone line cord; chassis-mount modular telephone connector with solder leads; pointer-type control knob; machine hardware; hookup wire; solder; etc.

Note: The following items are available from Steve Sokolowski, P.O. Box 5835, Spring Hill, FL 34606: Ready-to-wire pc board, $6.95; Teltone line sense relay, $5.75; six-conductor telephone line cord with spade lugs on both ends, $1.75. Add $2.50 ($4 in Canada) P&H per order. Florida residents, please add state sales tax.

the snap action associated with Schmitt-trigger devices that it has cleans up the pulse so that it can also be used as a "clocking" signal for *IC4*, a 4017 divide-by-10 counter.

Counter *IC4* provides a 1 of 10 output. An interesting feature of this chip is that it contains an ENABLE input at pin 13, as well as the standard RESET input at pin 15. With ground potential placed on these two pins, the 4017 repeatedly clocks through its 10 output states.

With each clock-pulse input, *IC4* places a positive voltage on its corresponding output. That is, if the third clock pulse were to be entered, OUTPUT 3 at pin 7 would have a positive voltage on it while the remaining nine outputs would be at ground potential. Similarly, when the fourth clock pulse is entered, OUTPUT 4 at pin 10 would be at a positive voltage while all other output pins would be at ground potential, including pin 7.

If ground potential is needed at pins 13 and 15 of *IC4* for the 4017 to count, what would occur if a positive signal is created by the counting circuit and applied to the ENABLE input at pin 13? Under this condition, the counter would automatically stop counting at a predetermined count.

By connecting pins 1, 6, 10 and 11 of *IC4* to the positions of a multiple-position switch as shown for *SW1*, the positive pulse from any counter output can be applied to pin 13 of the same chip to stop the 4017 from counting once the predetermined count cycle has counted out. This positive pulse can also be connected to the CONTROL input at pin 13 of *IC3*. This would close the first half of the two-switch combination inside the chip.

With the first half of *IC3* receiving a control voltage, all that is left to do is obtain an audio output. This is accomplished by applying a second gating voltage to pin 12 of this chip by "stealing" the output from pin 10 of *IC2D*. With this voltage applied, the warble tone generated by the Fone Sentry will be heard from the crystal transducer.

When the telephone is answered by picking up its handset, some means is needed to reset the internal counters of *IC4*. If a positive voltage were to be applied to pin 15 of this chip, counting will immediately cease and the counters will be cleared back to the zero state. Once this is done, the next clock pulse that is received will be counted as pulse 1.

The required reset voltage is very easily created. By using a special telecommunications device known as a "line-sense relay" (see Fig. 3), made by Teltone Corp., the lifting of the telephone handset can be sensed and an internal relay contact closed. It is the closing of this relay, *RY1* in Fig. 1, contact that applies the reset voltage to pin 15 of *IC4*.

When the handset is returned to the instrument cradle (hung up), the contact of *RY1* opens, disconnecting the + 12 volts from pin 15 of *IC4* and once again placing this pin at ground potential through *R12*. At this point, Fone Sentry is rearmed and ready to intercept the ring signal of the next incoming call.

Construction

There is nothing critical about component layout or conductor routing in this project. Therefore, you can use either a printed-circuit board or perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware on which to assemble the project. If you wish to fabricate your own printed-circuit board, you can use the actual-size etching-and-drilling guide shown in Fig. 4. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

Whichever method of assembly you choose, it is a good idea to use a socket for each IC to aid in assembly

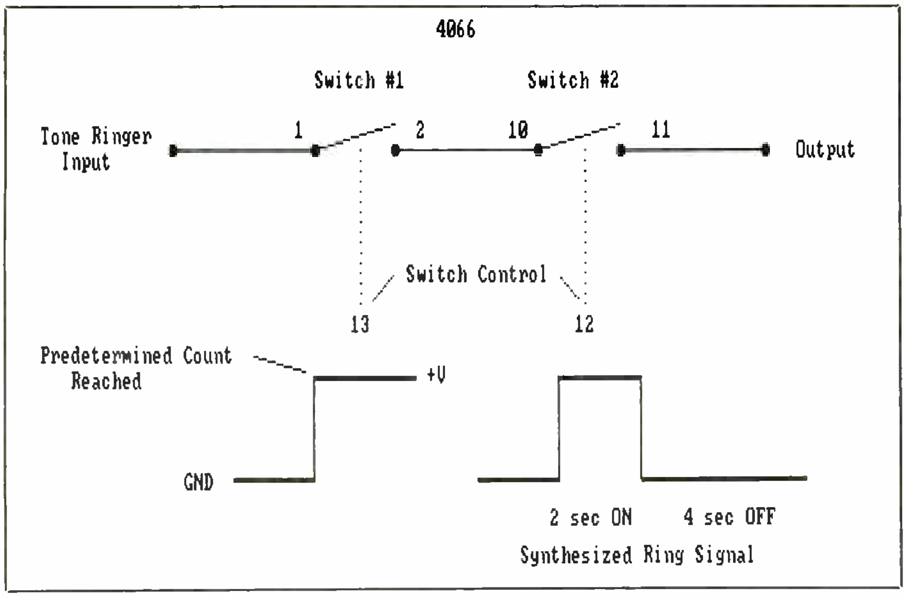


Fig. 2. Internal details of the bilateral switch used in this project and how it conditions the signal.

and ease component replacement should that ever become necessary. If you cannot obtain a six-pin socket for *IC5* and do not wish to attempt to cut down a standard-size socket to make one, substitute Molex Soldercon socket pins.

Assuming you are using a pc board, orient it in front of you as shown in Fig. 5. Begin wiring the board by installing and soldering into place the six jumper wires in the indicated locations. Then install and solder into place the IC sockets. Do *not* plug the ICs into the sockets until after you have conducted preliminary tests and are certain that the circuit has been properly wired.

If you are using perforated-board construction, use the same general layout shown for the components in Fig. 5. When wiring it, make certain to keep the +12-volt bus away from the telephone-line input. The telephone company will not appreciate having 12 volts added to its line.

Proceed with wiring the circuit-board assembly by installing and soldering into place the resistors and trimmer controls and then the capacitors. Be sure to properly polarize the electrolytic capacitors before soldering their leads into place. Also, note that some resistors—specifically, *R3*, *R4*, *R6* and *R7*—mount on-end to conserve board space. Install and solder into place *RY1*.

At this point, the only components you should have left to install are the various integrated circuits, crystal transducer and panel-mount potentiometer *R9*.

Strip ¼ inch of insulation from both ends of eight 5-inch lengths of hookup wire. If you are using stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Plug one end of six of these wires into the holes indicated for *SW1* and solder into place. Similarly, plug one end of the remaining two wires into the holes for *XTL1* and solder these into place.

Now, referring to Fig. 6, terminate the free ends of the *SW1* wires at the lugs of the rotary switch. Terminate the free ends of the remaining two wires at the two outer lugs of the panel-mount potentiometer. Make sure all connections are both electrically and mechanically secure before soldering them.

Now machine the enclosure in which the project is to be housed. Select an enclosure that will comfortably accommodate the circuit-board assembly and has sufficient panel space on which to mount the rotary switch and potentiometer on the front panel and the modular jack and entry holes on the rear panel. Also, drill a tight pattern of small holes in the top panel of the enclosure to allow the sound from the crystal transducer element to escape.

You can use either a metal, plastic or combination enclosure for the project. If you use metal or drill holes through a metal panel deburr the holes to remove sharp edges and line the cable entry holes with small rubber grommets.

After machining the enclosure, route the telephone line cord and cable from the plug-in power supply through their grommets. If either or both have a connector at the end, clip them away and discard them. Tie a strain-relieving knot in each cable about 5 inches from the free end inside the enclosure.

Prepare the ends of both cables by

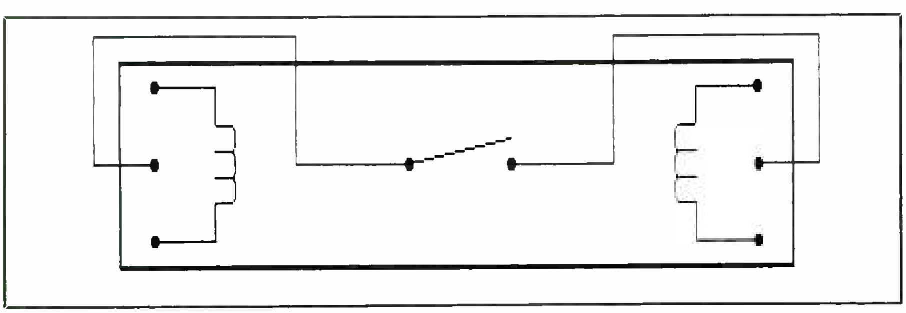


Fig. 3. Internal details of the line-sense relay used in this project.

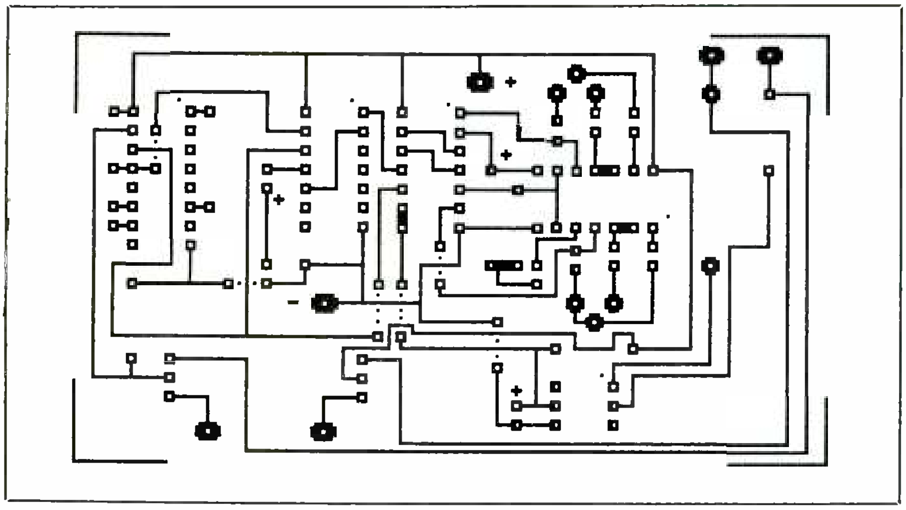


Fig. 4. Actual-size etching-and-drilling guide for project's printed-circuit board.

removing ¼ inch of insulation from the conductors. Tightly twist together the fine conductors then exposed and sparingly tin with solder. Now, making absolutely certain to observe proper polarity, plug the prepared conductors of the telephone line cord into the two holes at the upper left of the board and solder into place.

Similarly, plug the prepared + 12-volt end of the cable from the power supply into the hole labeled + 12V and solder the connection. Twist together the free end of the other cable conductor and one lead of the crystal transducer, plug both into the hole labeled − 12V and solder the connection. Connect and solder the remaining lead from the transducer to the center lug of the panel-mount potentiometer.

Mount the modular connector in the cutout you made for it in the rear panel. Then clip away any leads other than those that have red and green insulation on them. If the leads are terminated in spade lugs or any other connecting devices, clip these off and strip ¼ inch of insulation from both wires. Tightly twist together the fine conductors in both wires and sparingly tin with solder. Plug the free ends of these leads into the holes labeled RED and GREEN, matching insulation color to the legends and solder both connections.

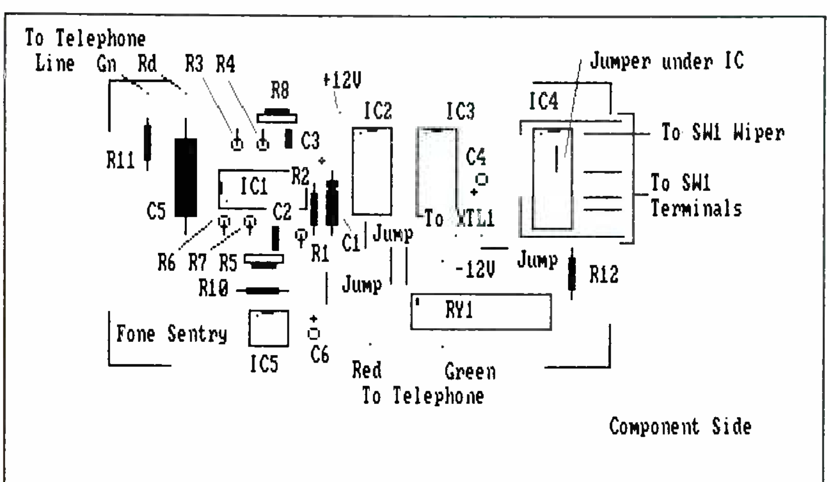


Fig. 5. Wiring guide for printed-circuit board. Use this as a rough guide to component layout when assembling project on perforated board.

Checkout

Before you attempt to mount the circuit-board assembly in its enclosure, visually inspect both sides of it for proper construction. On the top of the board, check component installations for proper values or numbers and orientations of the electrolytic capacitors. Check the bottom of the board for poor soldering, connections you might have missed and solder bridges, especially between the closely spaced IC pads. If you missed a connection, solder it now. If you suspect the integrity of any connection reflow the solder on it and add solder if needed. If you locate a solder bridge, clear it with a vacuum-type desoldering tool or wicking-type desoldering braid.

It is now time to perform some power-up tests. There should be no ICs in the sockets until after the voltage tests have been performed and you are certain that the project is properly wired.

Place the circuit-board assembly on an insulated surface and set the switch, potentiometer and crystal transducer on the surface away from the board. Clip the common lead of a dc voltmeter or a multimeter set to the dc-volts function to a convenient point that is supposed to be at circuit ground. The farthest-right jumper wire is a good choice.

Set the meter to indicate at least 15 volts dc full-scale. Plug the project's power supply into a convenient ac outlet. Then use the "hot" probe of the meter to check the voltages at pin 14 of the *IC1*, *IC2* and *IC3* sockets and pin 16 of the *IC4* socket. In all cases, the reading obtained should be very near + 12 volts. If you fail to obtain this reading at any one or more specified points, disconnect the project's power supply from the ac line and rectify the problem. Do not proceed until you have done so.

When you are certain that the project is properly wired, disconnect power from it and allow sufficient time for any charges to leak off the electrolytic capacitors. Then install the ICs in their respective sockets. Make sure you plug the proper IC into each socket and that it is properly oriented. As you push each IC home, make certain that no pins overhang the socket or fold under between IC and socket.

Mount the potentiometer and switch in their holes in the front panel. Place a pointer-type knob on the shaft of the switch and check for symmetrical detent pattern. If necessary, readjust the positioning of the switch to obtain symmetry.

The easiest way to mount the circuit-board assembly inside the enclosure is with two or more strips of thick double-sided foam tape. If the enclosure is metal, make certain that no part of the circuit-board assembly contacts it after mounting is complete. Then use a fast-setting epoxy or silicone adhesive to secure the crystal transducer element to the top panel, centering it in the pattern of small holes you drilled for the sound to escape.

Use a dry-transfer lettering kit or tape labeler to label the positions of the switch on the front panel. If you use dry-transfer lettering, spray two or more light coats of clear acrylic over the panel to protect the legends from damage. Allow each coat to dry before spraying on the next.

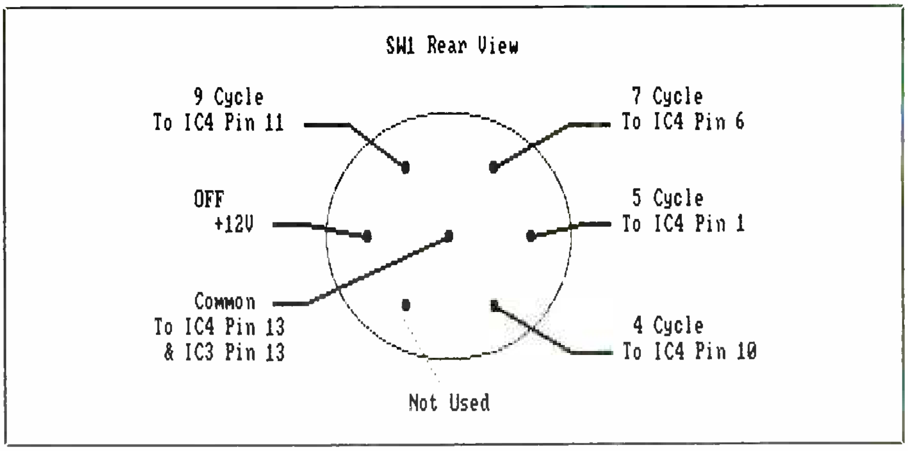


Fig. 6. Wiring details for rotary switch.

Installation & Use

Fone Sentry simply installs in series with an existing telephone instrument and the wall box to which the instrument is currently connected, as illustrated in Fig. 7. Simply unplug the telephone instrument from the wall box and plug it into the modular jack on the rear panel of the project. Then plug the project's line cord into the telephone wall box. Because the Phone Sentry is a telephone accessory, connection from it to the wall box *must* be made via a modular connector under FCC Regulations.

If you are using an old-type telephone instrument that does not have a modular connector at the wall-box end of its cable, you can eliminate the modular connector on the project's rear panel and simply wire the instrument's cable directly to the RED and GREEN holes near the bottom of the board, as viewed in Fig. 5. Then, replace the wall box with a modular type and plug the project's telephone cord into that.

If you are using a telephone instrument that has actual bells that ring to signal an incoming call, you must disconnect the bells when using the Fone Sentry. To do this, open the housing of the instrument. Locate the bells and then the solenoid winding that operates the clapper. Trace one of the solenoid wires to a place inside the instrument where it connects to the rest of the circuitry. Loosen the screw that holds it in place and withdraw the traced wire. Tighten the screw and wrap the freed spade lug with electrical tape. Reassemble the instrument.

Plug Fone Sentry's power supply into a convenient ac receptacle (where it will normally remain plugged). Now conduct an operational test to check out the ringer circuitry. To do this, temporarily connect a telephone receiver element through a 1-microfarad capacitor to pin 11 of *IC2* and connect the other lead of the element to circuit ground. At this point, you should hear some sound coming from the element.

