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MODERN ELECTRONICS™

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

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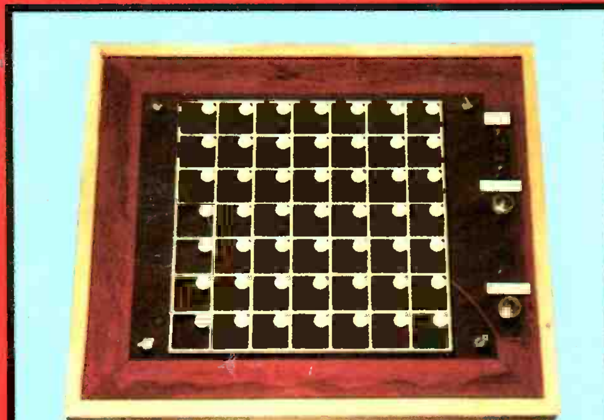
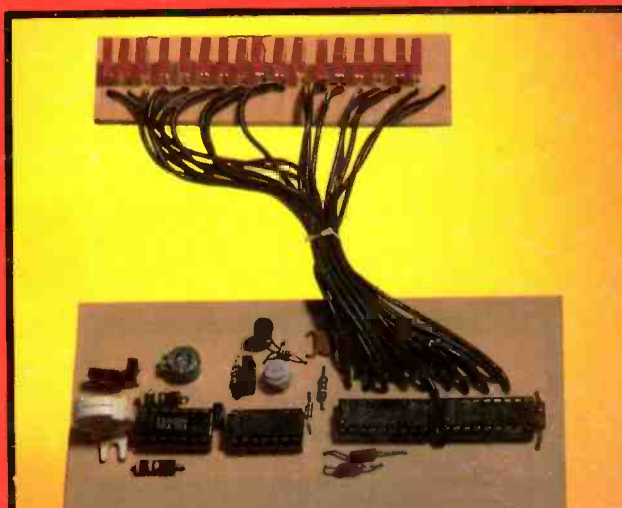
- "Pick Six Lottery" Number Selector
- Relative Humidity Metering Device


Random number selector for Pick Six lotteries (p. 22)

Also:

- A Blackout/Brownout Audible Alarm
- Beep Tone Converter
- Fabricate PC Boards Without Photography
- Final Two Modules For Smart Weather Monitor

Magnavox's new 3" hand-held LCD color TV receiver (p. 14)


All-electronic Relative Humidity Meter (p. 44)

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Plus: Forrest Mims' Piezoelectric Experiments • Evaluating Nemesis GO Game! • First Look at Gazelle Systems' OPTune Software • Pyroelectric Infrared Sensors & a Power Operational Amplifier • Electronics & Computer News . . . more.

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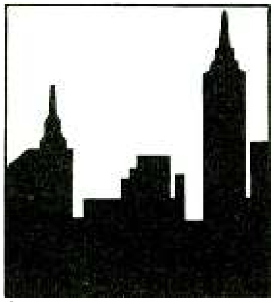
AUGUST 1989 VOLUME 6, NUMBER 8



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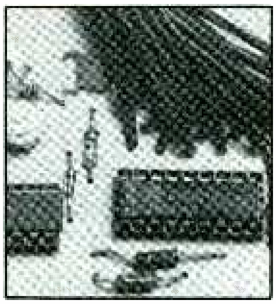

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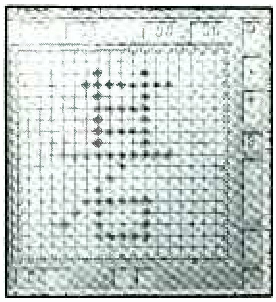

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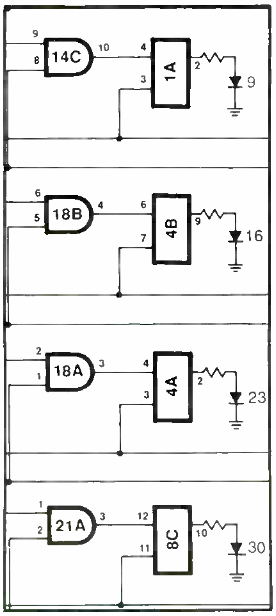

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BOB HANSON MAY WELL HAVE HAD 200,000 FRIENDS. NOW HE NEEDS THEM ALL . . .

The world of communications has lost a great friend and devoted public servant. On Wednesday, May 8, 1989 Bob Hanson, W9AIF, passed away on the operating table during a delicate and enormously costly liver transplant operation.

Bob will be mourned by literally hundreds of thousands of individuals whose lives he touched throughout the world as a noted columnist . . . public service association executive (SCAN, REACT, Community Watch) . . . communications industry advertising and marketing manager . . . and active radio amateur.

But mourning alone cannot pay adequate tribute to Bob's total dedication to serving others—including his wife of 23 years, Marilyn, and two teenage sons, Peter and Andrew.

Since liver transplants are regarded by some as "experimental surgery," not one dime of the expense—estimated in excess of $200,000—was covered by insurance. We simply cannot allow Bob's wonderful family to live with that impossible burden.

Your help is desperately needed. Immediately. Please, please send your contribution today. Make checks payable to: **Organ Transplant Fund Inc./Robert Hanson** a legally constituted non-profit organization. Any funds collected in excess of those required to pay actual medical expenses will be used to relieve similar transplant victims.

The Robert Hanson Fund. A Living Memorial.

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EDITORIAL

A Taxing Approach

"**Tax us,**" says Zenith Electronics' prez in a quest for high-definition TV funding. He proposed that Congress establish an "HDTV Trust Fund" to pay for a portion of HDTV research by U.S. companies. The money would come from a $5 excise tax on each TV receiver sold here. With 20-million sets sold annually, this would raise about $100-million. Zenith suggests a fixed term for the Fund of three to four years.

Some true-blue capitalists might object to this or other forms of governmental partnerships. But in today's world, private companies do need more federal support in selected areas in order to remain competitive with other countries that have enormous government backing.

HDTV represents a future industry that'll be in the many billions of dollars. Japan's Ministry of International Trade and Industry, for example, predicts that HDTV will be a $27-billion market in a decade. While our companies struggle on their own, Japanese and European governments have been investing in HDTV research and development for years now. As a result, they're far ahead of us in the HDTV area, among others.

We'll continue to be hurting without a supportive environment, I think. Whatever plan is adopted, whether it's raising money by a sales surcharge or tax-break incentives, we have to have some firm strategy to meet the challenges of other industrial countries. With military electronics declining, consumer and commercial electronics will hopefully fill the vacuum. With production of Free-World electronic equipment expected to exceed $500-*billion* this year, we've got to get our fair share. As it stands, the Far East and Western Europe have consistently displayed greater growth rates than the U.S.

Along these lines, a business plan for obtaining significant government incentives for private companies to invest in HDTV products has been developed by the Boston Consulting Group with the sponsorship of 36 companies. Presented to a Senate Committee in May, it observes that a government-supported, industry-led effort is needed to overcome technology gaps, and to establish world-class manufacturing infrastructures for high-resolution displays, advanced VCRs and memories.

If we want to win the global electronics/computer war, we'll have to nurture and protect the U.S.'s R&D with the help of government financial links. There's too much riding on this to ignore such need: Reducing the trade deficit, jobs, etc.

Japan's NHK, the Japan Broadcasting Corp., has been the HDTV world pioneer. It's already selling HDTV broadcast studio equipment and has prototype receivers and VCRs. Sometime in 1990 it's expected to launch a satellite to start direct-broadcast HDTV in Japan.

A bevy of companies have demonstrated their HDTV transmissions in the U.S., among them being Zenith Electronics and Philips Labs at an NAB (National Association of Broadcasters) convention some months ago. Around the same time, the first commercial over-the-air transmission of an Advanced TV signal was broadcast from WNBC-TV. It took place on the same day of the 50th anniversary of TV's debut at the 1939 New York World's Fair, and was received on prototype ACTV (Advanced Compatible TV) receivers at the David Sarnoff Research center in Princeton, NJ. Home viewers received a normal picture on conventional NTSC receivers.

Apparently, we're still in the HDTV game, though far behind Japan. In the event that some readers are unfamiliar with the promise of high-definition TV, it will yield color pictures that rival 35-mm film, stereo sound with compact-disc quality, and full compatibility with existing TV sets that will receive a normal picture from an HDTV transmission (you'll need an HDTV receiver to get motion-picture quality, of course).

Let's hope that the U.S. becomes a leader in this field, slowing down or reversing our losing of market share in the electronics industry. To make it happen, we need government cooperation—fast.

Art Salsberg

LETTERS

A Matter of Law

• According to FCC Rules Part 68, Subpart D: "The dc resistance between tip and ring conductors, and between each of the tip and ring conductors and earth ground shall be greater than 5 megohms for all dc voltage up to and including 100 volts." This minimum on-hook resistance is specified to enable the telephone company to check a subscriber's line for leakage from the central office test board and to minimize on-hook current drain on the central office battery supply. Figures 5 and 7 in "4-Add-On Phone Devices" in the February 1989 issue do not meet this requirement by a very large margin. The problem is compounded since in both cases it is expected that more than one such device will be connected across the same line. Thus, it is illegal to connect either of these circuits across a phone line.

T.M. Lott
San Mateo, CA

A Matter of Values

• After building the 10-Hz to 2.2-GHz Frequency Counter featured in the April issue, I thought I would advise you and any other readers who are considering building this project of some changes that will assure that it operates properly. The following changes, verified by kit supplier Optoelectronics, should be made in the Parts List: Y1—10 MHz; Y2—3.90625 MHz; R18,R19—1,000 ohms; R11—75,000 ohms; R12—100,000 ohms; and C31—Not Used. All resistors are ⅛-watt units. Once these adjustments have been made in building the project, a bit of calibration will yield top-notch performance from this counter.

As a new subscriber to *Modern Electronics*, I have one comment to make: Keep bringing us excellent construction articles like the one above.