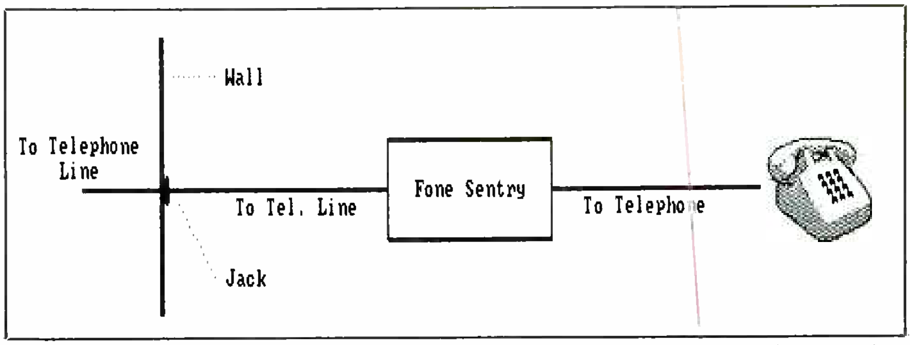


Fig. 7. Fone Sentry installs between incoming telephone line and telephone instrument.

Connect the ground side of the cable that feeds into the input of a frequency counter to a convenient ground point in the circuit and touch the "signal" lead to pin 10 of *IC1*. Adjust the setting of trimmer *R5* for a displayed frequency of 287 Hz. This done, touch the counter's "signal" lead to pin 4 of *IC1* and adjust the setting of trimmer *R8* for a displayed reading of 335 Hz. When these adjustments have been properly made, you should hear a pleasant warble tone from the receiver element. Remove the receiver element from ground and pin 11 of *IC2*.

For the next test, you need to enlist the aid of an assistant. With the switch set to its 4 CYCLE position, have your assistant call you on another telephone. Now, with an oscilloscope connected to pin 10 of *IC2*, note the detection of the incoming ring signal. At this time, you should not hear any sound from the Fone Sentry. Count off the pulses, as displayed on the scope's screen. On the fourth count, the project should suddenly come alive with the sound of its warble tone.

Answer the call and observe that a reset voltage is applied to pin 15 of *IC4*. Set the switch to its 9 CYCLE position and have your assistant call again. This time, the number of pulses you count should reach nine before the project sounds its alerting warble tone.

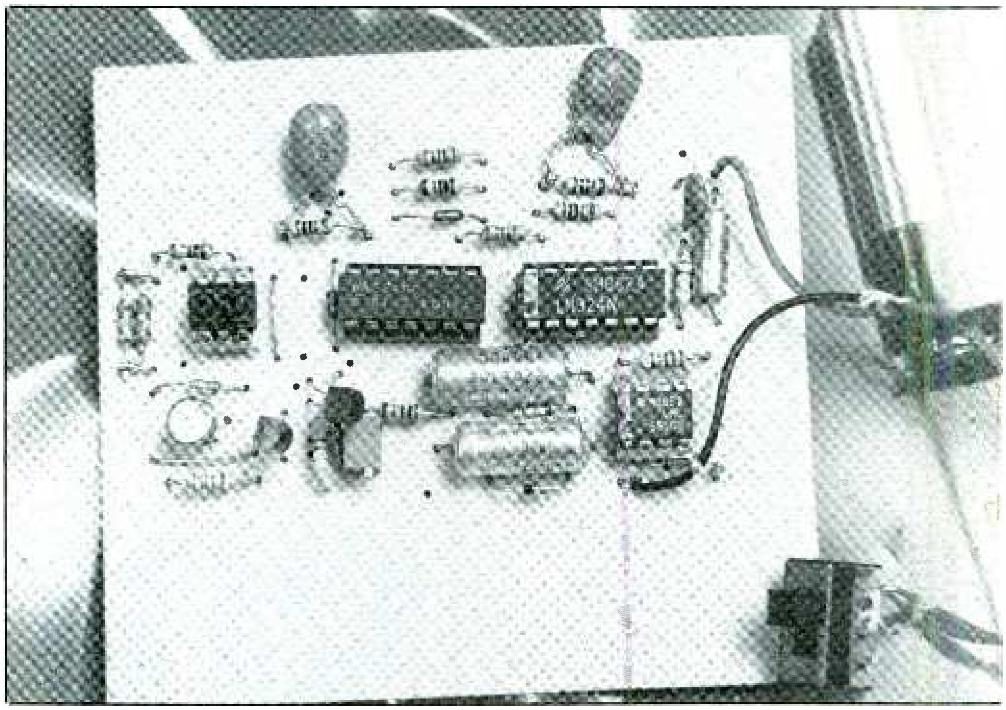
Now make a final check. Set the front-panel switch to its OFF position and have your assistant call one last time. This time, Fone Sentry should ring immediately upon reception of the first ring pulse from the telephone company.

Now that you have a working project, set the front panel switch to whichever position you want. During the normal daytime period, you might want to keep the switch set to OFF so that you can answer any incoming call on or after the first ring. But do not forget to select a different position for your sleep period. **ME**

An Electronic Altimeter

This portable all-solid-state instrument responds to ambient air pressure to provide altitude readings of up to 5,000 feet in 1-foot increments

By Anthony J. Caristi



People who enjoy hiking or climbing of small mountains and driving through mountainous area are often interested in altitude. The portable solid-state Electronic Altimeter described here will provide such readings. It is similar in design to the altimeters used in aircraft, though its range is relatively short—0 to 5,000 feet—but useful for the intended purpose.

Our Altimeter responds to ambient air pressure, which varies inversely with altitude. It contains a high-quality solid-state pressure sensor that measures absolute pressure and an electronic circuit that converts the sensor's output voltage into a meaningful altitude reading in feet.

Powered by an ordinary 9-volt battery, the project permits complete portability. The useful life of the battery will be many hours, using the project for taking on-demand readings. Alternatively, it can be wired into the electrical system of a motor vehicle to provide a continuous readout of altitude. A third alternative is to wire the project for a choice of either powering scheme for operation both in a vehicle and on foot.

You have a choice of readouts for the project. For greatest sophistication and easiest-to-interpret readings, an ordinary digital dc voltmeter (or digital multimeter set to the dc-volts function) can be used to provide direct numeric display in feet. A second alternative is to wire into the project a dedicated analog-to-digital converter and its own digital numeric display. Another alternative is to build into the project a low-cost analog meter movement.

About the Circuit

Shown in Fig. 1 is the schematic diagram of the basic Electronic Altimeter circuitry. At the heart of this instrument is miniature solid-state pressure sensor *PS1*, which was developed by Nova Sensor (Fremont, CA). This sensor takes advantage of modern integrated-circuit technology. It contains five resistors on a ceramic substrate. These resistors are connected in a Wheatstone-bridge arrangement.

One side of the sensor substrate is exposed to a sealed chamber that has an almost perfect vacuum. The other side is exposed to pressure applied to an external port. The resistors deposited on the substrate are piezoelectric in nature. They exhibit a change in value with any mechanical stresses applied to them.

An absolute device, the sensor responds to any pressure greater than 0 (a perfect vacuum). When the sensor is in such a vacuum, the four resistors are each essentially equal in value and the bridge is balanced. The output voltages taken at pins 3 and 6 of *PS1*, referenced to circuit common, are also essentially equal and the difference between them is 0. The values of *R1* through *R5* are specified by the manufacturer of the sensor to correct for differences in sensors that occur during the manufacturing process.

When the pressure sensor is placed in any environment other than a perfect vacuum, the mechanical stresses placed on the ceramic substrate of the bridge cause two of the substrate resistors to increase and the two others to decrease in value. This produces an unbalanced condition and results in the appearance of unequal voltages on pins 3 and 6 of *PS1*.

The Wheatstone bridge is driven by a constant-current source of about 1.5 milliamperes, provided by LM334Z constant-current semiconductor device *Q1*. The current supplied by *Q1* is a function of the values of *R6*, *R7* and *R8*. Potentiometer *R7* permits adjustment of the current supplied to the bridge to compensate for electrical differences in pressure sensors and to provide a means for varying circuit sensitivity.

When the pressure sensor is at or near sea level (0 feet of altitude), the atmospheric pressure is about 14.7 pounds per square inch (psi). The output of the bridge circuit is taken as a differential voltage between pins 3 and 6 of *PS1*, which is about 100 millivolts.

Over the 0-to-5,000-foot altitude range of interest for this project, the differential voltage will vary inversely with altitude as an almost linear function. For example, at 1,000 feet of altitude, the atmospheric pressure, under standard conditions, will be 14.18 psi. The resulting bridge output will change from 100 millivolts at sea level to about 96.4 millivolts at 1,000 feet of elevation. The

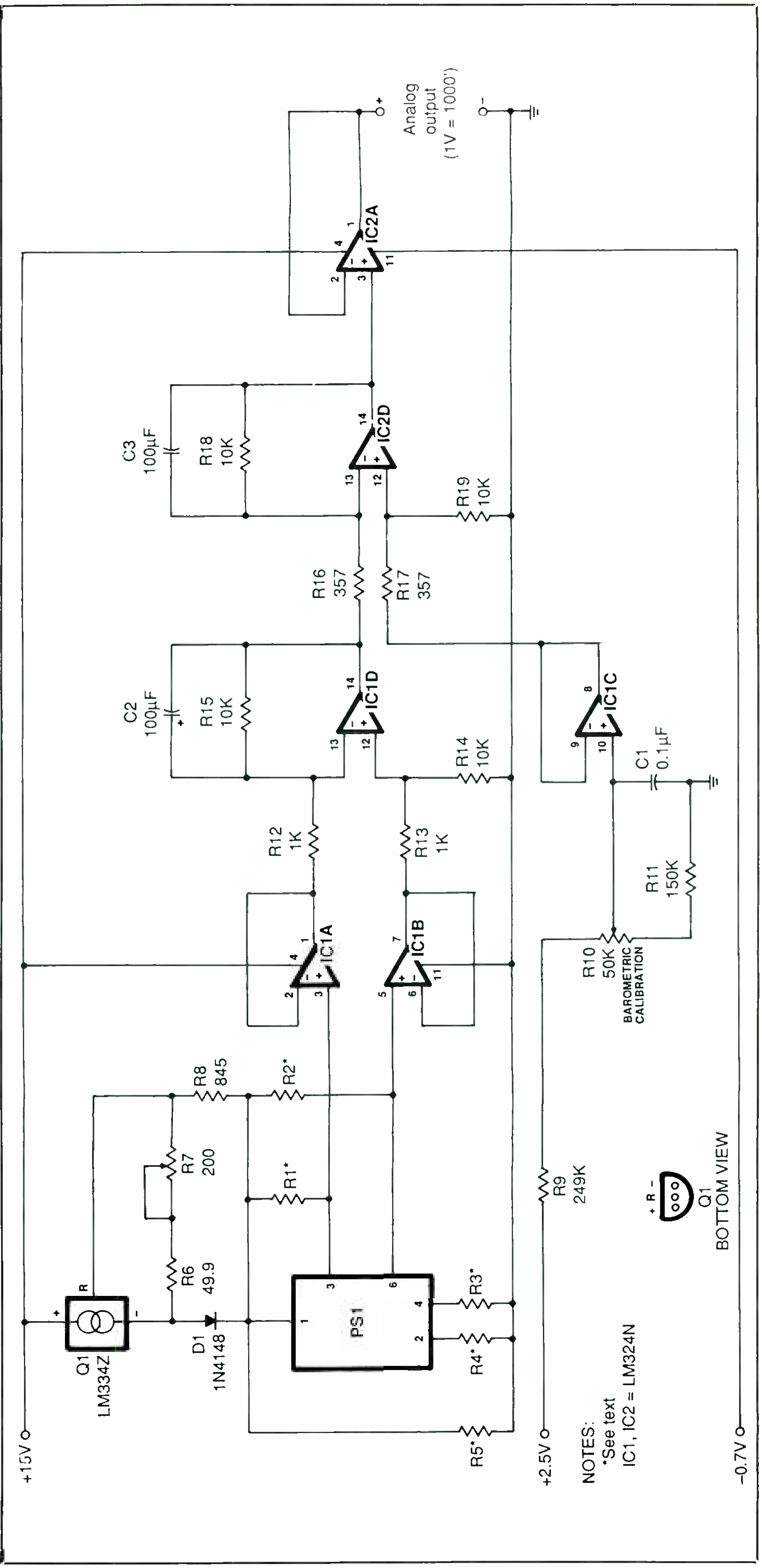


Fig. 1. Schematic diagram of the basic Altimeter circuitry minus its power supply.

PARTS LIST

Semiconductors
D1,D2,D3,D5—1N4148 or similar silicon diode
D4—1N4004 or similar silicon rectifier diode
IC1,IC2—LM324N quad operational amplifier
IC3—LMC555CN or equivalent CMOS timer
PS1—Nova NPS-100A 15-psi absolute pressure sensor (see text)
Q1—LM334Z constant-current source
Q2—LM336Z-2.5 voltage reference
Capacitors
C1—0.1-μF, 25-volt ceramic disc
C2,C3—100-μF, 10-volt electrolytic
C4—10-μF, 16-volt electrolytic
Resistors
(¼-watt, 1% tolerance metal-film)
R1 thru R5—See text
R6—49.9 ohms
R8—845 ohms
R9—249,000 ohms
R11—150,000 ohms
R12,R13—1,000 ohms
R14,R15,R18,R19—10,000 ohms
R16,R17—357 ohms
(¼-watt, 5% tolerance carbon)
R20—220,000 ohms
R21—100,000 ohms
R22—4,700 ohms
R23—680 ohms (for 12-volt dc powered unit—see text)
R24—1,000 ohms (for optional 1-mA meter—see text)
R7—200-ohm pc-mount cermet trimmer potentiometer
R10—50,000-ohm panel-mount potentiometer (see text)
Miscellaneous
B1—9-volt alkaline battery
BP1,BP3—Red 5-way binding pose with insulating hardware
BP2,BP5—Black 5-way binding post with insulating hardware
M1—0-to-1-mA analog panel meter (optional—see text)
S1—Spst slide or toggle switch
Printed circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (see text); display module (see text); snap connector and holder for B1; sockets for all DIP ICs and sensor module; lettering kit and clear spray acrylic (see text); ½" spacers; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire pc board, $12.95; LM324N, $2.25 each; LM555CN, $2.25; LM334Z, $3.75; LM336Z-2.5, $3.75; Nova pressure sensor No. NPS-100A, $39.75; set of 12 metal-film resistors, $3.95. Add $1.50 P&H per order. New Jersey residents, please add state sales tax.

change of 3.6 millivolts can then be amplified to provide a voltage that represents the altitude.

Very small changes in voltage are the norm for this circuit. Hence, a means of amplifying the output voltage from the bridge inside *PS1* to a level that can be measured with an ordinary dc voltmeter is needed. The voltage produced at pins 3 and 6 of the sensor are each passed through a voltage follower, *IC1A* and *IC1B*, to provide isolation from the bridge circuit and a zero-impedance source for the next stage in the chain.

Differential amplifier *IC1D* has a voltage gain of 10, as determined by the ratio of the values of *R15* to *R12* and *R14* to *R13*. This stage amplifies the difference in voltages at the sensor outputs. This amplification of the voltage difference results in a 1-volt level when the Altimeter is placed at sea level. At 1,000 feet, the output of *IC1D* drops to 0.964 volt. Large-value capacitor *C2* across *R15* causes the circuit to react slowly to pressure and helps to mask sudden voltage changes caused by ambient pressure disturbances.

The Altimeter must exhibit a voltage variation calibrated in feet. Therefore, the change of 36 millivolts at pin 14 of *IC1D* must be further amplified to a value that represents 1,000 feet. Because a convenient potential change would be 1.000 volt, the next amplifier stage is designed for a gain of 1.000/0.036 volt, which factors out to about 27.8.

It is also necessary that only the change in output (1 volt) be generated at 1,000 feet of elevation. The desired potential must be 0 volt at 0 feet of altitude, 1 volt at 1,000 feet, 2 volts at 2,000 feet, and so on up to 5 volts at 5,000 feet. Both amplification and offset are taken care of in differential amplifier *IC2D*.

There remains one additional factor that must be taken into consideration in a pneumatic-sensing altimeter of this type. As with any altimeter that reacts to absolute air pressure, the effect of existing weather conditions that cause a change in pressure from the "standard" 14.7 psi must be canceled out. All pneumatic aircraft altimeters are subject to this requirement, and the pilot or navigator must also periodically adjust them to the existing barometric pressure.

In this project, *R10* can be adjusted for a potential of between 0.85 and 1.15 volts at its wiper, which can be used to eliminate the effect of barometric pressure. This potentiometer is set so that the potential at pin 8 of voltage follower *IC1C* is equal to the output potential of *IC1D* at 0 feet of altitude. Under standard conditions, this would be about 1 volt.

Operational amplifier *IC2D* is wired as a differential amplifier whose voltage gain is determined by the ratios of the values of *R18* to *R19* and *R19* to *R17*. This stage amplifies the difference between the reference voltage set by *R10* and the voltage at pin 14 of *IC1D*. As a result, the output of *IC2D* can be set to 0 volt at 0 feet of altitude and 1 volt at 1,000 feet of altitude. It will increase linearly with altitude over the full 5,000-foot range of the project. The output of *IC2D* is passed through voltage follower *IC2A* to provide a low-impedance output than can be measured

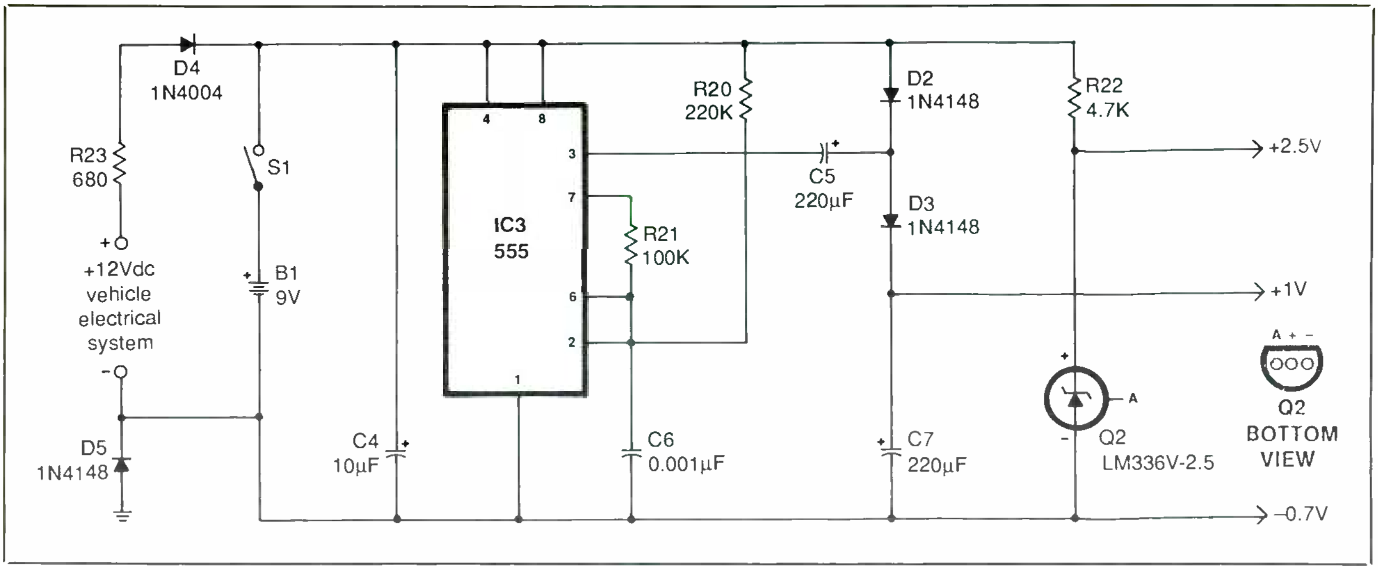


Fig. 2. Schematic diagram of project's power-supply circuit.

and read with a dc voltmeter.

Power for the project is supplied by either a 9-volt battery or a 12-volt vehicular electrical system, both of which are illustrated in Fig. 2. Since the bridge circuit inside the pressure sensor requires about 7.5 volts dc for proper operation, it is not possible to use the terminal potential of a 9-volt battery directly because it decreases as the battery becomes depleted and is not sufficient to drive *Q1* in Fig. 1. In addition, you want the circuit to work with input potentials as low as 7 volts to obtain a reasonable battery life. This requirement can be easily satisfied with a simple voltage-doubler circuit.

Timer chip *IC3* in Fig. 2 is operated as an astable multivibrator. It produces a square-wave output that has a peak-to-peak potential of about 7 volts at output pin 3. This square wave is ac coupled to the cathode of *D2*, which clamps it to the positive voltage supply rail. As a result, the potential at the junction of *D2* and *D3* cannot go more than 0.7 volt below the positive supply rail and will switch between 7 and 15 volts.

Diode *D3* rectifies the square wave and causes capacitor *C7* to charge up to the peak value. In effect, this produces a voltage that is almost twice as great as the battery voltage. This is used to power *Q1* as well as the operational amplifiers in Fig. 1.

When a 12-volt vehicle electrical system is used to supply power to the project, *R23* and *D4* reduce the supply potential to about 9 volts. The diode also prevents any reverse high-voltage transients from the vehicle electrical system from reaching the electronic circuitry of the project.

With the circuit powered by either dc source, voltage reference *Q2* provides a stable 2.5-volt reference for OFFSET control *R10*.

Since amplifier *IC2D* must be able to deliver potentials as low as 0 volt for a reading of 0 feet of altitude, this chip must be powered from a source that delivers a negative voltage. This is accomplished with *D6*, which provides −0.7 volt for the chip.

The easiest to implement and lowest-cost display option for your Altimeter is a pocket analog multimeter that is sensitive enough to resolve dc potentials down to 0.1 volt. Alternatively, you can dedicate a 0-to-1-milliampere analog-type dc meter movement for permanent display. All you need to implement such a display is the meter movement itself and a 1,000-ohm resistor, as illustrated in Fig. 3.

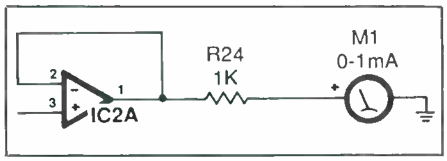


Fig. 3. Details for adding an analog milliammeter meter movement to output of project to provide a display.

The analog display option has an advantage over the digital option because it does not exhibit reading fluctuations the way digital numeric displays inherently do. Also, it does not require a separate power source for the display (it is driven directly by the output of the project), as would be the case with a dc voltmeter or multimeter. This can be an important consideration if you are back-packer or hiker who wants to keep down excess weight. A 0-to-1-milliampere movement provides a convenient 0-to-1,000-foot altitude range.

If you want a high-tech look for your Altimeter's display, you can invest an additional $25 to $50 to use an inexpensive dc voltmeter that has a digital numeric display system. If you go this route, it is best if you obtain a DVM that can be set to a 2-volt dc scale, which will display numbers that equate to a 0-to-2,000-foot altitude range.

A 20-volt scale could also be used, which will reduce display resolution to 10 feet. This may be an advantage because it also eliminates much of the display fluctuation usually encountered when using a 2-volt range, and it allows you to read altitudes up to 5,000 feet.

Many suppliers offer miniature digital dc voltmeter module assemblies that contain a low-power LCD display and D/A circuitry that are all that are needed to measure a low dc voltage. These modules, which are usually priced at between $50 and $60, can be powered from the same 9-volt battery used in the project. They are also rated for up to 15-volt operation, which makes them suitable for powering from a vehicle electrical system.

One supplier of dc-voltmeter modules is Acculex (440 Myles Standish Blvd., Taunton, MA 02780). The Model DP 176 is priced at $59. This miniature LCD digital panel meter can be built into the same enclosure that houses the Altimeter project.

The final display option for your Altimeter is to build your own A/D converter, complete with LCD display system. You can do so fairly inexpensively using a commercially available kit, such as the Intersil Part. No. ICL7106EV/KIT, which retails for about $36. This kit contains a 3½-digit LCD display, A/D converter, printed-circuit board and all components needed to build a dc voltmeter. It is available from any electronics outlet that handles the Intersil line of products.

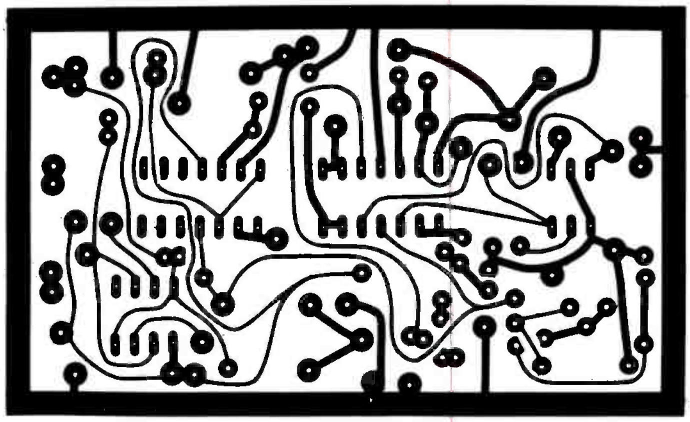


Fig. 4. Actual-size etching-and-drilling guide for project's printed-circuit board.

Construction

Two sections make up the Altimeter: the bridge, analog amplifier and power-supply circuitry and the digital or analog display device. Construction of the altimeter itself, including its power supply, will be discussed first.

A small single-sided printed-circuit board will accommodate all but the display device circuitry. You can etch and drill your own pc board using the actual-size etching-and-drilling guide shown in Fig. 4 or purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. Alternatively, you can use a perforated board on which to assemble the circuitry, using suitable Wire Wrap or soldering hardware.

From here on, we will assume printed-circuit construction and refer you to Fig. 5 for component installations. (If you are wiring the project on perforated board, use the same general layout shown in Fig. 5 for component placement, but refer back to Fig. 1 and Fig. 2 for details on wiring this circuit.)

Place the pc board in front of you, oriented as shown in Fig. 5. Begin populating it by installing and soldering into place sockets for all ICs (including on perforated board). Note that the specified pressure sensor is supplied in a standard six-pin DIP IC housing. It should also be plugged into a socket. You can make a six-pin socket for it by cutting down a larger socket or substitute two rows of three Molex Soldercon® socket pins. Do *not* plug the ICs or the pressure sensor into their sockets until after you have ascertained that your wiring of the circuit-board assembly is correct.

Now install and solder into place the resistors. Note here that neither the schematic diagram nor the Parts List give the values of *R1* through *R5*. These are specified by the manufacturer for the particular sensor you purchase. Note, too, that some sensors will not require all five resistors, one or more of which can be omitted or be replaced with a jumper wire. Obtain only metal-film resistors (for stability) of the appropriate values and install them and any jumpers in the specified locations. Accuracy of your Altimeter also depends on the stability of the amplifier resistor values. For this reason, you should use only metal-film resistors here as well.

Trimmer control *R7* mounts directly on the circuit-board assembly in the location shown at the lower-left in Fig. 5. The other variable control, *R10*, is a panel-mount pot that interconnects with the circuit-board assembly via three wire leads.

Next, install and solder into place the various capacitors, diodes and reference devices. Make certain that all electrolytic capacitors and diodes are properly polarized and that *Q1* and *Q2* are properly based (see Fig. 1

and Fig. 2 for basing details, which are different for the two devices) before soldering any leads to the copper pads on the bottom of the board.

Strip ¼ inch of insulation from both ends of eight 5-inch-long hookup wires. If you are using stranded wire, tightly twist together the fine conductors at all ends and sparingly tin with solder. Plug one end of these wires into the holes labeled R10 (three wires), +OUT and −OUT (two wires), S1 (one wire) and 12V VEHICLE ELECTRICAL SYSTEM (two wires).

Tightly twist together the fine wires at the ends of the leads of a 9-volt battery snap connector and tin with solder. Plug the black-insulated negative lead into the hole labeled B− and solder into place. The other lead will be connected later.

Double check all component installations for value, part number and orientation. Then turn over the circuit-board assembly and carefully inspect all soldering. Solder any connections you might have missed. Reflow the solder on any suspicious connection. Check carefully for solder bridges, especially between the closely spaced pads of the IC sockets. If you locate any solder bridges, clear them with desoldering braid or a vacuum-type desoldering tool.

It is important that you house the circuit-board assembly inside a secure metal or plastic enclosure that will protect the delicate pressure sensor and shield it from sudden changes in pressure, such as might result from a gust of wind. Even though it is located inside a closed container that is not hermetically sealed, the sensor will be able to detect the change in pressure as the project is taken increasingly higher in altitude.

If you use a metal enclosure for an Altimeter that will be powered by a vehicle electrical system, make absolutely certain that you isolate the circuit's common or ground from the metal of the enclosure. The vehicle chassis is the negative side of the 12-volt dc power source and, as indicated in Fig. 2, is not connected to circuit common.

Select an enclosure that will easily accommodate the circuit-board assembly, panel-mount control, switch and binding posts. If you are building into the project an analog meter movement or digital numeric display device, select an enclosure for this additional circuitry as well and that provides adequate panel space for the display device chosen.

Machine the enclosure as needed. Drill mounting holes for the circuit-board assembly, potentiometer *R10*, POWER switch *S1* and the battery holder. Also, drill mounting holes for the two pairs of five-way binding posts that provide the ANALOG OUTPUT (unless you are building in a dedicated display, in which case, eliminate the "output" binding posts altogether) and 12V VEHICLE ELECTRICAL SYSTEM INPUT connections. Drill the first two through the front panel, the remaining two through the rear panel, of the enclosure. Deburr all holes drilled through metal.

Use a dry-transfer lettering kit or a tape labeler to label the control, switch and binding posts. Make sure you also indicate the polarities of the binding posts. If you use a dry-transfer lettering kit, spray over the legends two or more light coats of clear acrylic to protect the lettering. Allow each coat to dry before spraying on the next.

When selecting a potentiometer for *R10*, keep in mind that this should be a control type whose setting cannot be accidentally changed during Altimeter use. A panel-mount screwdriver-adjust control is ideal. However, if you use a control that has a shaft that projects out of the front panel, be sure to use a locking type. Also, if you wish smoother, more precise adjustment capability, choose a multi-turn potentiometer.

Use ½-inch metal spacers and 4-40 × ¾-inch machine screws, lockwashers and nuts to mount the circuit-board assembly into place. Then mount the potentiometer and switch in their respective holes. Locate the wires coming from the R10 holes in the circuit-board assembly and crimp

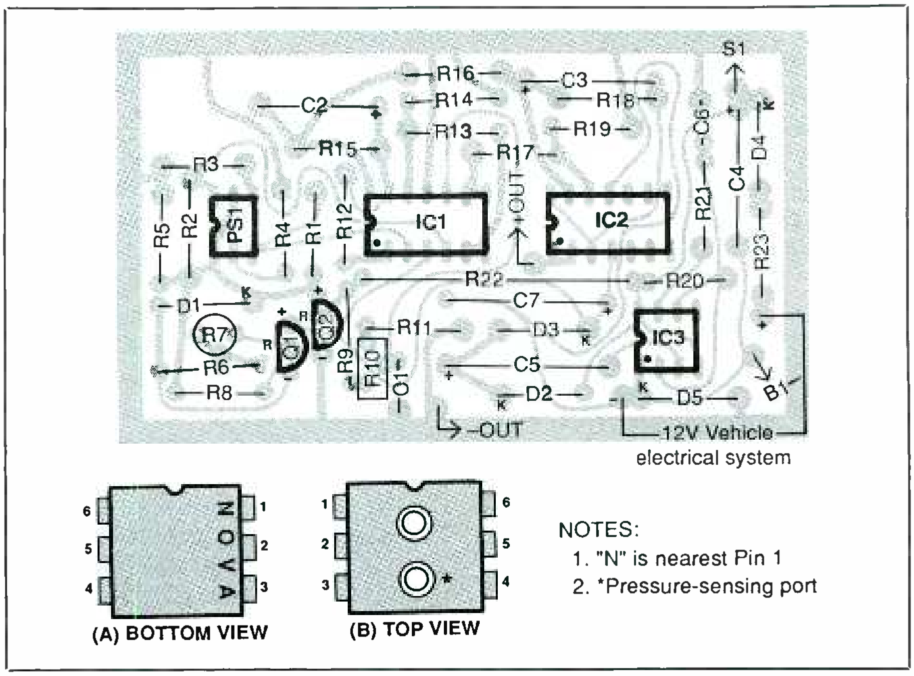


Fig. 5. Wiring guide for pc board and pinouts for sensor. Use this as a general layout guide if you wire project on perforated board.

and solder the free ends of them to the lugs of the potentiometer.

Crimp and solder the free end of the red-insulated positive lead of the battery snap connector to one lug of the switch. Then locate the wire coming from the B1 – hole in the board and crimp and solder the free end of it to the other lug of the switch.

Mount the four binding posts in the holes you drilled for them. Use one red and one black binding post for each pair. If you drilled the mounting holes through metal, make absolutely certain that you use shoulder fiber washers to insulate the binding posts from the metal.

After mounting the binding posts, locate the two wires coming from the 12V VEHICLE ELECTRICAL SYSTEM holes in the board and crimp and solder the free ends of these wires coming from the "+" and "–" holes to the red- and black-colored binding posts, respectively, on the rear panel. Repeat for the remaining two wires coming from the board and the binding posts on the front panel if you are using an external display device. Otherwise, connect and solder the free ends of these wires to the input of the built-in display device (observe proper polarity!).

Mount the battery clip into place and slide a fresh 9-volt alkaline battery into it. Make sure the POWER switch is set to its "off" position. Then snap the connector onto the terminals of the battery.

Checkout & Calibration

To perform the checkout procedure, be sure to start with a *fresh* 9-volt alkaline battery. If possible, use a well-regulated dc bench-type power supply that has current-limiting capability and adjust it to limit the current to less than 50 milliamperes to protect the circuit in the event of a malfunction. (Normal current drawn by the circuit is about 8 milliamperes.) Set the power supply for an output of either 9 or 12 volts, whichever is appropriate for the version you built.

Before starting the tests, set trimmer control *R7* on the circuit-board assembly to about mid-rotation. Now, the first part of the project you check will be the voltage-doubler circuit in the power supply. For this, you must have the 555 timer chip plugged into the IC3 socket. Make sure you properly orient it and that no pins overhang the socket or fold under between socket and IC. (This applies to installation of *all* ICs in their sockets.)

Connect the battery or bench power supply to the project via the binding posts on the rear of the enclosure. Make sure you make the connections to the binding posts in the proper polarity. Now connect the common lead of a dc voltmeter or a multimeter set to the dc-volts function to any convenient point in the circuit that is supposed to be at ground potential. A good choice is the anode of *D5*. Leave this lead connected here throughout the testing procedure.

Turn on power to the circuit by setting the POWER switch to its "on" position. Touch the "hot" probe of the meter to the positive (+) lead of *C7* and observe the reading obtained. If it is not about +15 volts, power down the project and rectify the problem before proceeding.

Check the components associated with *IC3* for correct values and orientations. If you have an oscilloscope, power up the project and check the waveform at pin 3 of *IC3* to ascertain that the timer chip is oscillating at a frequency of about 2 kHz. If you do not obtain an indication of oscillation, power down the circuit and try replacing the 555 timer chip.

Once you are certain that the power-supply portion of the project is operating properly, power up the circuit once again and touch the "hot" probe of the meter to pin 4 of the IC1 and IC2 sockets. You should obtain a reading in both cases of +15 volts. Once again, if you do not obtain the proper reading at either point, power down the circuit and rectify the problem before proceeding.

Power down the project and plug the sensor and two remaining ICs into their respective sockets. Power up the project once more and touch the "hot" probe of the meter to the cathode of *D1*. You should obtain a reading of +2.5 volts. Measure the potential at pin 11 of *IC2*, which should yield a reading of –0.7 volt. If you do not obtain either reading, check the basing of *Q2*.

Once you are certain that the project is wired properly, you must adjust the constant-current circuit that feeds the bridge circuit inside the pressure sensor. This is easiest done by setting the voltage at pin 14 of *IC1*. Connect the "hot" probe of the meter to this point and apply power to the project. Adjust trimmer control *R7* for a meter reading of +1.0 volt. If you are unable to obtain the proper reading, correct the problem before proceeding.

Determine where the problem exists as follows. Check the pressure sensor to make sure it is properly oriented and seated in its socket. Check the values of the resistors in the R1 through R5 locations. Also, if one or more jumper wires were required by the manufacturer of the sensor, make sure these are installed in the locations where zero resistance was specified. Then check the values of the resistors associated with *IC1* and the orientations of *Q1*, *D1* and *C2*. If all else fails, try a new chip for *IC1*.