Hugh Duff VE30YH/W1
Marlborough, MA

The author has informed us that the frequencies for the two crystals were accidentally transposed just prior to finalizing the Parts List. Resistor values were changed to add stability to the project and assure reliable operation, and C31 was eliminated as not needed in the final design of the instrument. These changes were discovered by the author after we went to press. Readers who purchase the kit from Optoelectronics will automatically receive the update and components of appropriate value.—Ed.

VIDEO CASSETTE PRODUCT DEMO. More and more companies are using video cassettes to promote their products. The latest Free examples in the oscilloscope area are available from Hewlett Packard and John Fluke. The former demonstrates its new 100-MHz digitzing scope, Model HP54501A ($3,465). Call 1-800-752-0900, Ext. 222 for the free copy. Fluke, in turn, offers a video that discusses its digital storage oscilloscope technology and what to look for when selecting a scope. To get the 11-minute video, "DSOs with a Difference," call 800-443-5853, Ext. 77....In the consumer world, Stanley Home Automation includes a video cassette that demonstrates how to install and adjust its garage-door chain-drive openers (except the 1/4 horsepower models).

VIDEO GAME NEWS. Nintendo was denied its legal motion to temporarily restrain Tengen Inc., a subsidiary of Atari Games Corp., from distributing its independently manufactured Nintendo-compatible version of the the video game "Tetris." The legal battle will continue, though....The $40 game, said to be the hottest arcade one, was originally developed by two computer programmers from the Soviet Union. It challenges a player's dexterity and spatial perception with geometric shapes dropping from the screen top that have to be rotated and placed in rows. Starting off slowly, pace and complexity increases. Russian folk tunes accompany video action.

Atari Corporation (not affiliated with Atari Games), which essentially founded the video game business, introduced the world's first hand-held color video game system recently. It claims high-resolution color graphics, realistic sound and vivid colors. Six arcade games are already available.

WIRELESS TV. Distributing TV signals to multiple TV sets without wires has been tried in the past. The devices used weren't legal, though, and there aren't any of them sold openly on the market now....But there promises to be legal wireless TV distribution in your future, based on FCC rules changes that open up five new frequency bands for wireless signal transmission purposes. The frequencies became legal last month: For video, 24 to 24.5 MHz, 902 to 928 MHz, 2400 to 2483.5 MHz, 5725 to 5875 MHz; for audio-only, it's in the 49 MHz band, sharing it with cordless phones. So you can look forward to being able to play a TV set anyplace in, say, your back yard, without connecting your antenna's cable to it in order to get good reception.

JAPAN MILESTONES. Konosuke Matsushita, founder of Matsushita Electric (parent company of Panasonic, among 164 others, with some 135,000 employees worldwide), died at 94 years. He had hocked his wife's kimono when he was 24 to start the company, which made sockets for a plug and a light bulb....The Society of Motion Picture and Television Engineers (SMPTE) bestowed its highest award, Honorary Member, upon 89-year-old Kenjiro Takayanagi, supreme advisor to JVC. The TV pioneer, who developed the two-head helical-scan video tape recorder, is the only Japanese ever to be so honored in the association's 72-year history, joining the likes of Thomas Edison, Vladimir Zworykin, and Walt Disney.

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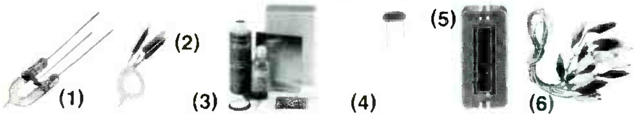

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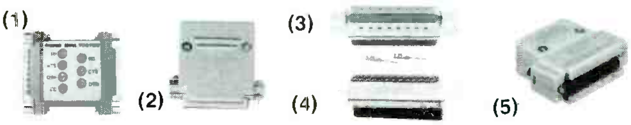

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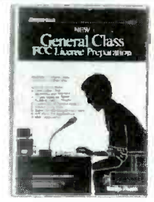

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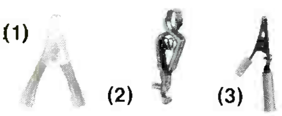

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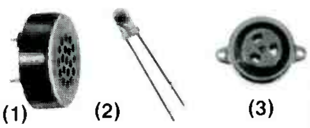

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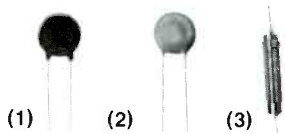

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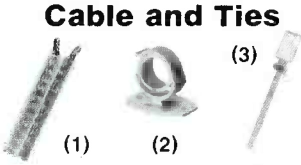

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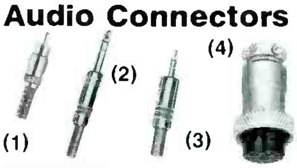

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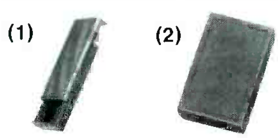
2	3-Conductor, ¼" Phone	274-856	3.99
3	3-Conductor, ⅛" Phone	274-858	3.49

(4) **8-Pin Mike Plug.** #274-025 .... 2.19

Instrument Cases



(1) **Professional Project Case.** Ideal remote enclosure. 5⅝ x 2¼ x 1¹¹⁄₁₆". #270-257 ...... 4.99
(2) **Transmitter Case.** Perfect for an RF or IR transmitter or beeper. 3¾ x 2⁵⁄₁₆ x 1". #270-293 ... 3.99

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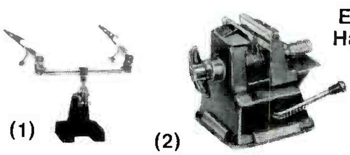

(1) **Project Holder.** A third hand for soldering, gluing, repairing. Ball joints and two alligator clips adjust to hold work. #64-2093 ..... 7.99
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CIRCLE 89 ON FREE INFORMATION CARD

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.

Keyboard With Trackball

KeyTrack from Octave Systems (Campbell, CA) combines for the computerist a trackball and a traditional keyboard in a single device. The trackball is said to be compatible with both MicroSoft and Mouse Systems serial mouse drivers. AT and XT switchable, KeyTrack comes with a Y-shaped cable that plugs into the keyboard port and a serial port. Three mouse buttons are located above the trackball, and the primary button is duplicated on the left end of the keyboard for greater operator efficiency. $189.

CIRCLE 90 ON FREE INFORMATION CARD

Mini LCD Color TV Set

Philips Consumer Electronics is now marketing a tiny pop-up 3-inch color-TV receiver under the Magnavox brand name. The Model CK1050CH TV receiver features a liquid-crystal display (LCD) that uses 92,160 picture elements (pixels) to produce a high-resolution picture display. A backlight that operates on six AA cells, included with the product, is provided for viewing enhancement.

Tuning of vhf and uhf channels is done electronically with keys that permit scanning in either direction. In addition, the TV tuner has channel memory and channel recall functions. On-screen color graphics show the state and action of the all-electronic color, tint and brightness adjustments.

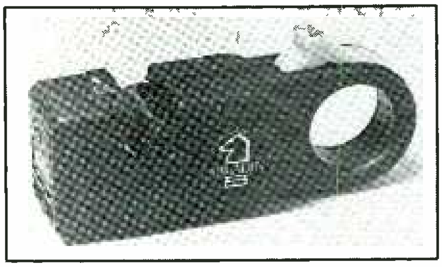
In addition to its video functions, the Model CK1050CH TV receiver also has built in an AM/FM-stereo radio, a stereo headphones jack, an audio/video input jack that permits operation as a video monitor for a camcorder, and an external-antenna jack for connection to a cable system or an outboard antenna. A loudspeaker is built in, and a telescoping whip antenna is supplied as standard equipment.

Supplied with the TV receiver are: an ac power adapter, an antenna adapter, an earphone, a soft carrying case, a shoulder strap and six AA cells. Available as options are a rechargeable battery pack, an external antenna adapter, stereo earphones/headphones, an audio/video cable, and a car-battery adapter. Weight is just 1 lb. 4 oz. $449.

CIRCLE 91 ON FREE INFORMATION CARD

Coaxial Cable Strippers

A new precision coaxial cable stripper has been announced by Paladin Corp. (Newbury Park, CA). The Models CST PA 1241 and 1240 strippers are small and lightweight enough (they measure 3.34"L × 1.65"H × 1.02"W and weigh just 2.3 oz.) to fit



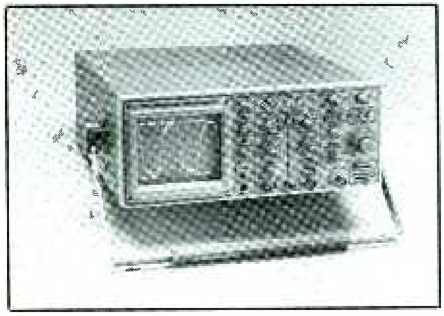
into a shirt pocket. They can be used to strip wires that measure from 0.100" to 0.315" in diameter. The tool offers reduced friction, thanks to roller support. Reproducible cutting force is controlled by an adjustable stop, and cam-wheel action helps in precisely locating the cable.

In use, after inserting the cable, the user simply advances an orange-colored cam wheel and rotates the tool around the cable. No pulling, tugging or extra work is involved. The tool utilizes optional interchangeable stripping cassettes for fast reset of stripping length when required for different applications, which eliminates time-consuming readjustment.

CIRCLE 92 ON FREE INFORMATION CARD

Oscilloscopes

A pair of new oscilloscopes that feature on-screen displays of cursor positions and scale settings are available from Beckman Industrial. The 20-MHz Model 9202 and 40-MHz Model 9204 both feature cursors that measure amplitude, time, frequency, duty cycle and phase shift. Called numeric readout display, the on-screen feature is said to increase the ease and accuracy of waveform analysis. The readout has two unique sets of cursor pairs, each with a reference and delta



cursor or as a duo in eight different directions.

Both models feature "A" and "B" sweeps with delayed sweep and segment amplifications; TV sync coupling for video servicing; a camera-mount CRT bezel, variable scale illumination and single-sweep operation for waveform photography; Z-axis input for blanking or intensified markers; and variable hold-off control to ensure proper triggering on complex signals.

Both scopes come with two switchable ×1/REF/×10 probes. $865 for Model 9202; $1,095 for Model 9204.

CIRCLE 93 ON FREE INFORMATION CARD

Outdoor Speaker System

Design Acoustics (Stow, OH) has introduced an improved version of its Model DA-360 omnidirectional outdoor speaker system. Retaining the

same model number as before, the new speaker system now has a foam surround that increases weather resistance and improves bass response. The inside of the enclosure is now coated with a special damping compound that is claimed to virtually eliminate unwanted resonances. The enclosure features a beige finish to blend better with a variety of environments and is easy to paint.

Designed to deliver high-quality sound out of doors, the speaker system features an omnidirectional 360° dispersion pattern. The combination of weather-resistant 6" woofer and 1½" tweeter and an enclosure that can tolerate snow, rain and high humidity make this speaker system ideal for use around a pool, in the garden and on a patio. Also, because of its weather resistance, the speaker system can be left out-of-doors the year around. For stereo listening, two such speaker systems, each connected to one channel of a stereo amplifier, must be used.

The Model DA-360 comes with a swivel mounting bracket, and a standard ½" threaded coupler provides for convenient post-mount installation. $120.

CIRCLE 94 ON FREE INFORMATION CARD

Laptop & Stand-Alone Computer Workstations

Heath/Zenith Computer Based Systems has a line of eight pre-configured laptop and stand-alone workstations designed for use in troubleshooting, engineering-design, manufacturing/process-control, production-testing and data-acquisition applications. These workstations are modular PC based, making it a simple procedure to upgrade, expand or modify them for future uses.

Four configurations of pre-configured laptop workstations are available for use in engineering design and data acquisition. These workstations can be used for spot checking on-line

NEW PRODUCTS . . .

production and performing diagnostic tests at remote sites. Each features a Heath/Zenith SuperSport 286 laptop computer with 3.5-inch floppy and 20-MB hard disk systems and its own battery pack.

The Laptop Engineering Workstation comes with a computer, logic analyzer and digital storage oscilloscope. Data acquisition workstations are available in three configurations. Choices include a computer and digital storage oscilloscope, and computer and either high-speed or combination data-acquisition modules.

Pre-configured stand-alone workstations are also available in four system designs: separate digital and analog ATE for production testing and two data-acquisition systems for manufacturing and process control. Each stand-alone workstation is built around a Heath/Zenith SW-3000 industrial computer that delivers high-speed processing in tough working environments. Each comes with an industrial EGA video monitor and 101-key keyboard.

One data-acquisition workstation features analog input and output, digital I/O, digital and analog termination panels, digital and analog signal cables, and a carrier board. Another features high-speed analog input. The analog ATE workstation comes with DMM, triple power supply, universal counter and 11-MHz function generator. The digital version offers a digital word analyzer and digital word generator for test and repair of digital circuitry.

CIRCLE 5 ON FREE INFORMATION CARD

Heavy-Duty Controllers

With a series of new modules from X-10 (USA) Inc., you can now control heavy-duty 220-volt room air conditioners by remote control or timed control or from any telephone anywhere on Earth. Two versions of the basic controller modules are available—the HD243 rated at 15 amperes and the HD245 rated at 20 amperes. Both are for 220-volt powered air conditioners but can also be used with plug-in water heaters to turn them off while the user is sleeping to conserve energy.

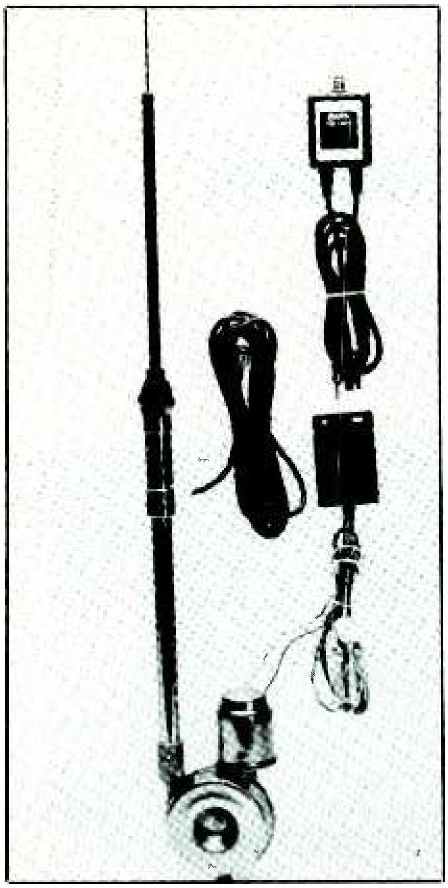
These modules are compatible with all X-10 controllers and timers so that the user can set his air conditioner to turn off while he is away and turn on an hour before he returns. For users who do not leave and return on a regular schedule, the Model TR2700 Telephone Responder/Controller is also available.

Both heavy-duty modules are designed to work on single split-phase 117/220- or 117/240-volt ac systems, which is the kind of wiring system used in most private homes. They do not work on three-phase systems sometimes encountered in apartments. Also, for safety, the modules do not respond to the "all lights on" code but do respond to the "all units off" code issued from the main controller. These modules plug directly into local ac outlets, between the ac line and appliances they control. They provide no local control.

CIRCLE 96 ON FREE INFORMATION CARD

Motorized Cellular Antenna

A fender-installed, fully automatic motorized cellular/AM-FM combination antenna has been announced by ORA Electronics (Chatsworth, CA) as the Model CMX1000. A specially designed motor is used to assure an electrically and mechanical-



ly reliable antenna. In addition, a unique stub matching device keeps the antenna tuned at all times and a tri-linear system is used to elevate the mast and extend the bandwidth of the antenna to full spectrum specifications. On the cellular side, the antenna has a rated SWR of 1.5:1 and 3 dB of gain, while on the radio side its specified insertion loss is rated at 0.3 dB and impedance is 75 ohms.

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Safe Dust Removal

E-Series Ultrajet from Chemtronics is an environmentally safe ozone-free aerosol-spray dust remover for cleaning electronic equipment, optics, photographic apparatus and precision instruments. Ultra-filtered to less than 0.2 microns, its abrasion-free jet action is said to be safe for even the most sensitive surfaces. Dust removal is accomplished with powerful jet blasts, using a higher-gauge pressure (120 psi) than conventional dusters. It will not contaminate or scratch delicate surfaces, it leaves no residue, and it meets Feder-

al Specification BB-F-1421. The product is packaged in a seamless 12-ounce can that features an extra-wide pushbutton valve for improved flow control and an extension tube for pinpoint application.

E-Series Ultrajet is also available as a complete reusable system for high-volume users. The system includes a surgical-grade chrome trigger valve for precise flow control, rigid 4-inch stainless-steel nozzle, final filtration disc, flexible 36-inch extension hose, and an E-Series Ultrajet 12-ounce refill can.

CIRCLE 8 ON FREE INFORMATION CARD

VHS Camcorders

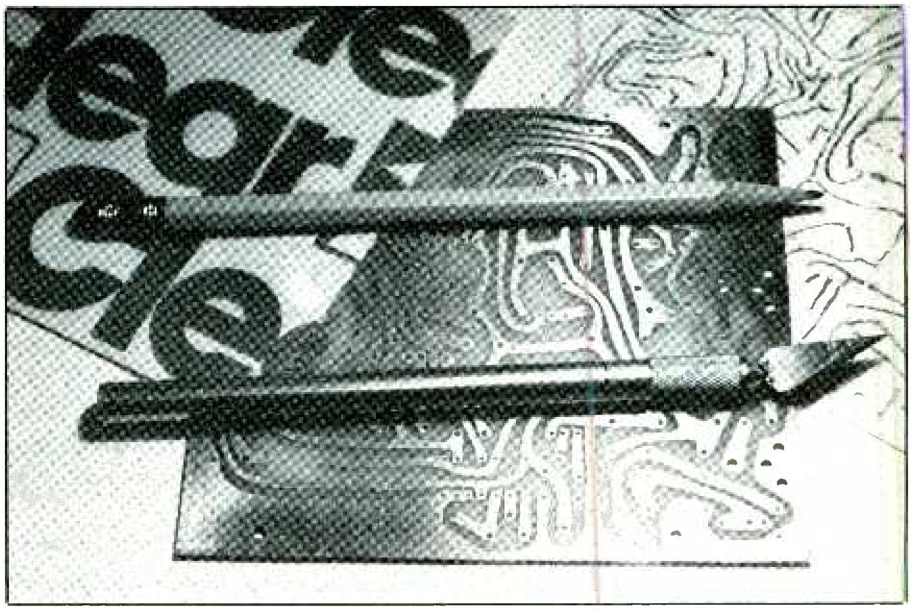
RCA's new Models CC310 and CC320 VHS camcorders have a Pro-Edit system that provides more flexibility and allows users to achieve more professional editing results. It offers five special features: a flying erase head that eliminates video interference and noise between recorded segments; audio/video dub to insert new video segments or records new sound tracks onto the tape; microphone mixing to add narration or new sound to an audio track already recorded; Edit Search to precisely position the tape at the start of a new recording; and Synchro-Edit that, with an optional editing cable, per-

(Continued on page 82)

Practical Printed-Circuit Boards

A simple direct-mask method of producing single-quantity printed-circuit boards

By Wayne Richardson



Home fabrication of printed-circuit boards can be a frustrating proposition. Those of us who have made our own pc boards are already familiar with the little things that make it so. Leading causes are the resist ink pen that works on everything but the copper on a pc blank, dry-transfer patterns that float off the blank in the etching bath, and messy photoresists that are costly and complicated to work with. Presented here is a reliable procedure for making pc boards inexpensively, though it does take a lot of patience.