When you are able to obtain the 1.0-volt reading at pin 14 of *IC1*, monitor the voltage at pin 8 of this chip as you adjust panel control *R10* for a reading of 1 volt. This completes preliminary adjustment of the Altimeter project. The Altimeter should now be able to respond to changes in altitude.

If you connect the display to the project, the voltage reading now obtained represents altitude in feet. Remember that potentiometer *R10* must be adjusted first to compensate

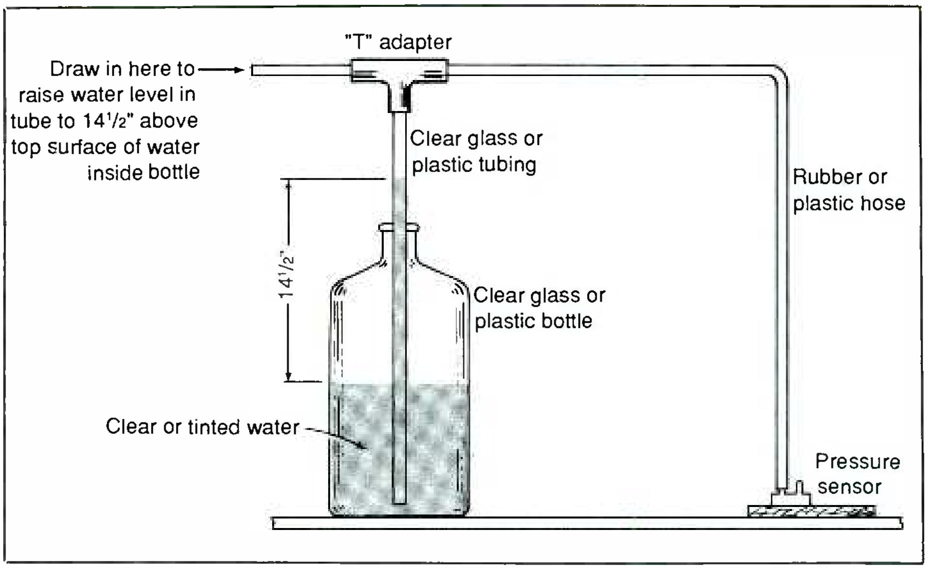


Fig. 6. The test setup for calibrating the project.

for the existing ambient barometric pressure and the physical location of your project.

As you adjust the setting of *R10*, you should be able to vary the display reading from a negative potential of about −0.1 volt to more than +0.5 volt. As you make this adjustment, allow sufficient time for the time constant capacitors in the amplifier circuits to stabilize (as indicated by the display finally settling down). Set *R10* for a reading that represents the approximate altitude of your present location, such as 0.1 volt for 100 feet of altitude.

If you are using a display that shows digitally generated numerals, you will notice that the reading will fluctuate somewhat. This is normal because the Altimeter will respond to any change in barometric pressure, where a small change of 0.1 inch of mercury at sea level is equivalent to 10 feet of altitude. Also, even though the resolution of a digitally generated numeric display is 1 foot of altitude, the project does not have either the accuracy or stability to correctly indicate altitude levels to this fine a precision. Even the most sophisticated pneumatic aircraft altimeters do not resolve altitude to this fine a degree.

You can check the response of your Altimeter to pressure variations by changing the location of the project to a higher altitude, such as moving from the basement of your house to the upper-most floor. You can also connect a small-diameter rubber tube to the orifice on the sensor and *very gently* create a vacuum by sucking the other end of the tube with your mouth. *Caution:* Do *not* blow into the tube, which can over-stress the sensor.

The following procedures are optional. They are performed to maximize the performance of the Altimeter. These procedures include temperature compensation and altitude calibration. Neither procedure is difficult to perform.

• *Temperature Compensation.* Since the stability of the circuit depends on the current provided by *Q1* and temperature drift of other components, it is possible to tailor the performance of the circuit by selecting the value of *R8* that provides best temperature stability of the altitude reading. This is easily accomplished by placing the project inside a box and gently raising its temperature while monitoring the altitude reading.

One way to raise the temperature is to place the project and a 25-watt lamp in a large cardboard container and turn on the latter. Make sure the enclosure is large enough to separate the lamp heat source from direct contact with the project. You do not want to overheat the project or raise the temperature too rapidly. A thermometer placed inside the box will provide a meaningful temperature reading. Do *not* leave this test setup unattended, owing the the possibility that a fire can accidentally be started if it overheats.

Start the procedure with the project turned on and lamp turned off to allow the circuitry to stabilize for about a minute or so. Set panel control *R10* so that the altitude reading on whatever display you are using with the project is about 100 feet. Write this reading on a piece of paper. Then turn on the lamp and close the box. Allow time for the project to heat up to about 20 degrees Fahrenheit greater than ambient and record the new reading obtained. This reading may be greater or less than the previous one you wrote down. Turn off the lamp and allow the project to cool down to ambient temperature.

The value of *R8* has a direct effect on the temperature drift of *Q1*. Parallel *R8* with another resistor that has a value of about 4,700 ohms to lower the effective resistance. Repeat the above procedure, recording your starting and ending readings and determine if the temperature stability of the circuit was improved, worsened or remained the same. The direction of any change will tell you whether you must reduce or increase the original value of the resistor for best temperature stability. You should not have to change the resistance by more than 100 or 200 ohms.

You will discover that just a few trials are all that are needed to be able to determine what is the best value of resistance for *R8*. When you have determined the final value, obtain a metal-film resistor as close as possible to that value and install and solder it into the R8 location on the circuit-board assembly.

• *Altitude Calibration.* This is the most informative part of the checkout procedure. It shows that the Altimeter really indicates the change in altitude, as detected by the pressure sensor, at altitudes that are far greater than can usually be obtained through changing the physical location of the project. It also permits you to calibrate the Altimeter at 1,000 feet of altitude.

To perform this procedure you need a tape measure, a piece of clear glass or plastic tubing, suitable rubber or plastic hose, a T adapter for three-way connection and a clear bottle of clean drinking water. A soda or wine bottle is a good choice for the last. Additional optional supplies are food coloring to make the water easier to see and a clamp to shut the open end of the hose so that it maintains the desired vacuum. The test setup is illustrated in Fig. 6.

In this test, the pressure that represents 1,000 feet of altitude is simulated by producing a vacuum that causes a column of water to rise in a clear tube. This procedure uses the basic laws of physics to set a desired pressure differential. It is so accurate that it is employed by manufacturers of pneumatic aircraft instruments for calibration of their altimeters during production tests.

Under standard conditions, absolute air pressure changes from 14.7 psi at 0 feet of altitude to 14.18 psi at 1,000 feet. This pressure may also be specified in other units, such as inches of mercury or water. In this case, the desired pressure differential of 0.52 psi is equivalent 14.5 inches of water. Thus, to simulate a change in pressure from 0 to 1,000 feet of altitude, a column of water 14.5 inches high can be employed.

Set up the Altimeter and apparatus as shown in Fig. 6. If possible, have someone assist you with the procedure because you must create a vacuum while measuring the height of the column of water with some degree of accuracy. It will be helpful if you first perform a dry run without the T adapter and Altimeter in which you hold the tubing in the bottle as straight and vertical as possible as water is drawn up to a level of 14.5 inches in the tube.

Keep in mind that the level of the water in the bottle will lower as the water is drawn up the tube. Mark the tubing with a grease pencil or piece of tape to indicate the desired height of the water column. Make sure that there are no bubbles of air in the tubing, and try to be as accurate as possible with the measurement.

With no vacuum created at the open end of the rubber tube and the Altimeter connected to the rubber hose as indicated, turn on the Altimeter and allow a minute for the circuit to stabilize. Then adjust the setting of *R10* for an altitude reading of some small positive number, such as 50 feet (0.05 volt) or so, on whatever display device is being used.

Now gently create a vacuum at the open end of the rubber hose so that the column of water rises 14.5 inches above the level of the water in the bottle. At the appropriate height, you can clamp the end of the hose to maintain the required vacuum. Again, make sure you have a solid column of water with no trapped air bubbles in it.

Allow the display to reach a stable reading and note on a piece of paper what it is. It should be about 1,000 feet higher than the 1.05-volt value originally set by *R10* (1,050 feet).

This test has simulated a change of 1,000 feet of altitude. If your Altimeter is reasonably accurate (5 percent or so), the test is completed. If your noted error is greater than 50 feet or you wish to improve the accuracy of the device, you can increase or decrease the sensitivity of the circuit by changing the amount of current fed to the sensor bridge by adjusting *R7* as needed.

To adjust *R7*, measure the potential at pin 14 of *IC1* with no vacuum applied to the circuit. Adjust the setting of *R7* for a reading of about +1.05 volts if your Altimeter has insufficient sensitivity (produced an altitude change of less than 1,000 feet) or +0.95 volt if the sensitivity was too great. This arbitrary 5-percent or so change in bridge current results in changing the sensitivity of the circuit by the same percentage.

Repeat the 1,000-foot test procedure described above to note the improvement in accuracy. If necessary, readjust the setting of *R7* and calibrate several times to obtain the desired 1,000-foot change in Altimeter reading.

Using the Project

Since the Altimeter is subject to the variations of barometric pressure readings, it is best if you set front-panel control *R10* at the last minute before you begin your climb. You do not have to know the barometric reading to set the Altimeter. Simply turn on the project, wait a minute or so for it to stabilize, and then set the control to obtain a reading that represents your altitude.

One way you can do the above is to learn the actual altitude at your home or other location. Then, before leaving that location, set your Altimeter to reflect the correct reading. Once it is set, do not readjust the control, since you will have no reference against which to adjust it.

When taking an altitude reading, turn on the Altimeter and allow the circuit time to stabilize. Remember, if there is a sudden change in air pressure, such as might occur with a strong wind, the reading may fluctuate. If so, wait a few moments for the reading to settle down.

Be sure to turn off your battery-powered Altimeter whenever you are not taking altitude readings. This will conserve power and provide a very long period of 10 or 15 hours of Altimeter operating time when the project is powered by an alkaline battery.

NEC's MultiSync Monitors

Unscrambling NEC's MultiSync video display models

TJ Byers

NEC has long been the leader in multiscan technology for good reason—the company invented and was the first to market a multiscan video monitor. If things had remained static in personal-computer graphics, the original MultiSync would have been all the monitor the personal computerist needed. However recent advances in graphics technology have made it necessary for NEC to further develop multiscan technology so that now there is a whole family of such monitors, each with its own special niche, from which to choose. This family of monitors and capabilities have created more than a little confusion for prospective buyers.

Multiscan monitors differ from standard computer video displays in that they can operate with a variety of video boards. Until the advent of the multiscan monitor, every video controller was inextricably tied to a specific monitor type. For example, a CGA video board required a CGA monitor, while a VGA video adapter required an EGA monitor. The match-up was one-on-one, a failing that forced PC users to purchase a new monitor and chuck the old one every time they upgraded their video.

The 14-inch MultiSync 2A features analog input for unlimited colors with support for VGA and SuperVGA (VESA).

NEC broke this cycle in 1984 with the introduction of its MultiSync multiscan monitor. Using variable-frequency scanning electronics (see "How MultiSync Works" box), the MultiSync monitor was able to work with virtually any video controller on the market in almost any video mode. Moreover, it had the capability of supporting new video modes as they were invented.

Recent video developments and competition from other multiscan monitor manufacturers prompted NEC to replace the aging original MultiSync (which PC users and NEC now label MultiSync I or MultiSync II, depending on which year the monitor was manufactured) with more advanced multiscan monitors, among which are the MultiSync 2A and Multisync 3D. Although both are multiscan monitors, each is cast for a slightly different role. We'll focus on these models because they are of interest for general-purpose applications, the likely widest use.

The MultiSync 2A

The MultiSync 2A is NEC's response to IBM's new VGA video mode (See "Understanding VGA Graphics," *Modern Electronics*, May 1989). Unlike the digital video modes that preceded it, VGA uses analog technology for its display. Analog video has the advantage of being able to display an infinite number of colors. For example, the VGA mode draws from a palette of 262,144 colors and can display up to 256 colors simultaneously on a VGA screen.

Another benefit of analog video is that a VGA monitor costs less to make than a CGA or EGA digital (TTL) monitor because it requires fewer components. This left NEC in a quandary because the original MultiSync monitor, which supported both TTL and analog video modes, began to lose sales to less-expensive, analog-only monitors. The MultiSync 2A (the "2" refers to the IBM PS/2 and the "A" refers to analog) is NEC's response to this dilemma. The 2A is an analog-only multiscan monitor designed to compete in price with standard VGA monitors. And because it is a multiscan monitor, the 2A can support analog video modes that are beyond the capabilities of a standard VGA monitor—including support for the new VESA mode.

VESA is an established 800-by-600-pixel super VGA video mode that has 56 percent more screen pixels than VGA for improved resolution. However, VESA won't work with a VGA monitor because its sweep rates are faster than that of VGA. Consequently, a multiscan monitor is required to display VESA. Here's where the MultiSync 2A has the edge over other multiscan monitors. Because it doesn't have a TTL interface, the 2A can be manufactured at lower cost than its analog/digital counterparts. In fact, the $799 2A is only slightly more expensive than a standard VGA monitor.

Low price and multiscan capabilities are achieved in the MultiSync 2A by limiting the scan capture range to just the VGA and VESA graphics rates. The monitor adjusts its scan rates to the video graphic mode by measuring the horizontal sweep frequency of the video controller. If a sweep frequency of 31.5 kHz is detected, the 2A locks in the VGA mode. Similarly if a sweep frequency of 35 kHz is detected, the monitor switches to the VESA mode.

Although the MultiSync 2A has been optimized for VESA, it will also work with non-VESA video modes that have the same scan rates as VESA.

How MultiSync Works

The concept of the multiscan monitor is simple but elegant. Instead of fixing the monitor's scan rate to one video type, scan rates are adjustable. One simply plugs the monitor into an EGA adapter, for example, and the monitor adjusts its scan rate to mimic an Enhanced Color Display. Switch to a VGA controller, and the monitor cranks up its scan rate to reproduce 640-by-480-pixel graphics. The multiscan monitor accomplishes this by separating the horizontal sweep function from the high-voltage flyback circuit. In single-mode monitors, like the CGA or VGA monitor, the horizontal sweep oscillator does double duty by also driving the monitor's high-voltage flyback transformer.

A flyback transformer generates the very-high voltage needed to power the CRT. It operates on the same principle as a car's ignition coil. Current flows through the primary of the transformer for a relatively long period of time to build up a strong magnetic field. At a predetermined point, the current is interrupted, causing the magnetic field to collapse. The sudden collapse of the field causes a high-voltage spike to be generated in the flyback transformer's secondary winding. This voltage (in the range of 10,000 to 30,000 volts) is then rectified and routed to the anode.

If the flyback transformer is driven at the same frequency used for the horizontal scan oscillator, both component count and money are saved because only one oscillator is needed. This is the method employed in VGA monitors and TV receivers. In a multiscan monitor, however, there's no telling what the scan frequency may be. It could fall anywhere within the monitor's capture range, which is usually between 15 kHz and 35 kHz. One of the things a flyback circuit needs to operate is a resonant-frequency tank circuit that oscillates at a given frequency. When the driving frequency is spread across a 20-kHz spectrum, it's difficult to keep the two in tune with each other.

As a consequence of the above, the multiscan monitor separates the two functions. A variable-frequency oscillator drives the CRT's horizontal sweep coil and a fixed-frequency oscillator powers the flyback circuit. This is why multiscan monitors are inherently more expensive than standard personal computing monitors.

The MultiSync 3D

Although analog video is the driving technology behind today's advanced PC graphics, there's still a huge demand for TTL-compatible digital monitors. NEC addresses this need with the MultiSync 3D multiscan monitor (the "3" refers to third-generation MultiSync technology and the "D" to digital), which is the company's replacement for the original MultiSync monitor. This $1,049 monitor supports both TTL and analog signals. It can display all the video modes IBM and Apple have to offer, plus VESA.

It might cost $150 more than the MultiSync II it replaces, but the 3D is well worth the extra cost because it's fully automated and programmable. Inside the 3D is a Zilog Z80 microprocessor that's the equal in power to Intel's 8088 CPU found in the IBM PC. The monitor comes with ten video standards already programmed into it, including 8514/A and VESA, and nine reserved memory locations that can be programmed by the user

The MultiSync 3D is a programmable, full-featured analog/digital multiscan color monitor with a 0.28-mm dot pitch for a crisp, better-than-average image.

IBM Video Scan Rates

Video Mode	Horizontal Rate (kHz)	Vertical Rate (Hz)
CGA	15.75	60
MDA	18.0	60
EGA	21.8	60
VGA	31.5	70
VESA	35.2	56
8514/A	43.5	60

to support non-standard video modes.

Programming of the 3D is done via eight pushbuttons located behind a front cover plate. The monitor first captures the video mode the best it can, then the user adjusts the vertical and horizontal size and position controls to fine tune the image. The new settings are then locked into the 3D's non-volatile memory so that programming isn't lost when power is removed. A special CLEAR button permits erasure of the contents in memory, allowing the user to make changes in the programming as his monitor needs change.

In addition to changing scan rates, the MultiSync 3D also automatically switches between digital TTL and analog video signals. In the original MultiSync, choosing between the two was accomplished manually, using a switch located on the back of the cabinet. The Z80 CPU in the MultiSync 3D automates the process, eliminating the switch.

Hands-On Observations

As would be expected of a product line from a company as reputable as NEC, the new generation of MultiSync monitors provide top-notch performance. The MultiSync 3D is nothing less than engineering elegance and a pleasure to use. In operation, it easily recognizes a video mode, and its 0.28-mm CRT dot pitch gives high-resolution color images that look like they came from the pages of a fine art magazine.

The programming features of the 3D are equally amazing. Two slide-type switches provide all the digital TTL color control needed, while the remaining eight pushbuttons permit fine tuning the position of the image on the screen for analog or digital operation. Saving new settings is easier than falling off a log. One just quits making changes for about 15 seconds, after which the 3D records the new values in nonvolatile memory.

The MultiSync 2A is an easy-to-use monitor that requires no participation on the part of the user, other than to making sure the POWER switch is set to "on." Although there are controls for horizontal and vertical position and size, they're used only when the monitor is attempting to capture an image generated by a video controller other than VGA or SuperVGA VESA. The screen image of the 2A isn't as crisp as that of the MultiSync 3D because of its 0.31-mm dot pitch, but it's every bit as good as any 14-inch VGA color monitor you'll find.