Being limited to single-quantity boards does not negate the utility of the procedure we are about describe. After all, it is only the rare project for which you want two identical pc boards. On the plus side, the material needed for the resist pattern is commonly available at any housewares supply or hardware store at relatively low cost.

By The Numbers

There are five basic steps involved in the procedure described here. No special training or experience is needed to fabricate working printed-circuit boards using this procedure. You can use it to fabricate very simple single-sided boards, more complex boards and even some fairly complex double-sided boards if you work carefully and follow the steps detailed exactly.

It is assumed that before you begin laying out your pc board you know exactly what the copper-trace pattern is to look like in 100-percent scale. If you are starting with a pc etching-and-drilling guide in a magazine or book, full-size artwork is already available. However, if you are fabricating a pc board for a circuit of your own design, you must prepare on paper a full-size pc guide from which to work.

Whichever type of guide you are going to work from, it is a good idea to work directly from an exact-size photocopy of it. This way, you will not ruin the original, to which you can always return if you make an error during the procedure.

• *Step 1.* Begin fabricating your pc board by cutting to the size needed a piece of copper-clad pc blank. Smooth the cut edges of the blank and then scrub the copper cladding with scouring powder and water until the copper is bright and shiny. Thoroughly rinse off the scouring powder and air dry the cleaned blank. From now on, handle the blank only by its edges.

Now trim the photocopy of your actual-size artwork to the final size of the board and rubber cement this to the copper-clad side of the now dry pc blank. Use only enough rubber cement to prevent the artwork from moving as you handle the board.

Once the cement has dried, drill an appropriately sized hole for each

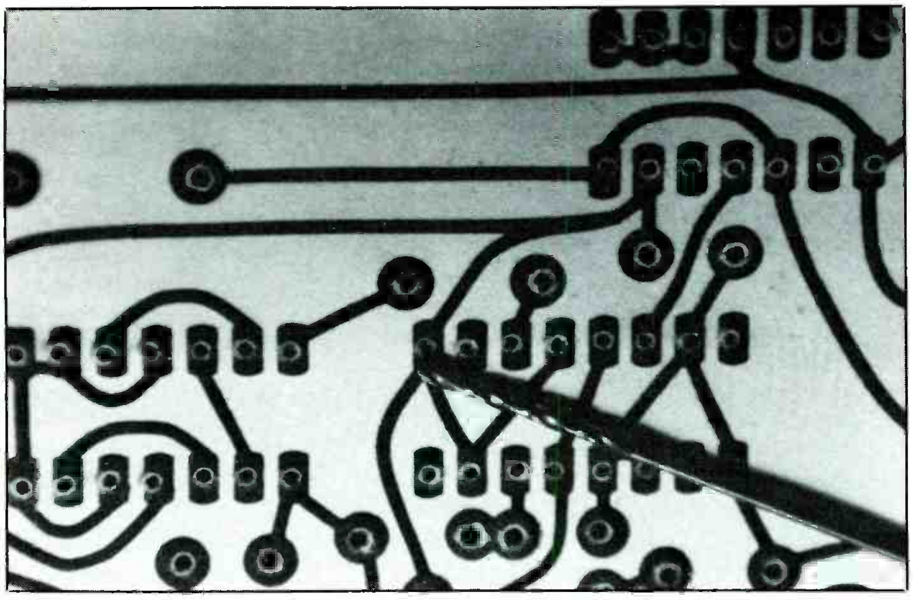


Fig. 1. After rubber cementing photocopy of original actual-size artwork to copper-clad side of pc blank, drill all component lead and pin holes and mounting holes for board.

component lead or pin and mounting hole in the pc guide. Use of a drill press stand or a hobby type drill will make this part of the procedure easier to perform. Work carefully, especially when drilling holes through the centers of IC pads. Use a sharp bit and allow the drill to do the work. The procedure up to this point is photographically illustrated in Fig. 1.

When you are finished drilling all component lead and pin holes and the mounting holes for the board, backlight the pc blank and check for any holes you might have missed. If you did miss one or more holes, drill them now.

Slowly and carefully to avoid tearing it, strip the artwork from the pc blank. If you are successful in peeling away the artwork in one piece, you can keep it for use at another time or later reference. Now examine the copper cladding to see if any rubber cement has been left behind. Remove any you find by rubbing it away with a fingertip.

If you are fabricating a double-sided pc board, turn over the drilled pc blank and use very fine sandpaper to smooth the rough copper edges only around each drilled hole (see Fig. 2). Next, test position the actual-size artwork for the other side of the board against your work thus far. It is helpful at this point to backlight the board to aid in positioning the artwork. Your second-side artwork should exactly mesh with the hole pattern already drilled in the blank. Set the artwork aside.

• *Step 2.* Now cut a piece of clear Contact™ or other self-adhering plastic sheet of the kind used to cover shelves to dimensions large enough to completely cover the copper cladding on the board. (You need two such sheets of clear plastic if you are fabricating a double-sided board.) Remove the paper backing from the plastic sheet.

Working carefully, roll the plastic sheeting, adhesive side down, onto the copper cladding. Firmly burnish the plastic sheeting onto the copper cladding to avoid wrinkles and eliminate trapped air bubbles. Work from the center outward in all directions. When you are finished, trim the plastic to the exact dimensions of the pc blank, using a safety or hobby knife. If the board is to be double sided, repeat the procedure for the second side.

Lightly sand with very fine emery cloth the entire exposed surface(s) of the plastic to give it a "tooth" on which to draw. Do not push down

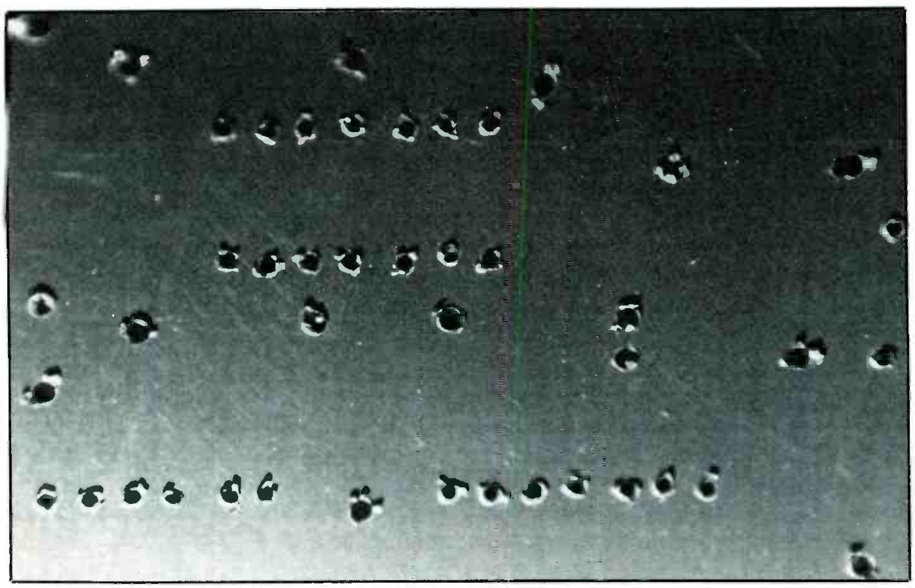


Fig. 2. Sharp copper edges will appear on the exit side of holes drilled through double-sided pc blank. These must be smoothed with very fine emery cloth.

hard or cut through the plastic with the sandpaper!

• *Step 3.* It is now time to draw the conductor pattern onto the plastic exactly as it appears in the original artwork. Place your artwork beside the pc blank in the same orientation as the holes you drilled in the latter.

Now use a soft lead pencil with a rounded—not sharp—point to draw each pad outline and conductor run on the dulled plastic sheeting exactly as it is shown in the original artwork. Work carefully, and draw each complete conductor run from beginning to end before proceeding to the next. This way, you are less likely to miss a conductor run. If you make any errors during this phase of the procedure, simply erase your mistake and correct it immediately.

If desired, you can adjust the width of the board perimeter (usually a surrounding ground trace) to make it possible to remove a minimum amount of copper during the etching operation—provided this does not interfere with circuit performance. By reducing the amount of copper to be removed to a minimum, you can extend the life of your etchant.

• *Step 4.* When you are finished drawing the copper-trace pattern (see Fig. 3), compare it point for point against the original artwork—for both sides of the blank if you are making a double-sided board. If you discover any errors at this point, correct them immediately. Then, when you are satisfied that everything is okay, use a very sharply pointed hobby knife to score the plastic around every drawn trace down to the copper surface(s). Think of each trace as an elongated circle. Before you do this, however, it is a good idea to practice on a scrap plastic-clad board. Spacing between cuts, working around IC pad locations and the amount of cutting pressure are the only difficult—but easily mastered—parts of this simple pc-board-making procedure.

If needed, you can make the traces quite wide, leaving only $\frac{1}{16}$ inch of space between them to cut down on etchant usage. This is safe to do because of the natural undercutting action of the etchant. Work only a few minutes and then rest for a few minutes. As you gain experience with this technique for fabricating pc boards, your pace will pick up considerably.