Another NEC offering worthy of passing mention is the MultiSync GS2A. This is a unique monitor in that it uses a monochrome CRT, meaning it has no dot pitch (see "Dot Pitch" box). Because there's no shadow mask, the image is of exceptional quality. The single-gun monochrome CRT also consumes half the power of the three-gun color CRT, which in itself may be an additional savings if you operate several video display terminals. Other than for a different logo on the cabinet, you can't tell the 2A and GS2A monitors apart—until you notice the missing colors on the screen of the latter during operation. Even without color, the near-perfect gray-tone reproduction of the GS2A leaves little to the imagination.

Making a Choice

The era of the single mode video monitor is rapidly drawing to a close. Video monitors of the future will have to serve a more diverse variety of video controllers, if for no other reason than the rising costs of the monitors caused by increasing complexities within the video modes. Very soon, it isn't going to be economically feasible to have a dedicated monitor for every video mode.

The most popular video modes of today, and for the next few years, is undoubtedly VGA and SuperVGA VESA. While they aren't the super-high-resolution modes slated for the next round of video graphics, they do meet the mainstream needs of the average PC user. To this extent, NEC offers the color-screen MultiSync 2A and gray-screen monochrome MultiSync GS2A monitors. Neither has a wide capture range, but what range they do have is sufficient to support present and future versions of SuperVGA. And while the MultiSync 2A and MultiSync GS2A monitors have been optimized for SuperVGA VESA, they'll also work with non-VESA video modes that have the same scan rates as VESA.

The list of non-VESA video modes that meet this criteria is extensive, and includes most proprietary 800-by-600-pixel extended VGA modes that were introduced prior to 1989. So if you have an older analog video controller card, the MultiSync 2A/GS2A may show you something you've been missing.

The MultiSync 3D is, of course, NEC's flagship. Although NEC has since launched the MultiSync 4D and 5D, only the 3D sails in the tradition

The gray-scale MultiSync GS2A provides high-resolution VGA and SuperVGA monochrome graphics for desktop publishing and general business text users.

Product Fact Sheet

	MultiSync GS2A	MultiSync 2A	MultiSync 3D
CRT type	Monochrome	Color	Color
CRT size (in.)	14	14	14
CRT dot Pitch (in.)	N.A.	0.31	0.28
Bandwidth (MHz)	38	28	45
Horizontal Capture Range (kHz)	31.5,35.2	31.5,35.2	15.5-38
Vertical Capture Range (Hz)	56,60,66.7,70	56,60,66.7,70	50-90
Input Signal	Analog	Analog	Analog,TTL
Weight (lbs.)	19	28	35
Power (watts)	40	90	90
Warranty Period	2 yrs.	2 yrs.	2 yrs.
List price	$349	$799	$1,049

Warranty 2 years parts, 1 year labor.
NEC Home Electronics, 1255 Michael Dr. Wood Dale, IL 60191; Tel.: 312-860-9500.

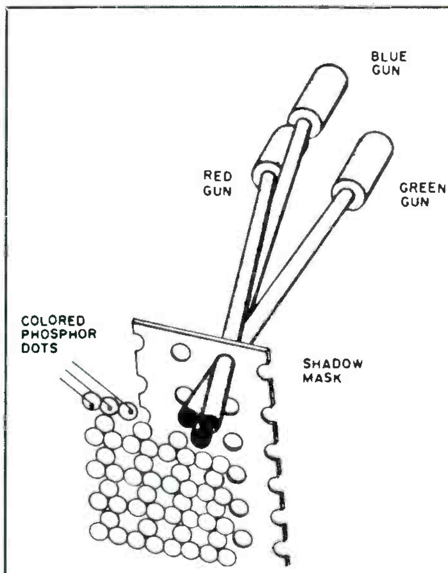
of original MultiSync intent. It's the only member of the NEC MultiSync family that supports both TTL and analog video controllers. The MultiSync 3D is also the unit that started the digital programming monitor revolution. By adding microprocessor control to the MultiSync 3D, NEC has taken a big step forward in advancing the quality of personal computing video displays.

Obviously, selecting an NEC MultiSync monitor isn't as simple as it once was, but then neither are the monitors. If you're satisfied with VGA graphics, your choice is between the MultiSync 2A and GS2A, depending on whether or not you want color and how much money you wish to spend for that privilege. On the other hand, if you need digital TTL support or want a growth path for 8514/A and future high-resolution analog modes, you need the MultiSync 3D. **ME**

Dot Pitch

The color you see on the screen of a color monitor is actually made up of three primary color dots—red, blue, and green—called a "triad," as shown in the drawing here. Hue is controlled by the intensity of the three colors. Pink, for example, has an excess of red, while white is a perfectly proportioned blend of all three colors.

To control the intensity of the triad colors, each color is assigned its own electron gun. A thin, metal mask (called a "shadow mask") that's perforated with hundreds of thousands of tiny holes is stretched across the interior face of the CRT to keep the electron beams from interfering with each other. The size of the hole determines the size of the color dot and, thus, the resolution of the image. The smaller the hole, the smaller the dot and the more detail the screen is able to display.



Color triad.

Experimenting With Conductive Ink

By Forrest M. Mims III

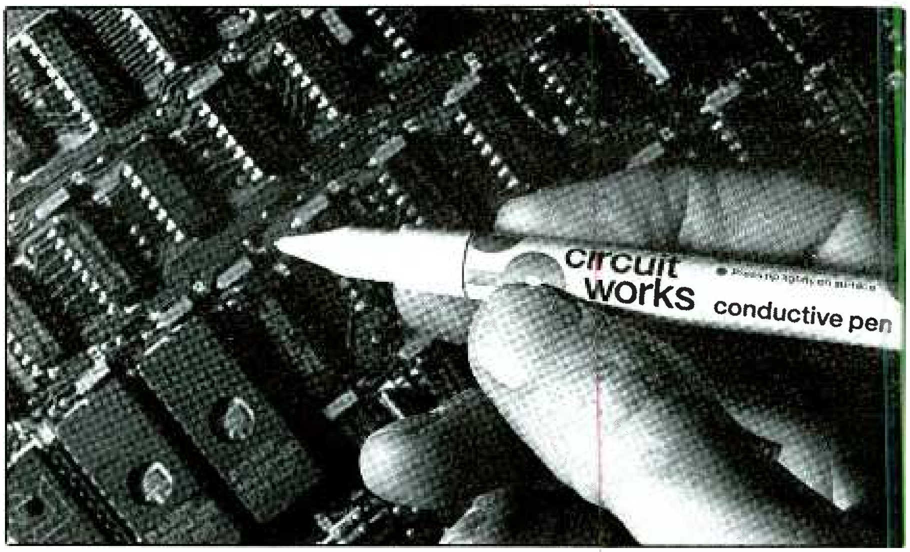


Fig. 1. Circuit Works conductive-ink pen. (Photo courtesy of Planned Products)

Electrically conductive ink is used for such common tasks as drawing conductive paths, repairing broken traces on printed-circuit boards and making switch contacts on flexible substrates. In this column, I'll explain how you can use conductive ink for each of these rather routine purposes. I'll also explore some applications for conductive ink that are considerably more interesting.

All these applications are generally simplified by the availability of a new conductive-ink pen. I'll describe this important new product shortly. First, however, it's important to review some details about conductive ink.

Conductive Ink

Electrically conductive inks have long been used to make miniature interconnection patterns in the manufacture of hybrid microcircuits. In a typical application, a pattern of conductive ink is screened onto a ceramic substrate. The substrate is then fired to permanently fuse the ink in place. Chip components are then attached to the conductive pattern by means of solder or conductive adhesive.

The inks used to make hybrid microcircuit interconnection patterns usually consist of fine particles of silver or gold suspended in a carrier. While silver and gold particles provide very-low-resistance inks, many other formulations are also available. Typical conductors include copper, nickel, carbon and graphite. Typical carriers include urethane, polyester, acrylic and epoxy.

The sheet sensitivity of a silver-filled epoxy ink can be as low as 0.015 ohm/mil^2. a silver-filled polyester ink may have a sheet resistivity of around 0.5 ohm/mil^2, and an inexpensive carbon-filled ink may have a sheet resistivity of 100 ohm/mil^2.

Conductive-Ink Pen

Several years ago, I described ultraminiature circuits using conductive ink in *Modern Electronics* (May 1987). While preparing that article, I asked several manufacturers of conductive ink if they could manufacture a conductive-ink pen. At that time, none were prepared to offer such a product. Therefore, I experimented with a variety of methods for applying conductive ink to various substrates. The method I recommended in the referenced article was to dip a toothpick into the ink and use it as a pen. While this method is very primitive, it works reasonably well.

In February 1989, Planned Products (303 Potrero St., Suite 53, Santa Cruz, CA 95060) introduced the low-cost conductive-ink pen shown in Fig. 1. Called the Circuit Works Conductive Pen, the pen contains enough silver-filled ink to draw approximately 150 feet of conductive traces. The pen can be ordered from Planned Products for $9.95 plus $1 shipping.

Two of my main concerns about a conductive-ink pen were shelf life and how to keep dried ink from clogging the pen's tip. Planned Products claims that the shelf life of its pen is 5 months. While that may seem like a rather brief time, it's actually very good when compared to the shelf life of bottled conductive ink. As for clogged tips, the Circuit Works pen solves this problem with a spring-loaded valve tip that opens under pressure and closes when the pen is not being used. This prevents the more volatile carriers in the ink from evaporating and causing the tip to become clogged.

The ink in the Circuit Works pen consists of 10-micron particles of silver suspended in a thermoplastic acrylic polymer that readily adheres to many different surfaces. Variations of this formulation are also used as conductive adhesives to bond chip components to circuit boards. The overall silver composition of the ink ranges from 39 to 45 percent. This provides a sheet resistivity of from 0.03 to 0.05 ohm/mil^2.

A particularly useful feature of the ink in the Circuit Works pen is its solderability. According to planned products, the material is readily solderable with tin, lead or silver solders. The ink must first be cured at 250 degrees Fahrenheit for 15 to 20 minutes after application.

The company says that while hand soldering is not recommended, it can be accomplished with an iron heated to 350 degrees Fahrenheit. Soldering time should not exceed 5 seconds. The preferred method is wave soldering at 350 to 400 degrees Fahrenheit using a 62 Sn/36 Pb/2 Ag solder with a mildly activated flux.

Using Conductive-Ink Pens

All of the conductive inks with which I have experimented require shaking or stirring before use. This is because the conductive particles settle to the bottom of the container when the container is at rest. The carrier fluid of some inks is so viscous that considerable time is required to place all the conductive particles in suspension.

The Circuit Works pen solves this problem with the same method used to mix aerosol cans of spray paint. The pen contains an insert that moves back and forth when the pen is shaken, thereby stirring up the fluid material and placing the conductive particles in suspension.

After shaking the pen, you must press the tip down on an unyielding surface while squeezing the barrel slightly to start the flow of ink. The ink will continue to flow so long as the pen is pressed down hard enough to keep the spring-loaded tip open.

If you move the pen too slowly, the trace being drawn will become too wide. However, if you move it too rapidly, the ink may not flow uniformly. With a little practice, though, you'll be able to produce a trace that has a width of about 1.5 millimeters (about 1/16 inch). While this width is fine for many applications, it's much too broad for interconnecting terminals on 100-mil centers. For this reason, Planned Products is developing a pen that is capable of producing a narrower line.

The carriers of most conductive inks are highly volatile and may be harmful if breathed in. The Circuit Works pen is no exception. Therefore, you should use it in a well-ventilated area. You should also promptly and thoroughly wash away any ink that gets on your skin.

Some Applications For Conductive Ink

Now that you know what conductive inks are and how to use a conductive-ink pen, let's look at some typical applications for them.

• *Circuit-Trace Repairs.* Repairing a broken circuit trace on a pc board is as simple as bridging the gap with a few drops of ink. But keep in mind that you should first determine why the trace separated in the first place. If the trace is broken because of a break in the underlying substrate, the conductive-ink repair job may fail the first time the board is flexed. Or the repaired joint may conduct only intermittently. The latter condition is often far more frustrating and more difficult to troubleshoot than the former. Therefore, be sure to repair a broken substrate with cement or a brace before bridging the broken trace.

• *Adding Traces to a Board.* You can use a Circuit Works pen to add traces to an existing board. You can even cross over existing traces if you first cover them with a circuit mask. If not, apply a layer of insulating enamel or acrylic over the exposed traces. Planned Products is working on a product for this specific purpose. After the insulating coating thoroughly dries, draw the new trace.

You can use the same technique to cross over traces you've previously drawn with a conductive-ink pen. In either case, you might want to first conduct some experiments to make sure that the insulating material you plan to use isn't dissolved or otherwise adversely affected by the solvents in the conductive ink.

When adding a new trace, the most important consideration is the end terminations. If the trace is intended to interconnect two existing traces or pads, simply draw the pen up to and over the copper pattern at each end of the new trace. If you're adding a new component pin or lead attachment point, the best procedure is to first insert the appropriate number of eyelets into the board and then insert the component pins or leads and solder them to their respective eyelets. Finally, draw the necessary interconnection pattern with the conductive-ink pen.

• *Conductive-Ink Shields.* Conductive ink provides a very convenient means of shielding sensitive components from noise and external electromagnetic fields. For example, the input leads of ultra-high input impedance CMOS operational amplifiers are highly susceptible to leakage currents. Even the tiny trickle of electrons flowing across a film of water vapor on a circuit board can be enough to mask the signal from a detector connected to the op amp's inputs.

One way to alleviate this problem is to surround the input leads with a so-called guard ring, which is a conductive trace that surrounds the input leads and diverts any unwanted current flow to ground. You can use a conductive-ink pen to add such a guard ring to an existing circuit.

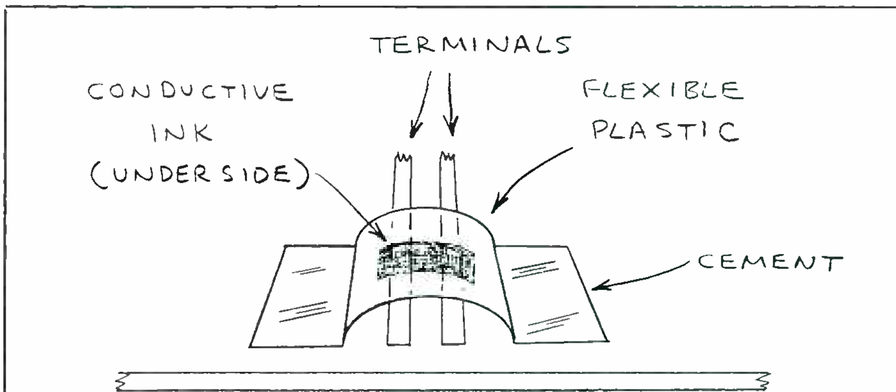


Fig. 2. Details of a simple conductive-ink switch arrangement.

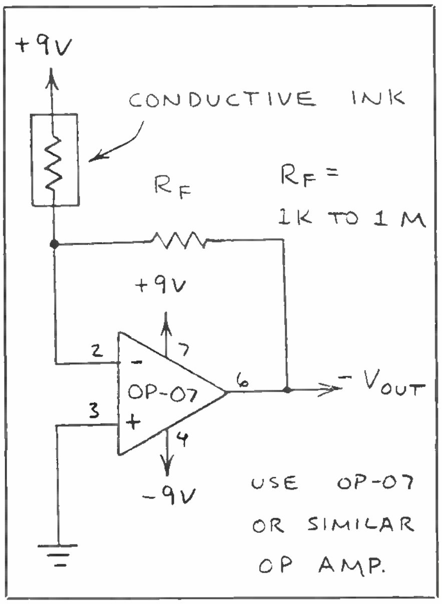


Fig. 3. Current-to-voltage converter circuit to amplify conductive-ink resistances.

Another interesting possibility for conductive ink is the shielding of epoxy and ceramic chips. While I haven't yet tried this, all that would be needed is to apply a coating of conductive ink over as much of the chip's package as possible. The coating should make contact with the chip's ground pins.

• *Switch Contacts.* You can use conductive ink to make many kinds of simple press-to-actuate switches. For example, Fig. 2 shows one way to make a pushbutton switch or key by cementing a flexible piece of plastic onto a circuit board over a pair of conductor traces. Conductive ink on the bottom side of the plastic bridges the space between the two conductor traces when the plastic is pressed down.

You can probably think of many other ways to make switches with conductive ink. You can even make entire keyboards by cementing strips of plastic over rows of exposed conductor trace patterns. Place a dot of conductive ink on the underside of the plastic strip at every point where it passes over each pair of terminals.

• *Conductive-Ink Resistors.* Conductive ink is ideal for making low-value resistors. A 3-inch (76-mm) line of conductive ink drawn with a Circuit Works pen has a resistance of approximately 10 ohms. You can easily vary this resistance by altering the length and width of the ink line. Use a short, wide line for low resistance or a long, narrow line for greater resistance. You can even make a variable resistor by using a clip lead to make contact with the conductive ink at various points along its path.

You can make a variable-resistance transducer by applying conductive ink to a flexible substrate like Mylar or even paper. For example, I applied a 4.5-inch length of conductive ink to a paper card and measured a resistance of 15 ohms when the card was lying flat on my workbench. When the card was bent over on itself so that the ink line was stretched, the resistance increased to 17 ohms. Bending the card in the opposite direction so that the ink line was compressed caused the resistance to fall to 14 ohms. While these changes are very small, they can be substantially magnified with the help of an operational amplifier connected as a current-to-voltage converter (see Fig. 3.)

• *Conductive Ink Antennas and Coils.* You can use conductive ink to make an infinite variety of antennas and coils. For example, I used a Circuit Works pen to apply a strip of conductive ink around the perimeter of a 3 × 5-inch paper card, as shown in Fig. 4. This provided a trace with a total length of 14 inches and a dc resistance of 35 ohms. While the resistance is very high, this simple arrangement works well as a pickup coil for locating ac electrical lines inside walls. All that's needed is to connect the opposite ends of the loop to the input of a small battery-powered amplifier. If current is flowing through a wire, its presence is revealed as a 60-Hz tone from the amplifier when the coil is placed nearby.