After cutting all trace shapes, you are ready to remove the unwanted portions of the plastic sheeting in the areas to be etched. To do this properly, slide the tip of your hobby knife

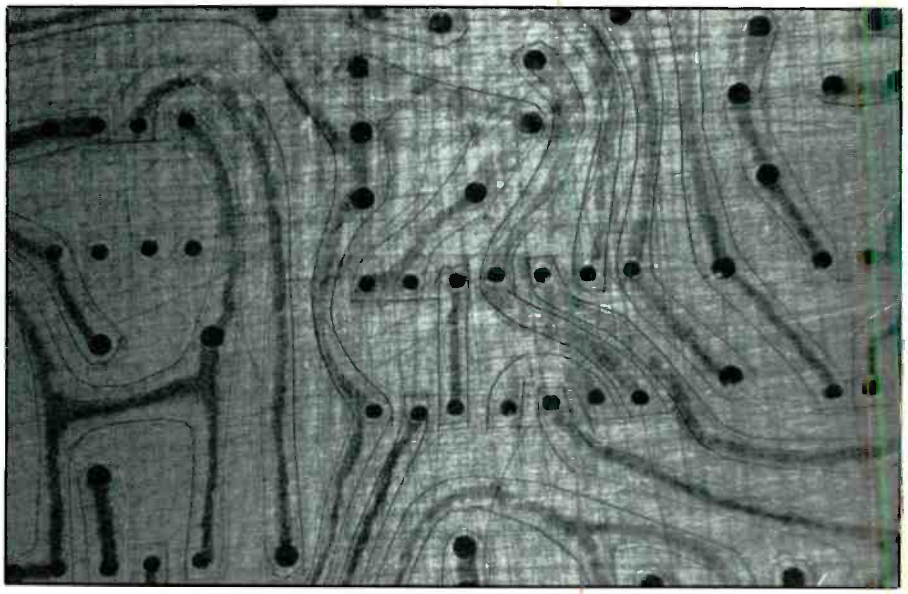


Fig. 3. Carefully following original artwork, conductor pattern is drawn on self-adhering plastic sheet with a soft lead pencil.

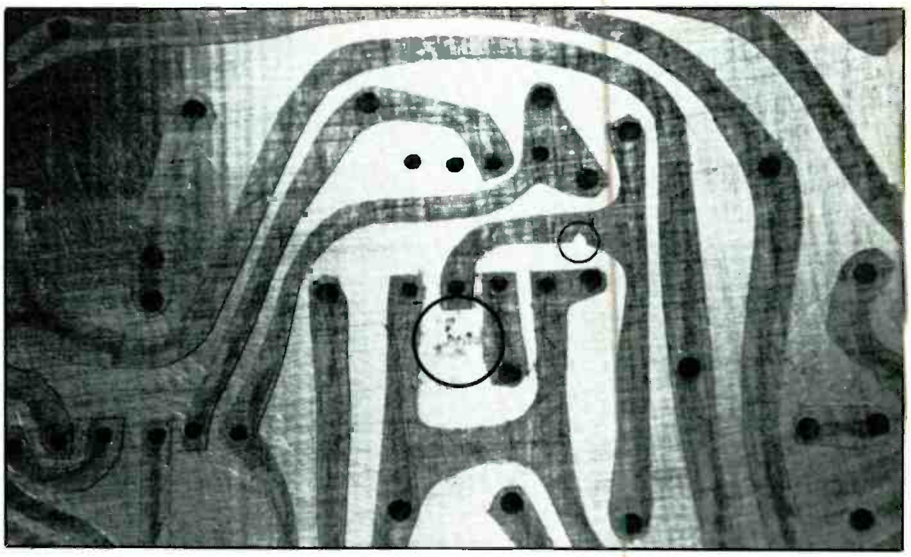


Fig. 4. After scoring around drawn trace pattern with sharp hobby knife and removing unwanted plastic sheeting, examination of result may show such potential problem areas like left-behind adhesive (inside large circle) and notches removed from traces (small circle).

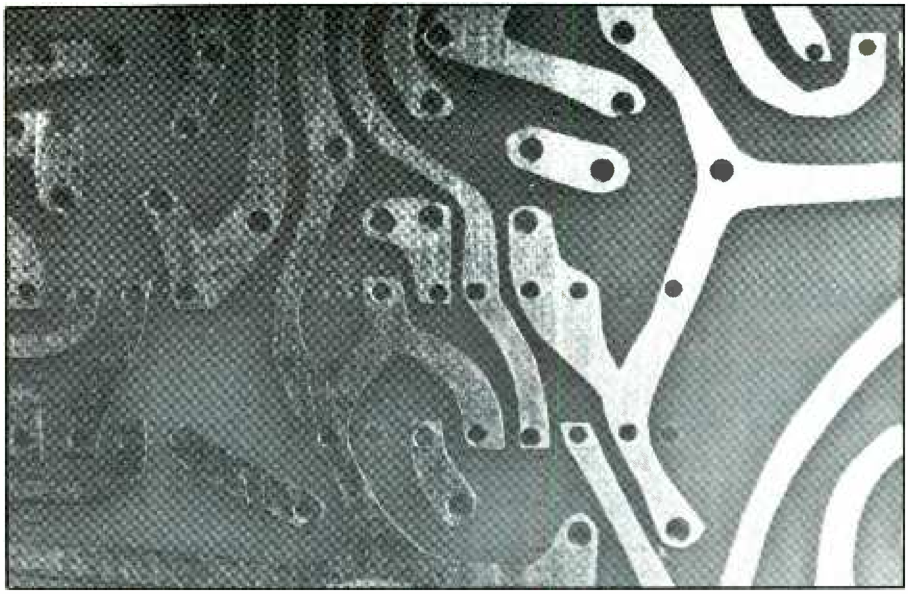


Fig. 5. After etching the pc blank and removing plastic-sheet "resist" and cleaning the blank, copper traces are sharply delineated from board substrate.

under a path to be removed and very carefully peel it away. If you encounter a point where your previous cutting failed to cut all the way through the plastic, stop and use your hobby knife to cut all the way through. Then continue peeling away the unwanted plastic sheeting until all of it has been removed. If you are working on a double-sided board, remove the unwanted plastic sheeting from the other side as well.

After discarding the unwanted pieces of plastic, place a sheet of paper over the blank and firmly burnish through it the remaining pieces of plastic sheeting into place on the copper cladding. This second burnishing operation will reseat any plastic pieces that might have lifted from the copper surface during the removal operation.

In bright lighting, carefully examine your board to locate any errors and remains of unwanted plastic sheeting and left-behind adhesive. At the center of Fig. 4 are shown two things to keep an eye out for. One is in the large circled area, which shows some adhesive that was left behind when the plastic sheeting was removed. The other, in the small circle, shows a notch of the plastic that was erroneously removed from a conductor run.

Remove unwanted adhesive with a cotton swab dampened with ether-based engine starting fluid (work in a well-ventilated area). Alternatively, stop by an art-supply store and pick up a rubber-cement pickup block and use this to "erase" the adhesive. Repair a missing piece of plastic by removing the damaged plastic and replacing it with a strip of Scotch Magic Transparent Tape™. Do *not* substitute another brand or type of tape or you will run the risk of the tape floating off the copper in the etchant. An alternative approach to repairing a damaged piece of plastic "resist" is to paint onto the accidentally exposed area of copper clear fingernail enamel.

• *Step 5.* Burnish down your plastic-sheet resist pattern one last time through a sheet of paper. Then place the prepared blank in the etching solution of your choice. Leave the blank in the solution for a few minutes to allow the etchant to begin removing copper in the exposed areas of the blank and then remove it from the solution. Check for air bubbles trapped against the copper cladding (break them with the point of a pin) or spots where you missed seeing left-behind adhesive before (remove them as described above) while the blank is wet.

Return the blank to the etching bath, but periodically remove it to check for problems. Rectify these as you encounter them. Problem areas will be clearly visible. You can rectify these problems before permanent damage is done to the pc blank.

Once the etchant has done its work, rinse the board under cool running water to remove all etchant and stop the chemical action. Peel away and discard all plastic resist from the remaining copper traces. You will be left with sharply defined copper traces on the board substrate, as shown in Fig. 5.

Once again clean both sides of the board with scouring powder and water until the copper traces are bright and shiny. Then thoroughly rinse the board to remove all vestiges of scouring powder, especially in the drilled holes, and then air dry it or force-dry it in a warm oven.

When the pc board is completely dry, handle it only by its edges. If you wish, you can immerse the new pc board in a solution to plate all conductors with a thin layer of tin to protect them from oxidizing and make them much more solderable.

Your printed-circuit board is now ready to be populated by the components for which it was designed. It is best to wire the board as soon as possible after fabrication to prevent oxidation of the copper traces from becoming a problem during the soldering operation. Of course, if you plated the traces with tin, you can

(Continued on page 82)

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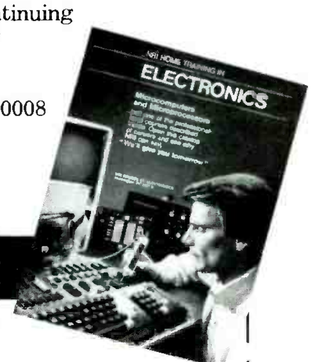

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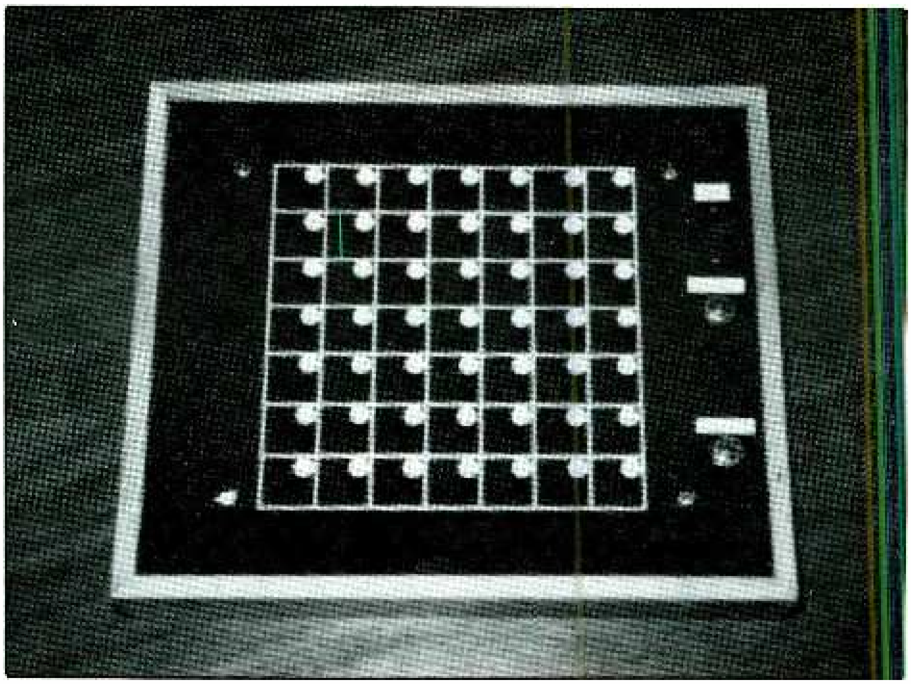
6/49 Lottery Number Selector

Allows you to choose six random numbers from a possible 49 for playing Pick Six state lotteries

By Walter W. Schopp



Many states have adopted the Pick Six (from 49 numbers) for their official lotteries. With payoffs frequently topping tens of millions of dollars, "lottery fever" is sweeping the country. Picking six numbers (hence the name of the lotteries) is easy. Players often select their numbers based upon birthdays, Social Security numbers, ZIP codes, etc. A more sophisticated way of selecting numbers is to use our all-electronic "6/49 Lottery Number Selector," though we do not guarantee that this project will provide you with "better" numbers than you can arrive at using other selection methods.

Our 6/49 Lottery Number Selector choices of six numbers are displayed by light-emitting diodes that are laid out in a 7 × 7 matrix layout. Using this arrangement, rather than a series of numeric displays, keeps down the cost of the project. The project is very easy to use, requiring only that you power it up and press a pushbutton switch to get it started selecting numbers. If you do not like the numbers selected on any try, you simply press and release a RESET button and once again press the first button. That is all there is to it.

Predicting Random Numbers

Very few rules govern the prediction of random numbers. One is that, on the first draw, the number chosen will have a close to 50-50 chance of being either odd or even. Since there are 24 even and 25 odd numbers in the 1 through 49 range used for Pick Six lotteries, however, odd and even selection of numbers will not be exactly 50-50. Too, on the first draw, the number has an even chance of being above or below 25 and a 1 in 49 chance of being 25.

Beyond the foregoing, the odds start changing as more odds or evens and highs and lows are removed with each selection from the original 49 numbers. One law of probability states that out of six numbers chosen, it is possible that three will be odd and three will be even. This same law implies that three numbers will be high (in this case, greater than 25) and three will be low (less than 25).

As is the case with most laws, the "laws" of probability have certain stipulations that limit their application. For the foregoing statement to be true, an extremely large number of samples—thousands to millions—must be taken, tallied and averaged. In the real world, you are interested in just six unique numbers out of the possible 49. Hence, you would "roll" the project only six times. As you do so, you might discover that your selections, based on such a limited number of samples, are weighted more heavily on the odd or even side or/and on the high or low side. Consequently, for all practical purposes, selection of any six consecutive num-

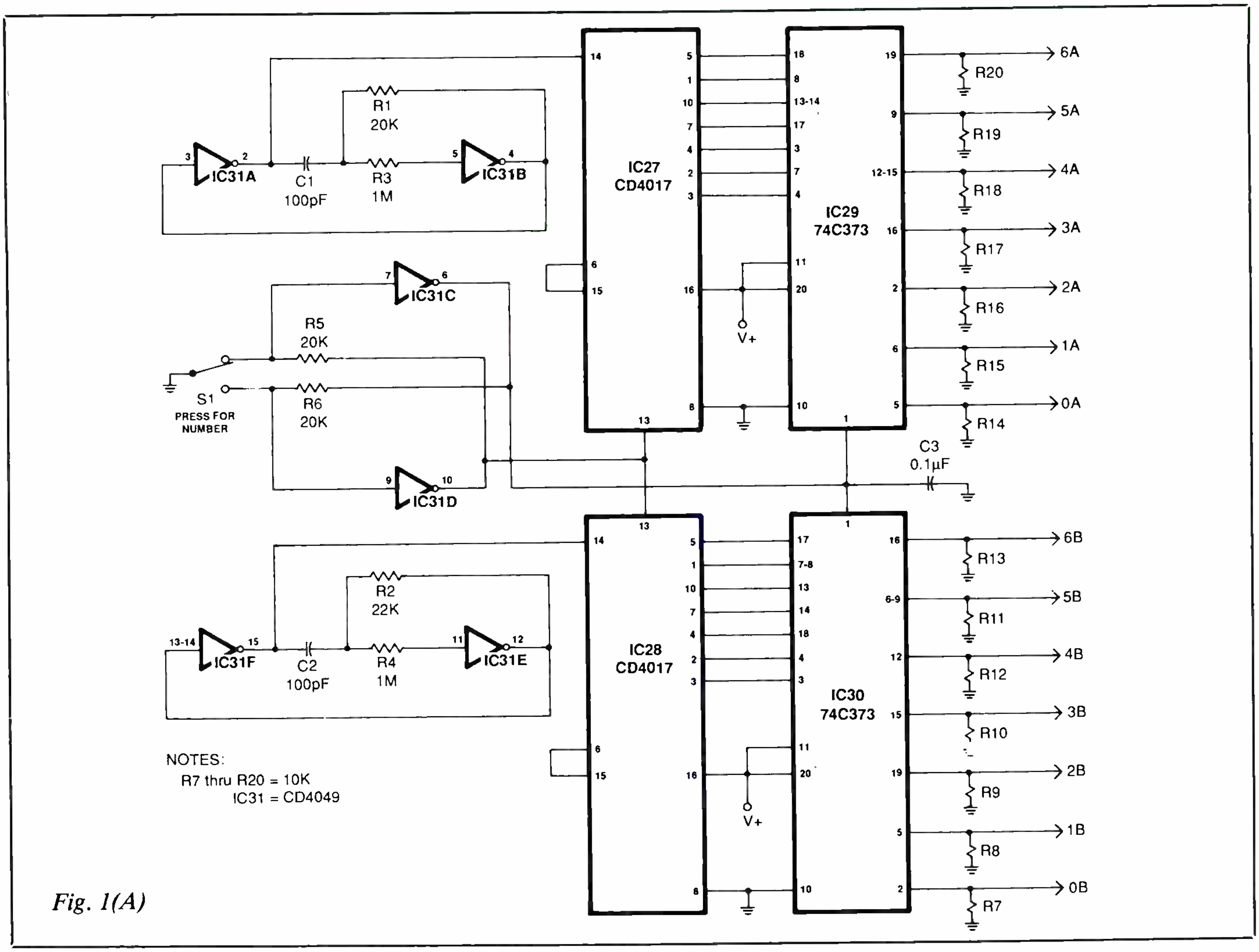


Fig. 1(A)

Fig. 1. Complete schematic diagram is shown here in three parts: (A) dual oscillator/counter/driver; (B) gate/flip-flop/LED system; and (C) power distribution and capacitor bypassing.

bers can have just as good a chance of winning as do six very carefully chosen numbers. Obviously, then, picking numbers for a lottery, no matter how sophisticated or crude the method used, still requires an abundance of luck to win.

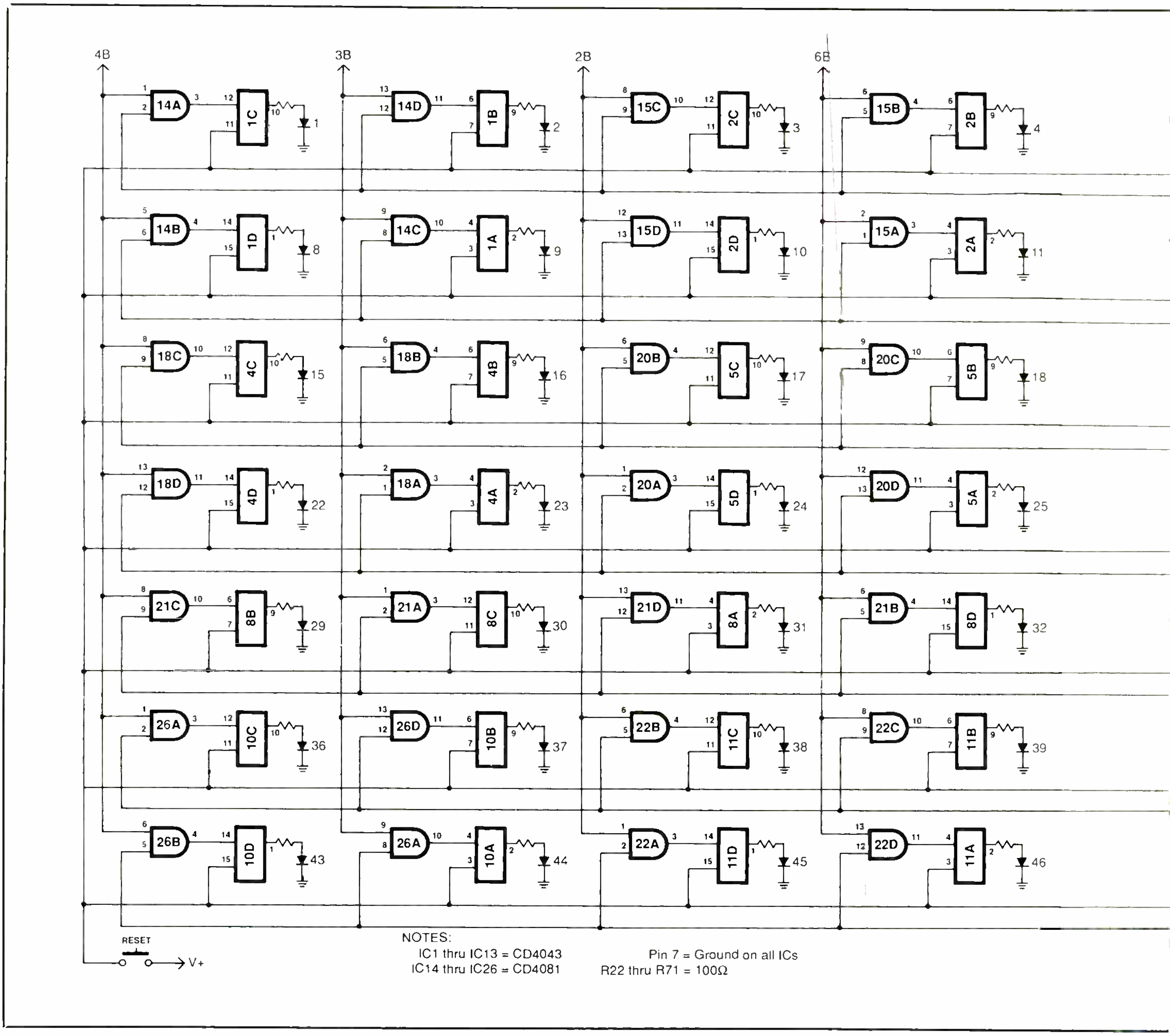
Picking numbers randomly by electronic means is difficult to accomplish because random-number generators are so precise that they always follow a repeatable pattern. If the span of the pattern is long enough, though, a few numbers selected from the pattern will appear to be truly random—even if they really are not.