An obvious question at this point is, "Why use conductive ink on a paper or plastic substrate when ordinary wire is cheaper and more readily available?" The answer is that with surface-mount technology you can build the amplifier on the same substrate as the coil. This is exactly what I intent to do for a future project. One can easily envision various kinds of ultraminiature transmitters and oscillators made by bonding surface-mount components to a substrate on which have been formed coils and inductors of conductive ink.

• *Security Systems.* Another possible application for conductive ink is as replacement for the self-adhesive aluminum-foil strips that are applied to windows as broken-glass sensors for security alarms. The sensor loop could simply be drawn around the perimeter of the window with a straight edge and a Circuit Works pen.

• *Component Bonding.* Conductive ink can often double as a conductive adhesive. For example, you can use conductive ink to bond surface-mount components to a circuit board. To do so, first place a small drop of ink on each of the component's footprints. Before the ink cures, place the component on the footprint. For best results, use just enough ink to provide a reliable bond. If you use too much ink, it may form an unwanted bridge between footprints.

Conductive Ink Suppliers

Thus far, I've emphasized Planned Products' Circuit Works conductive-ink pen, primarily because it's so convenient and easy to use. If you want to experiment with bulk ink, several alternatives are available.

The fastest and easiest way to purchase bottled conductive ink is to locate an automobile parts supplier that sells conductive ink for repairing breaks in rear window defogger traces. One such product stocked by many stores that carry NAPA parts is Loctite Quick Grid™ Rear Window Defogger Repair Kit. I paid $7.35 for one of these kits. In the kit is a tiny bottle that contains 0.05 fluid ounce of conductive ink. While this may not seem like much, it's plenty for initial experiments. I've made several surface-mount circuits using the ink from a single kit for both the interconnection patterns and component bonding.

GC Electronics is another good source of conductive ink. This company sells both silver- and nickel-based inks designed for repairing circuit traces but suitable for other purposes as well.

I listed a number of other suppliers of conductive inks in the May 1987 installment of this column. They included Amicon (25 Hartwell Ave., Lexington, MA 02173); Dynaloy, Inc. (7 Great Meadow Lane, Hanover, NJ 07936); and The Dexter Corp. (Hysol Div., 15051 E. Don Julian Rd., Industry City, CA 91749).

As with the Circuit Works pen, be sure to work with conductive inks in a well-ventilated area, promptly remove ink from exposed skin, and store conductive inks where they cannot be reached by children. **ME**

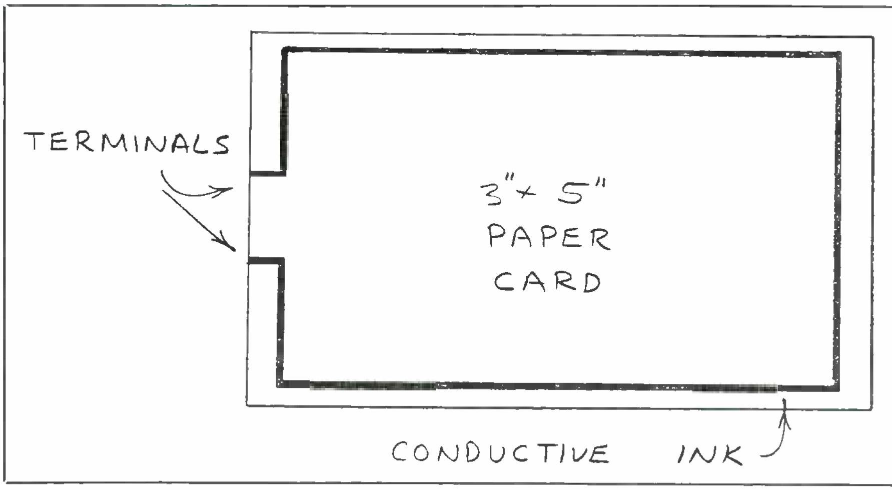


Fig. 4. Details for constructing a conductive-ink search coil.

Power Semiconductors and How Not to Mount Them, and New Super-Blocks from National Semiconductor

By Joseph Desposito

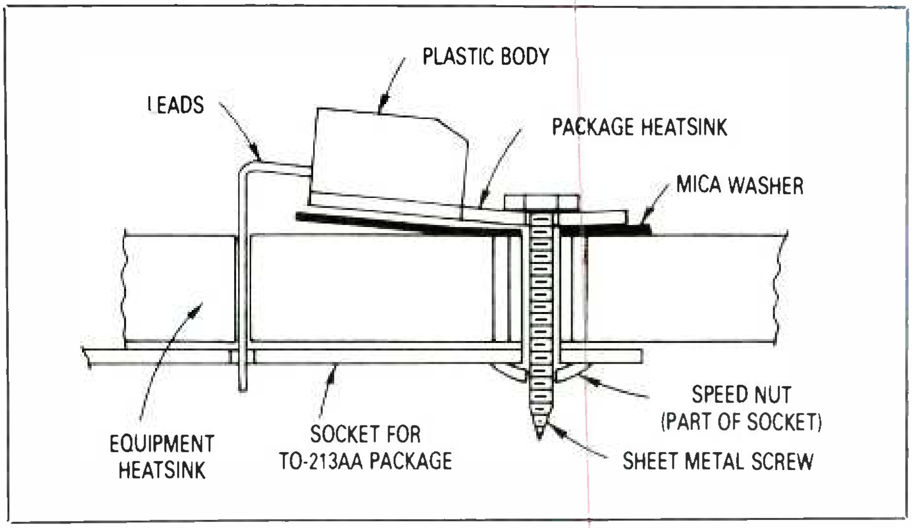


Fig. 1. An example of an extreme case of improperly mounting a semiconductor from Motorola's "Mounting Considerations for Power Semiconductors."

Motorola (Semiconductor Products Sector, Phoenix, AZ) not only manufactures a line of power semiconductors, but will give you tips on mounting them, too. Some of the products in the line include power field-effect transistors, bipolar power transistors, and power-darlington transistors.

The MTP3055EL is a logic compatible, high avalanche energy rated TMOS power MOSFET. The device is designed with low threshold voltage (fully "on" with 5V drive), which enables users to design power control circuits that can be driven directly from 5V logic ICs or microprocessors, or any of a number of other low-voltage sources.

Applications of the device include switching power supplies, lamps, motor controls. solenoid drivers, and a variety of general-purpose applications where the drive signal is limited. The 100-to-199-unit price for the device is 63 cents (TO-220 package) and 69 cents (surface-mountable DPAK).

The SWITCHMODE IIIB bridge series of bipolar power transistors have switching and dynamic saturation characteristics that result in low operating case temperatures and/or higher operating frequencies. This results in overall system cost reduction and extended long-term reliability. The MJ16110 and MJH-16110 are rated at 15 amps continuous collector current, while the MJE16106 and MJH16106 are rated at 8A.

Applications for these devices are found in line operated half bridge and full bridge switching power supplies, line operated single transistor forward converters, high voltage dc-to-dc converters, motor controls and instruments. Pricing of the various devices in the line range from $1.69 to $4 in 100 to 999 quantities.

The MJE5420Z is a high gain, 8A power Darlington transistor developed to drive inductive loads. The device incorporates an active 25V clamp that provides protection from voltage transients and can be driven by CMOS or LSTTL level signals. It is ideal for controlling automotive loads, such as fans, pumps etc.

The chip includes a proprietary zener compensation circuit that improves the thermal coefficient from the normal 100mV/°C to 6mV/°C over the temperature range −40° to +150°C, making the power Darlington operation very stable in any application. It is priced at 95 cents in quantities of 1,000 in the industry standard three-pin TO-220AB package.

Motorola has published an application note (AN1040/D) called "Mounting Considerations for Power Semiconductors" that covers various aspects to consider when designing with power semiconductors. The publication discusses design considerations such as mounting surface preparation, state- of-the-art insulators and thermally conductive material performance data, fastener and hardware characteristics, fastening techniques, free-air and socket-mounting techniques and thermal-system evaluation in mounting power devices. Also included are mounting techniques for some of the newer packages available from Motorola such as the surface mount DPAK, isolated FullPak, ICePAK, and EMS power modules.

The application note states that most early life field failures of power semiconductors can be traced to faulty mounting procedures. With metal packaged devices, faulty mounting generally causes unnecessarily high junction temperature, resulting in reduced component lifetime, although mechanical damage has occurred on occasion from improperly mounting to a warped surface. With the widespread use of various plastic-packaged semiconductors, the prospect of mechanical damage is very significant. Mechanical damage can impair the case moisture resistance or crack the semiconductor die.

An interesting figure given in the note shows an extreme case of improperly mounting a power semiconductor (see Fig. 1). In the illustration, a tab mount TO-220 package is shown being used as a replacement for a TO-213AA (TO-66) part that was socket mounted. To use the socket, the leads are bent—an operation which, if not properly done, can crack the package, break the internal bonding wires, or crack the die. The package is fastened with a sheet-metal screw through a ¼-inch hole containing a fiber-insulating sleeve. The force used to tighten the screw tends to pull the package into the hole, possibly causing enough distortion to crack the die.

In addition, the contact area is small because of the area consumed by the large hole and bowing of the package; the result is a much higher junction temperature than expected. If a rough heat-sink surface and/or burrs around the hole were displayed in the illustration, most poor mounting practices are covered.

To find out how to correct these poor mounting practices, call Motorola at 1-800-521-6274 and ask for a copy of publication AN1040/D—it's free.

Power Solid-State Switch

While we're on the subject of power semiconductors, GE Solid State (Somerville, NJ) manufactures a quad-driver power switch (see Fig. 2) that incorporates both current and thermal protection on-chip and is designed for heavy-duty drive applications in automotive electrical systems. The bipolar device, the CA3262, is for interfacing low-level logic to high-current resistive or inductive loads. It contains four individual driver circuits, each of which can switch output currents in excess of 700 mA. Inputs to the device can come from either CMOS or TTL logic circuits operating from 5V.

The CA3262 provides four two-input logic-inverting circuits, each connected to an open-collector output transistor. Because of the generally high power levels associated with its operation, the chip is built on a special "web" lead frame to better dissipate heat.

The protection features of the chip are meant to handle the harsh temperature and voltage transients of automotive applications. Each output transistor is equipped with a metallic current sensor that develops a voltage drop proportional to the current. The voltage is amplified differentially and fed back to a current-limiting amplifier on the transistor's base, reducing base drive. This controls the output sink current by limiting it in the range of 0.7 to 1.5A. The maximum saturation voltage is 0.6V at 700 mA of

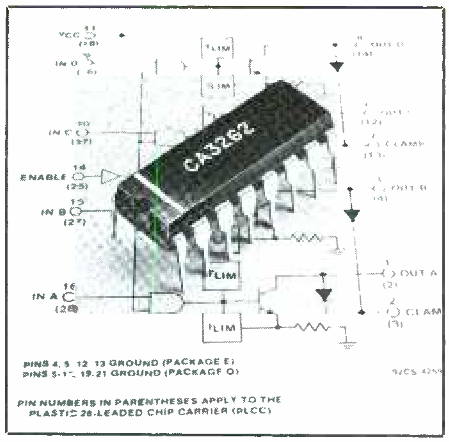


Fig. 2. GE's solid-state power switch features two-way protection.

sink current. Maximum output current for each transistor is 1A.

In addition to current limiting, each output transistor has a nearby temperature-sensing diode. The thermal-limiting operation of these diodes acts on the output transistor in the same manner as current limiting—it reduces the transistor's base drive. A reference voltage derived from the on-chip band-gap regulator provides a bias voltage for comparison to the sensing diode's voltage. If any transistor's temperature exceeds 150°C, thermal limiting is activated. If the internal temperature rises too high, the device will shut down thermally. To prevent thermal interaction among transistors, the output devices are located in each of the chip's four corners to provide maximum spacing.

Each output transistor connects to internal clamp diodes to limit inductive transients when driving motors or other magnetic loads. A common enable-control line is provided for the drivers to permit independent control. The chip contains separate logic and power grounds to isolate the low-level logic from the often noisy high- current power drivers.

Applications for the CA3262 extend beyond automotive systems. The device can be used as a motor driver in industrial controls, robotics, and computer-integrated manufacturing systems, as well as in electrical appliances, home heating, and home entertainment products.

The open-collector outputs of each transistor can be connected to supply voltages of 35V dc but will withstand instantaneous voltages up to 50V. The logic inputs can handle levels up to 15V, although most applications will use standard 5V logic levels. When housed in either a 16-lead plastic DIP or a 28-lead PLCC, the CA3262 operates over a temperature range of −40° to +85°C. The

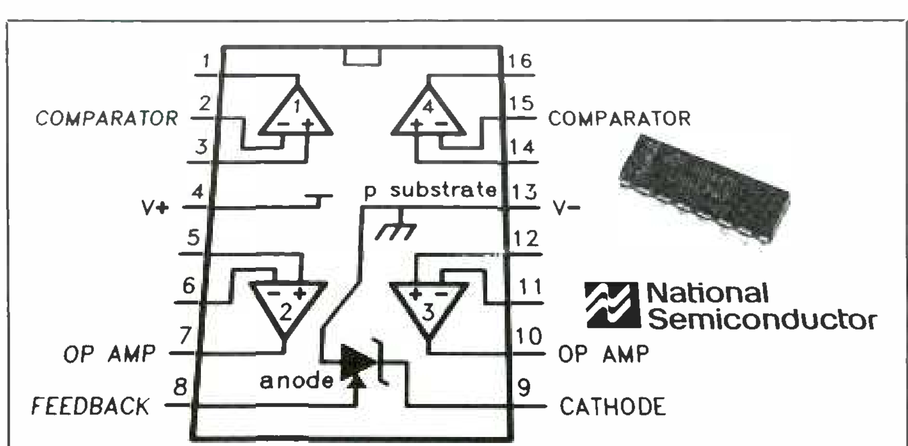


Fig. 3. Pinouts and internal details for National Semiconductor's Super-Block analog-circuit ICs.

device is priced at $2.87 each in quantities of 100 pieces.

Super-Block Analog ICs

National Semiconductor (Santa Clara, CA) has unveiled a new Super-Block family of high-performance analog ICs. Each Super-Block circuit combines multiple analog functions on a single chip (see Fig. 2), providing a higher level of integrated performance.

According to the company, the monolithic design of these circuits offers improved matching of device characteristics, such as temperature coefficients, and also improves reliability. And the higher level of integration also provides significant price/performance benefits.

The first four members of the new family include the LM604 four-channel multiplexer-amplifier, the LM611 single-supply op amp and adjustable micropower reference, the LM613 dual op amp and dual comparator with adjustable micropower reference, and the LM614 quad op amp and adjustable micropower reference.

The LM604 multiplexes four differential-input channels to a single op amp, and has a bi-state output that can drive a 600-ohm load. When the output is disabled, two or more devices may be stacked or used in parallel for true 8-to-1 multiplexing.

Due to its wide power range, the LM604 is equally at home in a 5V logic system or in the ± 15V high-performance analog environment. Switching time is 5 μs for a minimal delay when using alternate channels. Although the LM604 is easy to interface to microprocessors, it can also stand alone.

The LM611 and LM614 combine and improve the functions of National's LM324 low-power quad op amp and the LM385 adjustable micropower voltage reference. The company expects next-generation power-supply circuitry and portable test instruments to take advantage of the 0.4% voltage accuracy of the LM611 and LM614 16-μA references, as well as their low operating currents of 300 μA and 250 μA per op amp, respectively. Both possess a large supply voltage range of 3V to 36V and reference voltage adjustment from 1.2V to 6.3V. A better temperature coefficient of ± 20 ppm/ °C on both the LM611 and the LM614 Super-Block devices is a distinct improvement over National's building block predecessor, the LM385.

The fourth member of the Super-Block family is the LM613. It combines dual operational ampifiers, dual comparators and an adjustable reference on a single chip. The dual op amps in the LM613 Super-Block circuit are op amps like National's LM324 series with improved slew rate, wide power bandwidth, reduced cross-over distortion and low supply current. The LM613's dual comparators enable low input current of 1,000 μA for large differential input voltages and swings of ± 36V. The voltage reference has an accuracy of ± 0.4% and temperature coefficient drift of ± 20 ppm/ °C.

Pricing of the devices for 100 pieces is: LM604, $2.30; LM611, $.84; LM613, $1.30; and LM614, $1.22. **ME**

Scanners and Scanner Antennas

By Curt Phillips

	A	B	C	D	E	F	G	H
1			Center	Calc.	Exp.	No. of	Second	Third
2	Low	High	Freq.	Length	Length	Elem.	Harm.	Harm.
3								
4	30.00	33.00	31.50	89.1	92.7		63.00	94.50
5	33.00	36.30	34.65	81.0	84.3		69.30	103.95
6	37.25	40.98	39.11	71.8	74.7	1	78.23	117.34
7	40.98	45.07	43.02	65.3	67.9	2	86.05	129.07
8	45.07	49.58	47.33	59.3	61.7	3	94.65	141.98
9								
10	108.00	118.80	113.40	24.8	25.8	4	226.80	340.20
11	118.80	130.68	124.74	22.5	23.4	5	249.48	374.22
12	130.68	143.75	137.21	20.5	21.3	6	274.43	411.64
13	143.75	148.00	145.87	19.2	20.0	7	291.75	437.62
14	148.00	162.80	155.40	18.8	18.8	8	310.80	466.20
15	162.80	179.08	170.94	16.4	17.1	9	341.88	512.82
16								
17	400.00	440.00	420.00	6.7	7.0	10	840.00	1260.00
18	440.00	484.00	462.00	6.1	6.3	11	924.00	1386.00
19	484.00	532.40	508.20	5.5	5.7	12	1016.40	1524.60
20								

Calculations of Frequency Ranges & Quarter-Wave Antenna Lengths

Frequencies are in MHz and lengths are in inches.

The hobby of scanning, the monitoring of the vhf-uhf "public service" frequencies with multi-channel scanning receivers, has exploded from the minor sub-set of shortwave listening that it was a decade ago into the primary activity of many radio hobbyists.

Multi-band, programmable scanners are so prevalent and reasonably priced now that crystal-controlled scanners almost have to be given away at hamfests. Even if someone would give you a 16-channel crystal-controlled scanner, by the time you bought crystals for it (if none of the existing crystals could be used) you would have spent almost enough to purchase a good low-end programmable rig.