To make the selection of numbers truly random, the human factor must be added. In our Number Selector, a matrix is used. Each side of the matrix is fed a different counting frequency. This arrangement produces a very long repeatability pattern. If each number were automatically chosen by electronic circuitry at a precise time interval during the span, the same number would be chosen each time. Hence, by making you do some of the work (pressing a button), the human element brings into the equation the random factor.

You select your six numbers by pressing a PRESS FOR NUMBER button on the project an equal number of times. Since there is no way you can accurately time the presses of the button down to a few microseconds, the numbers you pick with this project will be almost totally random.

As you can see, with this project you can pick six truly random numbers with which to play the lottery. The way the system works is like having a bin of 49 numbers pass you by at a rate of thousands of numbers per second so that you cannot see individual numbers as you "draw" one of them at a time until you have the six needed for the lottery card.

Built into the project is a memory system that stores each number as it is drawn. You keep drawing until six numbers are displayed. These numbers will continue to be displayed un-



til you press a RESET switch. At this point, you can once again press the PRESS FOR NUMBER switch to draw six more numbers for the next game on your card.

Though selecting numbers for the Pick Six lottery is one fun way to use the Number Selector, you can also use the project to study the laws of probability. You do this by selecting many sets of random numbers and see how they apply to the game.

About the Circuit

Because of its very large size, the schematic diagram of the Lottery Number Selector is shown in Fig. 1 in four parts. Part (A) contains the circuitry for the dual-oscillator/counter/driver circuit; Part (B) contains the circuitry for the gate/flip-flop/LED circuits; and Part (C) shows power distribution and capacitor bypassing for all ICs.

Our discussion begins with the two pulse generators that are the heart of the project. Each pulse generator is made up of two inverter/buffer stages and RC components, and both operate at a frequency of about 100 kHz.

Clocking pulses for counter *IC27* are delivered from the first pulse generator. This generator is made up of inverters *IC31A* and *IC31B*, resistors *R1* and *R3*, and capacitor *C1*. Similarly, counter *IC28* is clocked by the

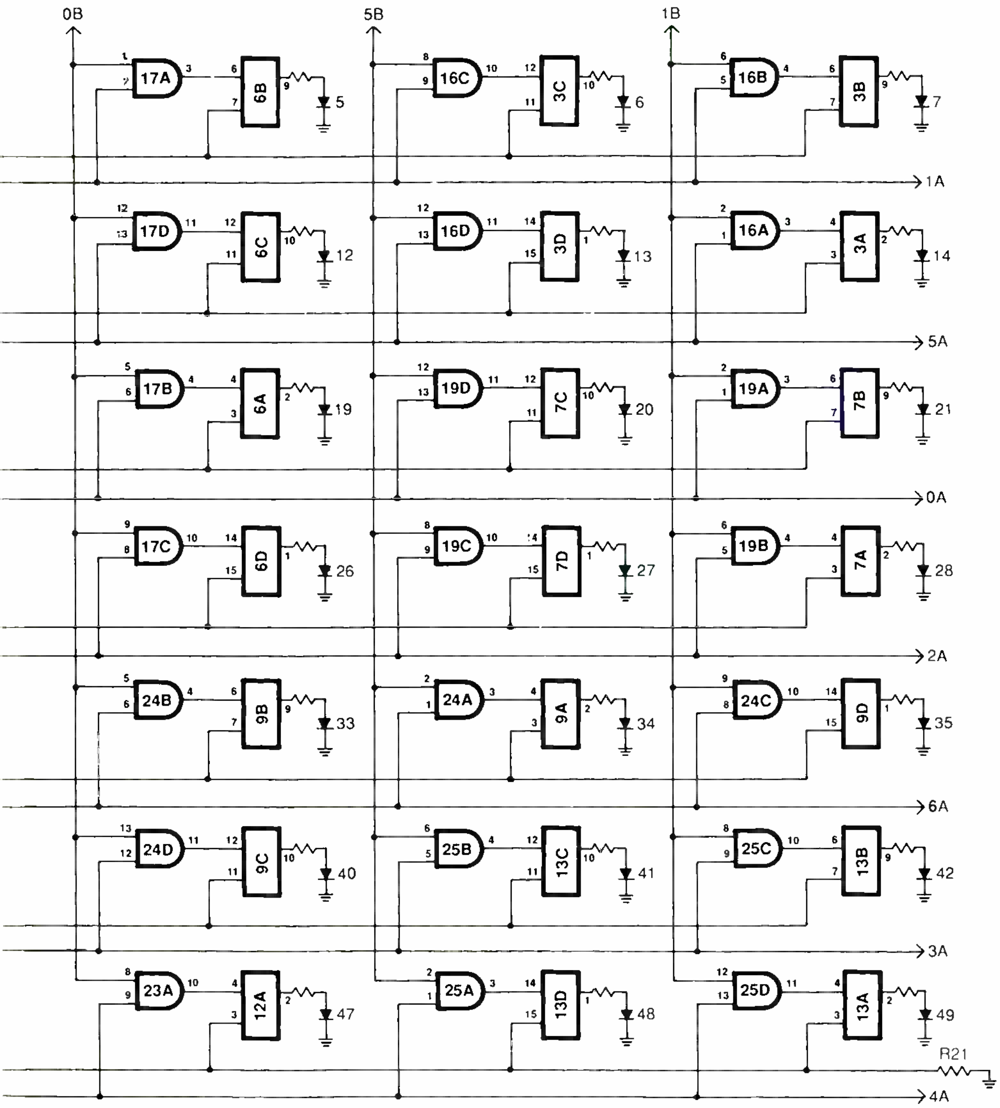


Fig. 1(B)

PARTS LIST

Semiconductors

IC1 thru IC13—CD4043 quad set/reset flip-flop
IC14 thru IC26—CD4081 quad 2-input AND gate
IC27,IC28—CD4017 decade counter
IC29,IC30—74C373 tri-state octal buffer
IC31—CD4049 hex inverter/buffer
LED1 thru LED49—Jumbo red light-emitting diode

Capacitors

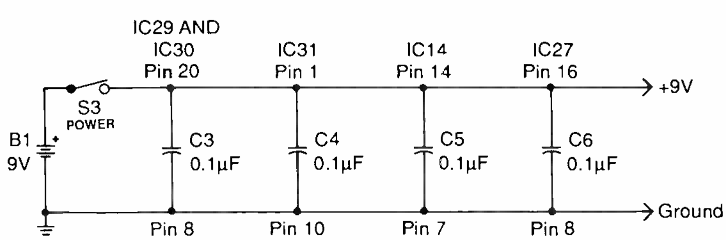
C1,C2—100-pF ceramic disc
C3 thru C6—0.1-μF ceramic disc

Resistors (⅛- or ¼-watt, 10% tolerance)

R1,R5,R6—20,000 ohms
R2—22,000 ohms
R3,R4—1 megohm
R7 thru R21—10,000 ohms
R22 thru R79—100 ohms

Miscellaneous

B1—9-volt battery (six AA cells in series)
S1,S2—Momentary-action pushbutton switch (Radio Shack Cat. No. 275-407)
S3—Miniature spst toggle switch (see text)
Printed-circuit board or perforated board with holes on 0.1" centers and suitable soldering or Wire Wrap hardware (see text); suitable enclosure (see text); sockets for all ICs; six AA-cell holders for B1; red-tinted clear-plastic sheet for top panel of enclosure; labeling materials (see text); narrow graphing tape (see text); ½-inch spacers; machine hardware; hookup wire; solder; etc.