If you haven't joined the scanning ranks yet, here's a sampling of what you can hear and where you can hear it:

30 to 50 MHz. This is called the vhf low-band. Most users are gradually leaving this band because it requires a relatively large antenna and as with Citizens Band (which at 26.9-27.4 MHz is just below it) "skip" can be a problem. Still, some highway patrol (including North Carolina's) and sheriff's offices continue operations in this frequency range on FM, so it's good that most scanners include it. Cordless telephones also transmit within this band. Given their very low power, if you hear one, it is sure to be close by.

108 to 136 MHz. This is the aviation band and almost all operations are in AM. Primarily used by civilian aircraft, this band is omitted from the many scanners that only have FM demodulators. If you live close to an airport, this can be a very interesting band. Several of the selectable mode AM/FM scanners expand the upper end of this tuning range to 144 MHz to receive the FM military mobile operations often found between 136 and 144 MHz. Some restrict the lower end of this tuning range to 118 MHz, since there is very little activity from 108 to 118 MHz.

144 to 148 MHz. Referred to as the 2-meter band by Amateur Radio operators, this is the most active of the vhf ham bands. There is some SSB activity here, but FM is overwhelmingly the most common mode.

150 to 174 MHz. This is called the vhf high band and is the most active and diverse of the scanner bands. Within this range, FBI, Secret Service, police, fire, and rescue-squad stations can be found, as well as less exciting business, taxi, paging, railroad and other general-purpose radio services. Transmissions in this band are primarily FM.

220 to 225 MHz. Despite the fact that there is an on-going court battle between the FCC and the amateur radio community over the bottom 2 MHz, this band is becoming increasingly active as Novice class licensees begin to exercise their new voice privileges here. FM is predominantly used on this band.

225 to 400 MHz. Military operations in AM, primarily aviation, are found in this range. It is omitted on almost all but the continuous-coverage scanners.

406 to 420 MHz. Operations by the federal government can be found in this frequency range, including transmissions from Air Force One, the Bureau of Alcohol, Tobacco and Firearms and the FBI. This FM band is common on most recent-vintage scanners.

420 to 450 MHz. This amateur radio band is heavily used in the metropolitan areas, and, as with the other two vhf ham bands, is overwhelmingly FM.

450 to 470 MHz. Law-enforcement agencies predominate on FM in this range, although some general-purpose radio services can be found here also.

470 to 512 MHz. This is called the T-band because the primary allocation in this range is for uhf TV. Rarely used for general radio service, scanner coverage here is most often used to receive the FM audio for TV channels 14 through 20.

806 to 960 MHz. Cellular phones occupy parts of this range, along with some police agencies and the high end of the uhf TV channels. Some scanners block coverage of the cellular frequencies, but it often can be easily restored. It is illegal to listen to cellular phone transmissions, which is why so many people are now interested in it. "Friends" tell me that most cellular phone conversations are boring, although occasionally details of a drug deal or a romantic rendezvous can be overheard.

Equipment

Programmable scanners are generally priced from $100 to $500, but for well-heeled enthusiasts there is the $695 AOR AR2515, which with its 5 MHz to 2,000 MHz coverage (2,000 channels), is also a shortwave receiver. ICOM's $1199 Model R7000 (only 25 MHz to 2,000 MHz and 99 channels, but it's an ICOM) caters to that even more elite group that wants to add both high-performance and ambience to their listening posts.

Within the moderate price range, more expensive units are characterized by broader frequency coverage and more channels. At the top of this range common features include a priority channel and frequency search capability, which allows for general band scans to seek out new active frequencies. Most of the popular scanners have reasonable sensitivity and selectivity, so the choice of which to buy is reduced to frequency coverage, number of channels and the user convenience features. A number of amazingly high performance scanners are now available as hand-held (Walkie-Talkie type) units, and definitely merit your consideration if portability would be useful.

Some good sources for scanners, frequency lists and scanner accessories are Universal Shortwave Radio (1280 Aida Dr., Reynoldsburg, OH 43068), Radio Shack, Communications Electronics (P.O. Box 1045, Ann Arbor, Michigan), Electronic Equipment Bank (137 Church St. N.W., Vienna, VA 22180) and Scanner World (10 New Scotland Ave., Albany, NY 12208).

Antennas

Radio hobbyists show a pronounced tendency to spend lots of time and money on their electronic equipment, and a relatively small amount of time and money on their antennas. Most scanners are sold with a whip antenna that attaches to the radio and many scanner listeners never get beyond using it. This type of antenna would be only marginally effective in the best of locations, but because it is attached to the radio it can't be placed to best effect. At least these antennas usually are oriented vertically, which corresponds to the vertical polarization of most vhf transmissions.

An outdoor antenna can enable you to listen to transmissions that are totally impossible to receive on an indoor whip. In my case, a Tactical Air Command Air Force base (Seymour Johnson AFB) and Fort Bragg, with the Delta Force and the 82nd Airborne, are about 55 miles from my listening post. There is no way an indoor antenna could pull in these very active and interesting signals. With an outdoor antenna at a height of 30 feet, they come in quite well.

Still, there are times when you just can't use an outdoor antenna. Apartment dwellers and residents of areas with restrictive covenants have to contend with this situation constantly. But even for those people who have outdoor access there are times when using an outdoor antenna isn't prudent.

Thunderstorms present a particular dilemma. Leaving the scanner connected to an outside antenna during a thunderstorm is an open invitation for lightning damage, but the police, fire and rescue frequencies are particularly active in such severe weather. The solution is an effective indoor antenna.

A Multi-Band Indoor Quarter-Wave Groundplane

When antennas claim effectiveness over a given frequency range, it's usually a claim that their performance is approximately equivalent to a tuned quarter-wave ground plane on these frequencies. From my ham radio experience, I have found that antennas remain well matched for transmitting purposes out to about 2 percent either side of their tuned frequency. Receiving antennas don't have to be matched to quite as precise specifications, so I decided that a 5-percent range would be reasonable.

You won't find this in an antenna handbook; it's "Phillips' Law." Having decided that a 10-percent total range (± 5 percent) would be good, I set up a spreadsheet to calculate the frequency ranges and quarter-wave antenna lengths, as shown here in an accompanying table.

I punched in the bottom of the vhf low band into cell A4, and had the spreadsheet calculate the frequency 10 percent above it in B4. Cell C4 calculates the middle frequency of this range, and D4 calculates the quarter-wave antenna length based upon this middle frequency. The formula used here is Length (inches) = 2,808/frequency (MHz), and can be found in most antenna handbooks.

The high-end frequency in cell B4 becomes the low-end frequency in the next row of calculations and is carried down to cell A5; all the other calculations are repeated. Because antennas are usually effective at harmonics (even multiples) of their fundamental frequency, I calculated the second and third harmonics of each length in columns G and H.

Eliminating unneeded frequency ranges and those duplicated by second or third harmonics, rows 4 through 19 were left (with a blank line separating non-contiguous frequency ranges). Since I wanted the longest element to be about 6 feet long, row 6 became the first element in my antenna and I numbered the elements in column F.

Ribbon cable immediately came to mind as well suited for 12 parallel elements, so I separated 12 conductors from a 7-foot length of 36-conductor ribbon cable. Stripping one end of the ribbon cable and twisting the wires together, I soldered them to the center conductor of a short piece of RG-58 coax. Normally, a quarter-wave vertical requires several radials, but in this case I decided to try a single radial wire equal to the longest element. Therefore, I soldered a 7-foot piece of insulated wire to the coax shield and taped all the soldered connections.

To see if my theoretically tuned antenna system was actually resonant, I tuned one element with my 2-meter transmitter. Experimentation showed that it was most resonant with the element approximately 4 percent longer than the calculated length, no doubt due to the interaction between the elements and the small diameter of the conductor used. Column E was used to calculate the experimentally determined antenna lengths.

After cutting each of the 12 conductors to the specified length, I attached the antenna vertically to a curtain in my radio room, with the "radial" extending horizontally along the floor. A little experimentation showed that the antenna worked best up-side down, probably because this places the shorter elements up higher. The radial wire is now taped horizontally along the wall.

As expected, this antenna doesn't work nearly as well as my professional scanner antenna at 30 feet, but it works substantially better that the whip and in general is an excellent indoor antenna. Best of all, it was free because I already had the materials on hand. With all the materials purchased new, you still should be able to build it for under $10.

The Law

For years scanning was relatively unregulated, governed primarily by the same law as shortwave listening. This is the Secrecy of Communications Act, which said it was illegal for the listener to divulge or profit by monitored communications not intended for the general public.

But as mentioned previously, it is now illegal to even listen to cellular phone transmissions. It is not illegal to own radios that cover the cellular frequencies, but you're not supposed to listen to them. This law, the Electronic Communications Privacy Act of 1986, also makes it illegal to "intercept" (listen to) ". . . all forms of common-carrier communication, except cordless phones and tone-only paging communications, and of any non-common-carrier or private radio communications when they are encrypted [or] scrambled . . . " This law was primarily passed based on lobbying pressure from the cellular phone manufacturers and service providers to give their users a (false) sense that their unscrambled conversations were private and secure.

The monitoring of transmissions from state, federal and local law enforcement agencies, public safety services, aviation, business, military, cordless phones and most other sources that are "readily accessible to the public" is not illegal. It is up to you to determine why our law makers consider a police transmission on the 800-MHz band "readily accessible to the public," and the cellular phone transmission a few megahertz up the band not "readily accessible" (lobbying money?).

The practical effect of this law has been minimal, since the pertinent law enforcement agencies have made it clear that they have more important things to do than to become the radio Gestapo. Generally speaking, it would be difficult to prove that a person had listened to a prohibited transmission unless they confessed, but this is the law and as with all laws you ignore it at your own risk.

Scanners mounted in automobiles are subject to restrictions in some locales. If you are interested in scanning on the move, you definitely should check your local laws.

Comments and suggestions are welcome. You can contact me through Delphi (CURTPHIL), CompuServe (73167, 2050) or at P.O. Box 678, Garner, NC 27529. ME

PC Flight Guide & MacPrint Software

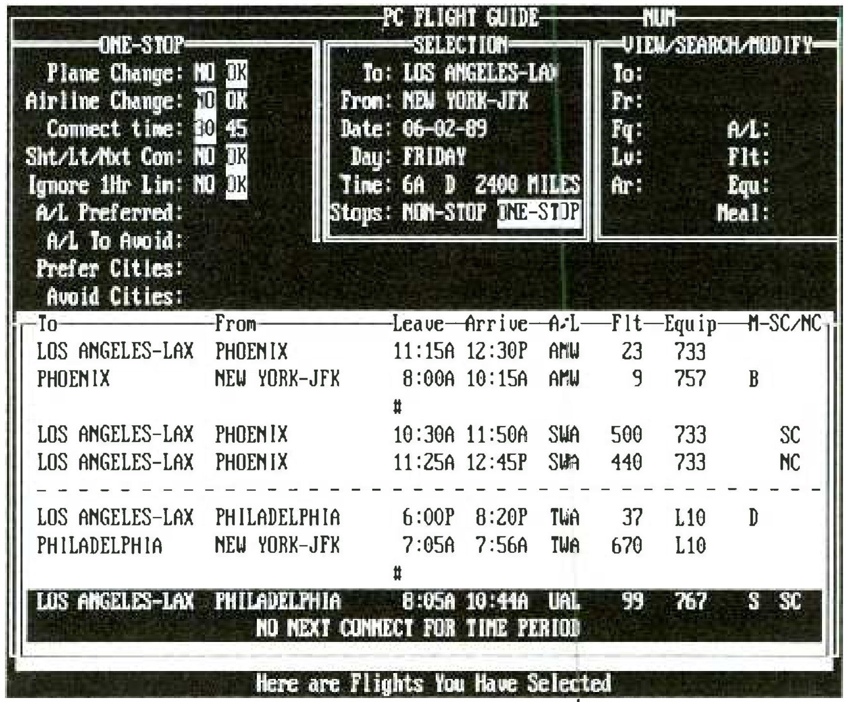
By Ted Needleman

As we start a new decade, I can't help but think how far we've come in the everyday use of high-technology. While many of the applications we perform with our PCs are either refinements or derivatives of applications that have always been performed on computers, such as modeling, mathematics, data and text manipulation, word processing, and accounting, other applications have been made possible only by the availability of inexpensive data processing power.

This was recently brought home to me when I realized how casual I've become about some of the tasks I frequently use my PCs for. One such area is how easy it's become to transfer information. When I first started writing, ten years ago, my articles were all submitted on hardcopy. Some publishers even insisted that they be re-typed on a typewriter because their editors and typesetting people found the dot-matrix output from my Epson printer more difficult to read than the typewritten material they were used to. Things improved in 1981 when I bought my first letter-quality printer, a $3,000 NEC SpinWriter thimble printer. This produced "typewriter" quality output, but cost more than the computer it was attached to!

When I submitted a book in 1983 to a major publisher, however, it still had to be submitted as hardcopy—hundreds of pages of slowly produced paper, rather than the 300K of text files that my word processor had created. And when a revised manuscript was requested, another several hundred page printout needed to be generated.

Things are much different today. A majority of my articles are submitted electronically. Either by transmitting the text files directly to a publisher's system over the phone lines, by uploading the file to MCI Mail so that an editor can download the file at his or her leisure, or in the worst case, by dropping a disk containing the file in the mail. This method eliminates mistakes made when keying in text from hardcopy, and saves hours of time for everyone concerned. And while I've been using modems for almost the entire two decades I've used computers, it is only recently that transferring files has become both simple and commonplace.



PC Flight Guide features an easy-to-use query screen.

Telecommunications has become so commonplace, in fact, that most of us tend to take it for granted. We're so blase about being able to dial into services like CompuServe and Genie, or transfer files back and forth to friends and coworkers, that the only time we give the process much thought is when it doesn't work with the expected smoothness.

For all the impressive applications we perform on our computers, it's still important to remember that the computer's major worth is that it is an information machine. It not only allows us to turn data into information (I define the term information as data that has been manipulated and presented so that it has relevance to a user), but provides easy and rapid access to information we need both in business and our personal lives.

As we enter the 90s, I find it exciting that not only will computers make information access even easier, but that refinements in the areas of data manipulation, extraction, and analysis will make the data we can access even more usable.

PC Flight Guide

As part of my job, I have to do a lot more traveling than I like. Shows, conferences, and visits to hardware and software companies take me away from home fairly frequently. In the past, as many frequent travelers do, I relied on a little book called the OAG (Official Airline Guide) to help me select the best flights to book. Issued monthly, it is similar to many airlines' flight schedules, except it gives times and flight numbers for all airlines flying from a departure airport to a target city. Not only is the OAG handy in determining itinerary, but the times I've finished up early, it was helpful in determining if I could catch an earlier flight home.

More recently, I've moved away from

the hardcopy OAG to the electronic version offered on CompuServe and several other electronic information utilities. This electronic version, along with American Airline's EasySabre service, also offered on CompuServe, give both flights and fares. This is convenient, but with the time it takes to track down the right flights and check the fares, it's a fairly expensive service to use.

I'm still using my PC to plan my trips, but I'm doing it without tying onto an on-line service or accruing time charges. PC Flight Guide is a database of flights and connections that is updated every two months. You use it pretty much the same way that an on-line service is used, by entering in an input screen the departure city, the arrival city, date of departure and either the earliest departure or arrival time. You can specify non-stops only, or allow the software to find both non-stops and connecting flights. You can even specify the layover time, a preferred airline, and preferred connection point. Likewise, PC Flight Guide also allows you to specify airlines you don't wish to use, and cities that you will not consider catching a connecting flight in.

In addition to flight information, which is the major use that I put the software to, there are also databases of hotels, seating arrangements on the most common equipment used by a particular airline, toll-free numbers for airlines, car rental agencies, and hotel chains, and even the visa requirements for traveling to many foreign countries. Release 2.0, which should be available about the time this appears, will also have airport layouts and business lunch information, making it even more valuable to many frequent travelers.

PC Flight Guide is available on both 5.25- and 3.5-inch disks. In the 3.5-inch version that I use with my Epson LT laptop, there are four disks that are installed by creating a subdirectory on the hard disk and transferring files over to it. You can also use the Flight Guide on a dual floppy disk system, but you may have to swap disks around occasionally.

PC Flight Guide is easy to use, and very useful for those on-the-go. It's nice to be able to check and alter your travel plans in mid-flight (on those airlines that let you use a laptop on the plane) and at a yearly subscription price of $119.50 plus $12 (for 5.25-inch disks) or $22 (for 3.5-inch disks), it's about the same price as a subscription to the OAG or fairly infrequent use of an on-line service. This package isn't for everyone, but if you take several business trips a year, or vacation extensively, you owe it to yourself to take a look at PC Flight Guide. It runs on a PC, AT, 386 or compatible with at least 640K of RAM. A hard disk is preferred, but not essential.

MacPrint

If you've been following this column, you know that I use both PCs and Macs. PCs, however, are the systems that I use most often. As such, the laser printers I employ tend to be Hewlett-Packard LaserJet compatible, rather than the PostScript printers more commonly used with the Macintosh. With the limited room I have in my home office, the Star LaserPrinter 8 is my main printer.

In the past, when I've wanted to print something from my Mac, I've had to drag an Apple ImageWriter printer out of the closet and find somewhere to rest it until the Mac was done printing. Needless to say, with this much inconvenience to go through, I haven't done a lot of printing with my Mac, and tend to let these printing tasks pile up until I have a number of them to do.

This has always bothered me because the laser printer I have in the house gives excellent-quality output, but you can't just hook it up to a Macintosh and expect it to work. Even if you get the cabling right, the Mac's QuickDraw and PostScript printer languages are not compatible with the PCL (Printer Control Language) that the LaserJet and its compatibles (like my Star) uses.

MacPrint, from Insight Development Corp., can fix that. It consists of a set of software drivers that are installed in your Mac's System Folder and a cable to hook the Mac up to the LaserJet. This cable, incidentally, is a round DIN connector on the side of the Mac, for use with the Mac Plus, SE or Mac II series. Older Macs, which use a more familiar DB-type connector, are out of luck unless you can get an adapter cable that converts the DIN connector to a DB type connector.

As my old Mac 512E has been upgraded in memory, but still uses the DB connectors for output, I initially tested MacPrint in the office, where I have a Mac SE. Hunting through the "old cables" box at home, I found a cable that came with a Mac-to-IBM transfer package. To be on the safe side, I hung an IQ Technologies SmartCable on the PC side of the cable, plugged the other side of the SmartCable into my laser printer's serial input port, and was able to use MacPrint with my old 512E Mac computer without any problem.

Installing the MacPrint system is simple and takes just a few minutes. The cable is hooked up to either the Printer or Modem port on the Mac side, and the serial I/O port on the printer (unless you have to cobble together a cable as I did). The printer must be set for serial input at 19,200 baud, with XON equal to on, and DTR polarity set to high. On a Laserjet II or IID (the duplex version of the LaserJet II) these settings accomplished through use of switches on the printer's front panel. With a compatible, you may have to set DIP switches on an interface board.

Once the printer has been set up, power up the Mac. Insert the MacPrint disk into a floppy and open it. There are two folders on the disk; one labeled "Place Contents In System Folder," and the other "Make Fonts Here." The contents of the "Place Contents" folder should be dragged to your system folder on the startup disk. The second folder should be moved in its entirety to the startup disk. Then eject the MacPrint disk from the Mac computer.

The next step is to run the LJ FONT MAPPER utility, which allows you to make Mac versions of whatever LaserJet fonts are available both in the printer and as font cartridges for the LaserJet. Once these fonts are made, you must install them in your System Resource using the Mac's FONT/DA MOVER. Once installed you pull down the CHOOSER and click on the MacPrint Driver, select an external font cartridge if one is installed (and wanted), and click the SETTINGS box to set the port and baud rate.

Once the installation is complete, you can choose a LaserJet font from an application's FONT menu just the same way you select a native Apple font. Apple's QuickDraw fonts are also available.

MacPrint works very well. In my test, most of the native LaserJet fonts looked a bit better than the QuickDraw fonts. This is to be expected, as the QuickDraw fonts are sent to the printer as a bit-mapped image of the character. This tends to make them a bit more "dotty" looking, especially in the larger sizes.

Overall, the MacPrint, at $149, is an excellent value if you have one of the Macs it supports and a LaserJet or compatible printer. I don't really recommend its use on an older Mac, as Insight cannot be expected to help you troubleshoot problems on setups they haven't tried. It will even let you perform a screen dump, at 300-dpi resolution, to the laser printer, something not easy to accomplish on the Mac even with Apple's own LaserWriter.

Products Mentioned

PC Flight Guide
$119.50 + $12. or $22.
5 Argent Circle
Irvine, CA 92714
714-651-9405

MacPrint
$149.
Insight Development Corp.
1024 Country Club Drive, Ste. 140
Moraga, CA 94556
415-376-9451

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Customize Your Home Entertainment System: TV and VCR. *By Steve Sokolowski. (Tab Books. 272 pages. $15.95.)*

This book provides details for building 20 projects that can enhance the performance or provide features lacking in a video entertainment system. A true hobbyist's book, it begins with five chapters devoted to preliminary information. A basic course in TV and VCR equipment, the first chapter discusses the early history of TV and makes then-and-now comparisons. It also covers TV signals, interlacing, vertical blanking, monochrome TVs, digital TV and the VCR revolution and makes some projections about the future of VCRs. The next four chapters deal with electronic project assembly tips, reading schematics, circuit board fabrication and soldering techniques.

Projects covered in this book include such items as a tunable notch filter, audio delay line, equalizer, noise-reduction circuits, four types of audio amplifiers, bass boost filter with preamplifiers and a stereo audio control. There are also VU- and audio power meter add-on projects. More specialized projects include a low-cost IR audio transmitter/receiver system for private listening, a surround-sound decoder and a stereo simulator with amplifier. These are supplemented with details on building a TV stereo adapter, tone controller, stereo audio switch and VCR ac controller. The final chapter is devoted entirely to power-supply circuits.

Individual chapters are devoted to each each project. These chapters contain schematic diagram with parts list, a brief description of the task the project fills, a printed-circuit-board fabrication guide with component-installation diagram, construction, assembly and installation details.

One of the two appendices that close the book gives names and addresses of semiconductor manufacturers and mail-order distributors from which materials can be obtained. The other appendix is packed with IC package outline and pin-out information.

IBM PS/2—A Reference Guide. *By TJ Byers. (McGraw-Hill Book Co. 316 pages. $39.95 hard cover; $34.95 soft cover.)*

Whether you are planning to buy or already own one of the computers in the IBM Personal System/2 series, this book contains just about anything you would ever want to know about the PS/2 series, from choosing the right model for your needs to doing advanced work with the computer. It does so with light, breezy text that does not bog you down with unnecessary technical detail, but it does not skimp on technical material where it might be needed.

Appropriately, the book begins with an introduction to the PS/2 family of computers and gives a description of each of the seven models that currently make up the line. A buyer's guide comes next. It is here that the author gives very helpful advice on selecting the right model for your needs. Then it is on to initial system setup, telling you how to install internal options and initializing them, creating and using passwords and loading and configuring DOS. This is followed with a chapter devoted entirely to DOS.

Chapter 5, titled Batch Files, is particularly informative for newcomers to computers who wish to use hard disks. It details how batch files work and how to create and run them. It also discusses DOS screen commands, batch file conditional commands, using ERRORLEVEL, autoexec batch files, and configuring the system. The remaining five chapters deal with the keyboard, disk drives, video graphics, interfacing the PS/2 with peripherals and other outside-world devices and, finally, IBM PS/2 networks.

Coverage throughout the book is detailed and complete. The text is supported with unusually good photos and drawings (most from IBM). Tables summarize important material. For the advanced user who wants to get more out of his system than applications permit, shortcuts and programming hints allow him to take advantage of the keyboard and video display. In sum, this is a fine reference book for the person who wants to buy an IBM PS/2 computer or weigh it against compatible models on the market.

NEW LITERATURE

Shortwave Products Catalog. The latest catalog from Universal Shortwave Radio lists and fully describes a wide range of table-top and portable communications receivers, headphones, antennas, protection devices, 12- and 24-hour format

NEW LITERATURE

clocks, radioteletype and facsimile equipment, accessories, and books for the shortwave listener. Except for some books and literature and a few accessories, each item listed is accompanied by a photograph or drawing. Included are a one-page "Introduction to Shortwave" section that gives general details on the hobby and a two-page section titled "Introduction to Radioteletype." For a copy, write to: Universal Shortwave Radio, 1280 Aida Dr., Dept. ME, Reynoldsburg, OH 43068.

Computer Products Catalog. Micromint's SB180 ImageWise Catalog provides a listing for a variety of computer products. The colorful 16-page catalog features SB (single-board) and RTC (real-time controller) families of computers and controllers, ImageWise and ImageWise PC video digitizers, power supplies and components, as well as such software offerings as cross-compilers and simulators from Avocet and networking software from MCnet for distributed microcontroller applications. For a free copy, write to: Micromint, Inc., 4 Park St., Dept. ME, Vernon, CT 06066.

Communications Catalog. The "Great Radio Reads" catalog from Tiare Publications is devoted to listings of radio-interest. Seventeen major titles, ranging from shortwave listening to ham radio to scanning monitoring interests, are described. Also listed are a radio-frequency spectrum chart; world status map; international travel briefing service; computer program that displays colorful maps, population, age distribution, language, ethnic groupings, religious, economic, commodity and trade information, political organization and leaders for each nation; and Infocards with such useful information as FCC addresses and phone numbers, world call-sign prefixes, shortwave frequency bands and users, and more. Accompanying the catalog is a separate order form. For a copy, send $1 to: Tiare Publications, P.O. Box 493, Lake Geneva, WI 53147.

Data-Acquisition Products Catalog. National Instruments is offering a six-page, full-color brochure that describes the company's line of data-acquisition hardware, software and accessories for IBM PC/XT/AT and PS/2 and Apple Macintosh computers. Detailed technical specifications are given for plug-in data-acquisition boards for analog, digital and timing I/O functions. The brochure also describes the company's LabDriver, LabWindows, Measure and LabView software for simplifying development of data acquisition, analysis and presentation applications. For a free copy, write to: National Instruments, 12109 Technology Blvd., Austin, TX 78727-6204.

Test & Interface Devices Catalog. A 16-page 1989 catalog that lists and describes serial RS-232 test and interface equipment is available from: B&B Electronics, 4000 Baker Rd., P.O. Box 1040, Ottawa, IL 61350.

Measurement-Instrument Catalog. Listed and described in the 156 pages of the Third Edition of the Grainger Test and Measurement Instrument Catalog are more than 2,000 products from 45 leading manufacturers. The catalog is broken down into nine major product categories (General Testing, Precision Measurement Tools, Electronics, Electrical, Temperature/Humidity Measuring, HVAC/Refrigeration, Environmental, Automotive Diagnostic Systems and Accessories/Reference. Among the items listed are multimeters, tachometers, analog panel meters, calipers, thermometers, charging meters, static pressure gauges, diagnostic scopes and tach/dwell meters. For a free copy, write to: Eugene Wesoloski, Prod. Adv. Mgr., W.W. Grainger, Inc., 5959 W. Howard St., Chicago, IL 60648.

A/V Processor Brochure. A line of audio/video processors for recording onto and copying video tapes is described in detail in a color brochure from Vivanco. All provide 5-MHz, 400-line high-resolution images, and each can produce multiple copies simultaneously. The five models listed range from a low-end video switching console that permits making copies claimed to be as good as the original, to a model that is said to make copies that are better than the original, to another model that provides manipulation of the image and offers split-screen capability, to the top-of-the line model that offers white-light correction, special effects circles, boxes, split screens and color generations. Compact connectors that eliminate individual cables simplify installation and ensure interference-free recording. An instructional VHS video tape comes with each processor. For a free copy, write to: Vivanco/GMI Photographic, 1776 New Highway, P.O. Drawer U, Farmingdale, NY 11735.

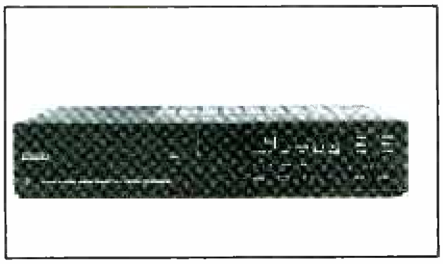
490 test method allows the CRT's cathode to control its own restoration duration, which reduces the risk of cathode damage.

The Model 480 is similar to the Model 490, except that it has a single meter for displaying test results and does not include a line-voltage test function. Both units are housed inside rugged molded-plastic cases with carrying handle and CRT adapter storage space in their lids. Both are also supplied with six CRT adapters, and other adapters are available for a variety of video display terminals, video monitors and TV receivers. $715, Model 490; $500, Model 480.

CIRCLE 71 ON FREE INFORMATION CARD

Compact-Disc Player

The Cyprus PCMII from Mission Electronics USA (Seattle, WA) compact-disc player is designed for the "audio purist." It features four-times oversampling and independent D/A converters for the left and right channels, the latter said to be preselected and carefully matched to preserve exact channel balance. Residual phase-shift artifacts are removed after conversion by a built in 16-bit digital filter.



Four separate power supplies provide maximum control and separation of the signal within the chassis itself. Each channel utilizes independent regulated power supplies, with their own separate transformer windings, for the digital and analog circuit sections.

The player's volume control is designed to maintain the purity of the processed signal delivered at the output. Twin solid-state resistance loads create individual circuits for each step of the volume control. The circuits attenuate the output in 1-dB steps and are controlled by an integrated circuit.

A phase-reverse switch is provided for correcting the sound when a disc has been recorded out-of-phase. A large fluorescent display shows track number playing, index point, elapsed time and programmed tracks. The display is electrically isolated from the circuit path to minimize interference and can be switched off for ultimate interference elimination. The digital output is loaded with resistors to stop stray r-f interference.

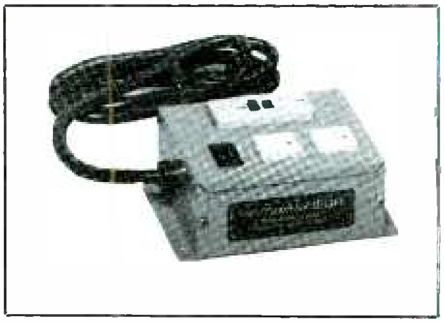
The player can be programmed (locally or via its infrared remote-control transmitter) for up to 20 tracks and can repeat play of a phrase, program or the entire disc. Other features include indexing and scan. $999.

CIRCLE 72 ON FREE INFORMATION CARD

Ground Fault Interrupter

Verite's new Veri/Protektor™ II is described as an all-inclusive power-line protective device that covers ground leakage and high-voltage threats, surges, spikes, transients and emi/rfi interference. Employing high-power-capacity MOV technology and line filters, the device is claimed to withstand transients in excess of 10,000 amperes and to clamp multi-thousand-volt spikes in less than 5 nanoseconds.

The device's ground fault interrupter circuit protects equipment and people against shock and damage resulting from power-line leakage caused by defective test equipment, power supplies and soldering irons. The circuit is said to act instantly to shut off electronic equipment upon sensing an unbalanced line current of less than 5 mA. The Veri/Protektor II is based on a proprietary design that employs an air-core transformer that is not susceptible to saturation. It clamps over-voltages with zero current on the line, while other de-



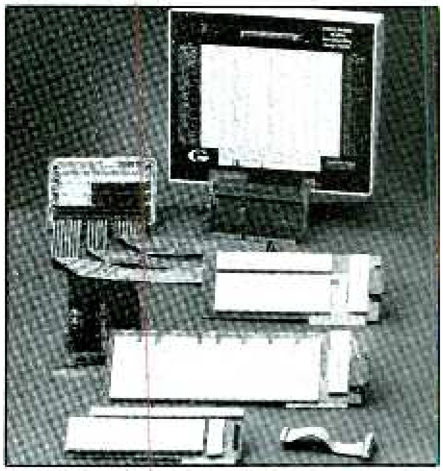
vices may require as much as 5 amperes of line current before clamping begins.

Packaged in a sturdy metal container with 6-ft. grounded power cord, the product features four receptacles, an on/off switch, 15-ampere circuit breaker, power-on indicator, leakage test and reset switch. $149.95.

CIRCLE 73 ON FREE INFORMATION CARD

PC Prototyping Aids

A new Proto-Card Series consisting of a variety of plug-in boards expands Global Specialties' line of Proto-Board line to PC applications. The development cards that make up the series are designed to plug into the bus of any IBM XT/AT or com-



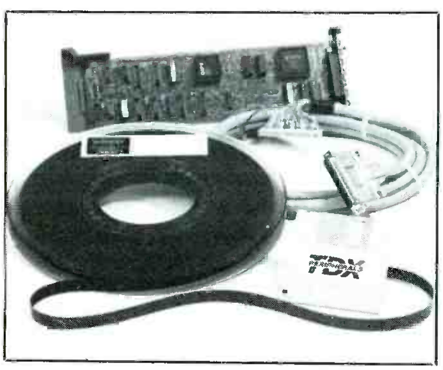
patible computer to permit wiring and testing of circuits. The PB-88™ cards provide access to the computer's bus signals through Global's solderless interface sockets, and they have a selection of breadboarding socket areas for assembly of custom circuits. Many cards include built-in address decoding that reduces the time needed to build circuits. For applications that require a larger breadboarding area, two external console versions are available.

Slot extender and slot expander kits provide handy tools for testing and repairing PC add-on cards. The SE-7 extender raises the computer's slot to the top of the console to provide easy access to both sides of a card while it is operating. The SE-75 expander provides four additional card slots and has an on-board power supply for use with external power supplies.

CIRCLE 74 ON FREE INFORMATION CARD

Tape-Drive Interface

TDX Peripherals' (Hauppauge, NY) Model IN-330 IBM-PS/2 Micro Channel Interface Board is said to be compatible with the entire line of TDX nine-track tape drives and all Micro Channel systems. It conforms to the auto-configuration specification that eliminates the need to set DIP switches and jumpers. The full-size board connects to the tape drive via a single shielded 50-conductor cable. Employing VLSI technology, it includes an on-board 64K data buffer.



Supplied is a 3.5-inch diskette on which is software based on a flexible DOS-installed driver that includes programmable ASCII/EBCDIC code conversion and automatic record deblocking. The Model IN-330 is said to be fully reverse-compatible with software written for a TDX AT or PC-type tape system. $1,200.

CIRCLE 75 ON FREE INFORMATION CARD

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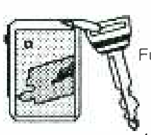

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supply and injecting a low-frequency TTL-pulse signal at pin 1 and observing the pulse at pin 4 of the IC.

Adolph A. Mangieri

Author Feedback

• I have been informed that the IEEE1257R displays specified for DISP1 and DISP2 in my "Solid-State Oscilloscope" (November 1989) are no longer available. Suitable, though not exact, substitutes for them are Siemens Components, Inc. (Optoelectronic Division, 19000 Homestead Rd., Cupertino, CA 95014; tel.: 408-257-7910) Part No. DLR5736 (red) and DLG5736 (green) matrix displays. If these are difficult to come by at reasonable cost, one can use MAN2 5 × 7 matrix displays, which are considerably smaller and leave a gap between the two when mounted side by side. They are available from Jameco and other mail-order suppliers.

Other alternatives are Radio Shack Cat. No. 276-081 and All Electronics Cat. No. BG-10 LED bargraph displays, which have individually accessible LED elements. Ten of each of these are needed to make up the complete display system for the Oscilloscope. A final alternative is to use discrete light-emitting diodes of any color in place of the matrix displays. If you go this route, obtain matched LEDs for a uniform display.

While I am at it, one small error in Fig. 3 should be corrected. Eliminate the center contact from S4A and S4B and move the legend FREE RUN from the center to the lower contact of S4A.

Jeff T. Williams

It's On the Market

• "Choosing the Right Computer Power" Part I in the October 1989 issue has a small error in it. Mr. Desposito stated that there is no 80486 personal computer, but there is. It's featured on the cover of the October 1989 issue of a major computer magazine. I understand that Mr. Desposito probably wrote the article that appeared in *Modern Electronics* before the announcement of the 486 PC was made. However, the 486-based units are power machines, so a future article on them would be of real interest to us readers.

Brian P. Vavrina
Minneapolis, MN

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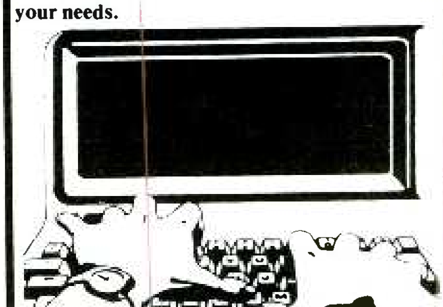

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