	+9V pin	Ground pin
IC1–IC26	14	7
IC27, IC28	16	8
IC29, IC30	20	10
IC31	1	8

Fig. 1(C)

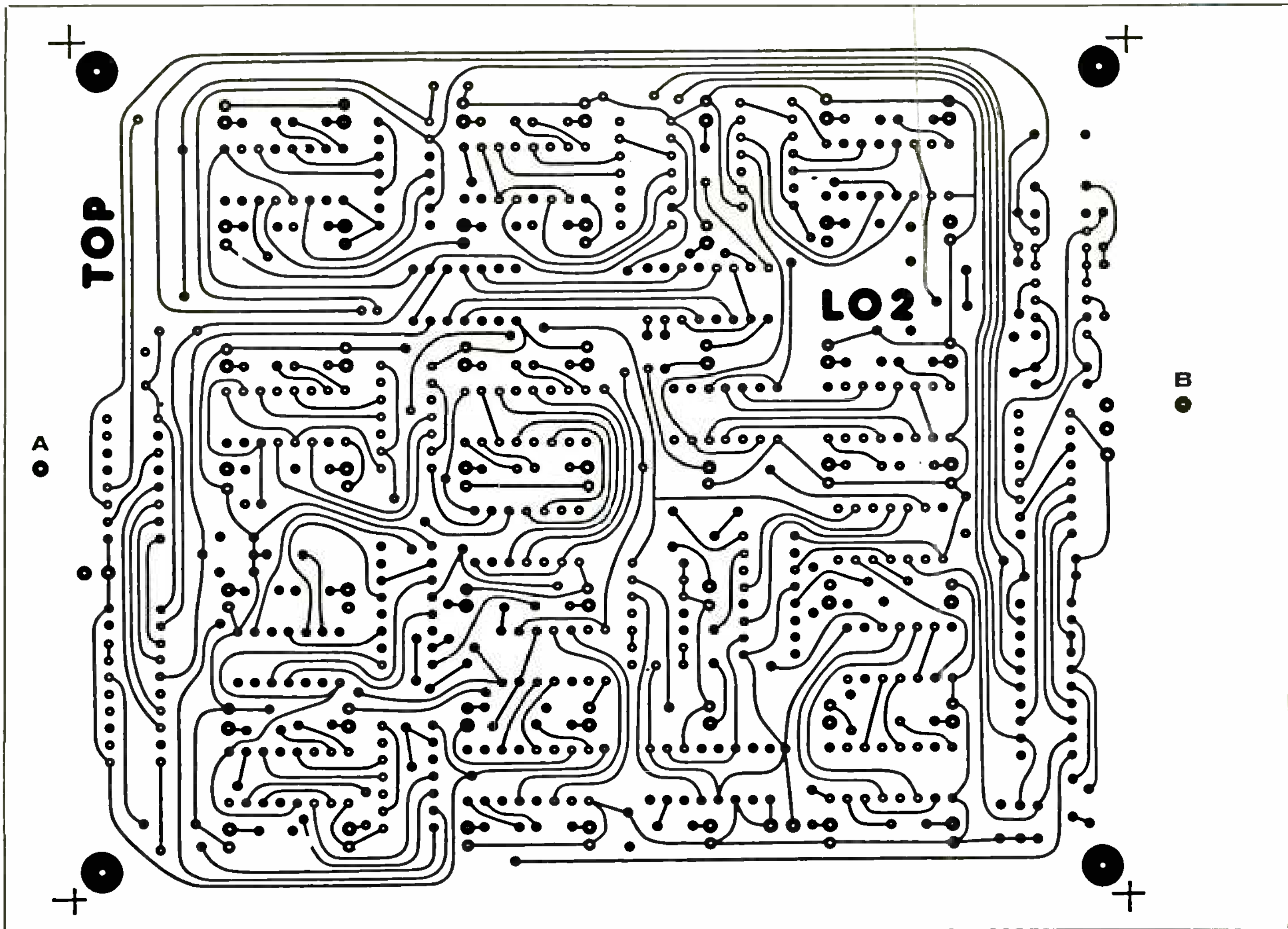


Fig. 2. Actual-size etching-and-drilling guides for top (left) and bottom (right) of printed-circuit board

pulse generator made up of inverters *IC3E* and *IC3F*, resistors *R2* and *R4*, and capacitor *C2*.

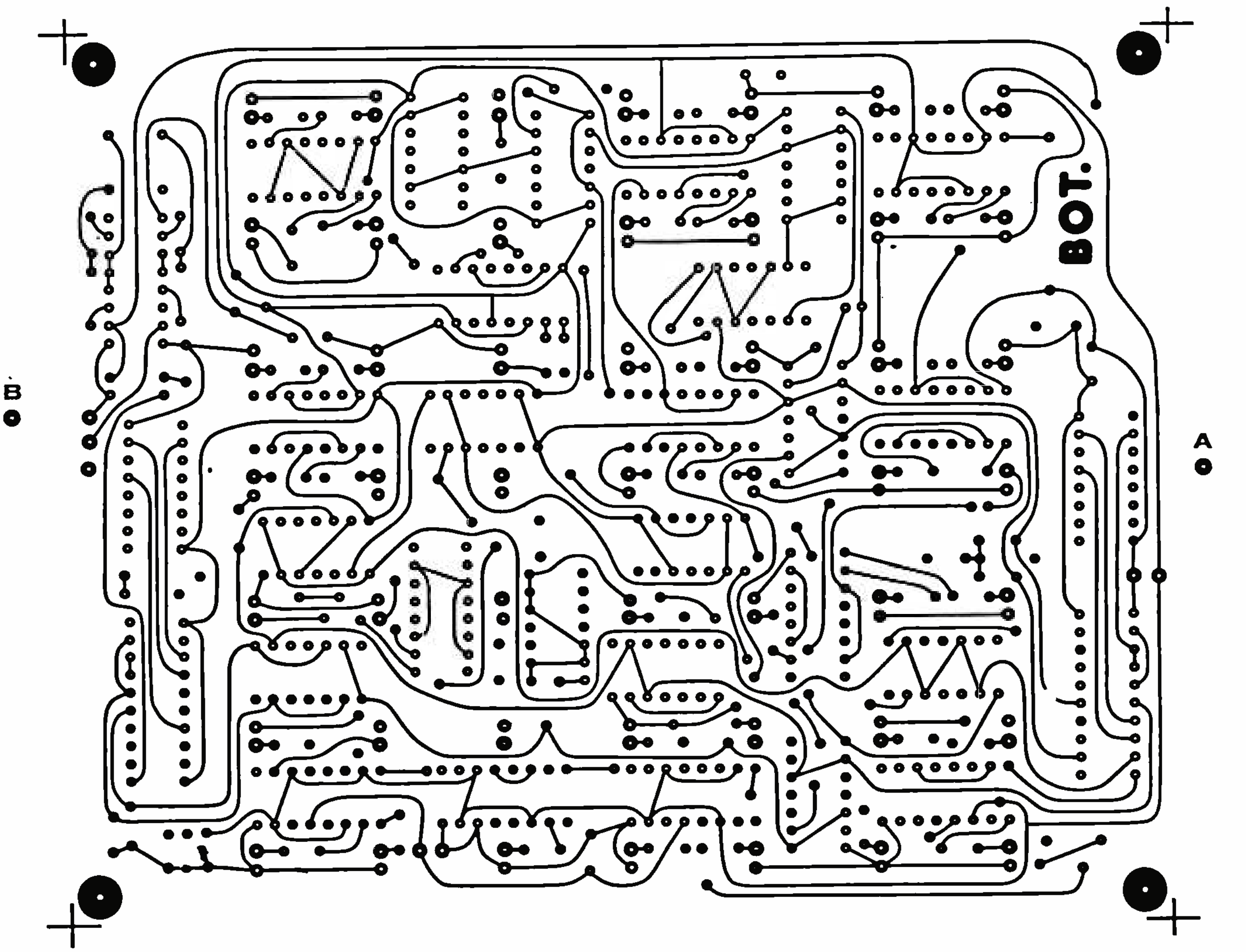
Decade counters *IC27* and *IC28* count the pulses applied to their pin 14 inputs. At the seventh count, they reset. The outputs of the counters are applied to the inputs of tri-state buffers *IC31* and *IC32*. These two buffers supply count pulses to the two sides of the seven-by-seven matrix network.

Note here that two buffers, *IC31B* and *IC31C*, are used to condition the inputs from PRESS FOR NUMBER switch *S1* to prevent the circuitry from responding to each pulse generated due to mechanical contact vibration. Thus, the two inverter/buffers make *S1* "bounceless."

Switch *S1* is shown in its normal "run" position. Pushing it down, breaks the circuit to the upper contact and makes the circuit to the lower contact. When this occurs, a positive voltage is applied to enable pin 13 of *IC27* and *IC28*, which stops the count operation. At the same time, a negative voltage is applied to pin 1 of *IC29* and *IC30* to enable the outputs of the tri-state buffers. When this occurs, one vertical and one horizontal lines of the matrix are made positive. When *S1* is released and its contacts return to their normal closed and open conditions, the counter starts running again and the buffers float.

When the two intersecting lines of the matrix are positive, the appropriate AND gate (*IC14* through *IC25*) is turned on and sets one of the set-reset flip-flops (*IC1* through *IC13*) and applies a voltage to the LED connected to the output of that particular flip-flop. Because of the latching action of the flip-flop, the LED remains on until RESET switch *S2* is pushed and released. When *S2* is operated, all flip-flops, except the last one that was set, are reset.

One of the quirks of this type of circuit is that the counter must rest on one output, leaving one output on when it is stopped. This always leaves the LED for the last number selected



lit after RESET switch *S2* is pressed and released. The way around this when you are selecting numbers with the project is to press and release the RESET switch after selecting the first number of the series. This way, the first number will be retained, while the last number of the previous set will be "erased." After doing this, proceed with selecting your next five numbers by pressing and releasing PRESS FOR NUMBER switch *S1* five more times.

As you can see by examining Fig. 1 and the Parts Lists, the entire Lottery Number Selector circuit is built around low-power CMOS devices. The only devices that draw appreciable current are the light-emitting diodes, of which a maximum of only seven can be on at any given time. Thus, the power demands of the circuit are minimal. Consequently, you can easily use a 9-volt battery made up of six AA cells connected in series to power the project, making it a truly portable device that you can take right to the lottery-ticket vendor for on-site number selections.

Construction

Except for the battery and two switches, all components that make up the Lottery Number Selector circuit mount on a single circuit board. You can fabricate a double-sided board using the actual-size etching-and-drilling guides shown in Fig. 2. If you prefer not to make a pc board, you can use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware.

Whichever wiring scheme you decide to use, sockets are recommended for all ICs. Note, though, that if you fabricate a double-sided board you will not be able to use ordinary DIP sockets, which do not give top- and bottom-of-the board soldering access to all pin pads. However, you can easily solve this dilemma by substituting strips of Molex Soldercon socket connectors.

Assuming you are using printed-

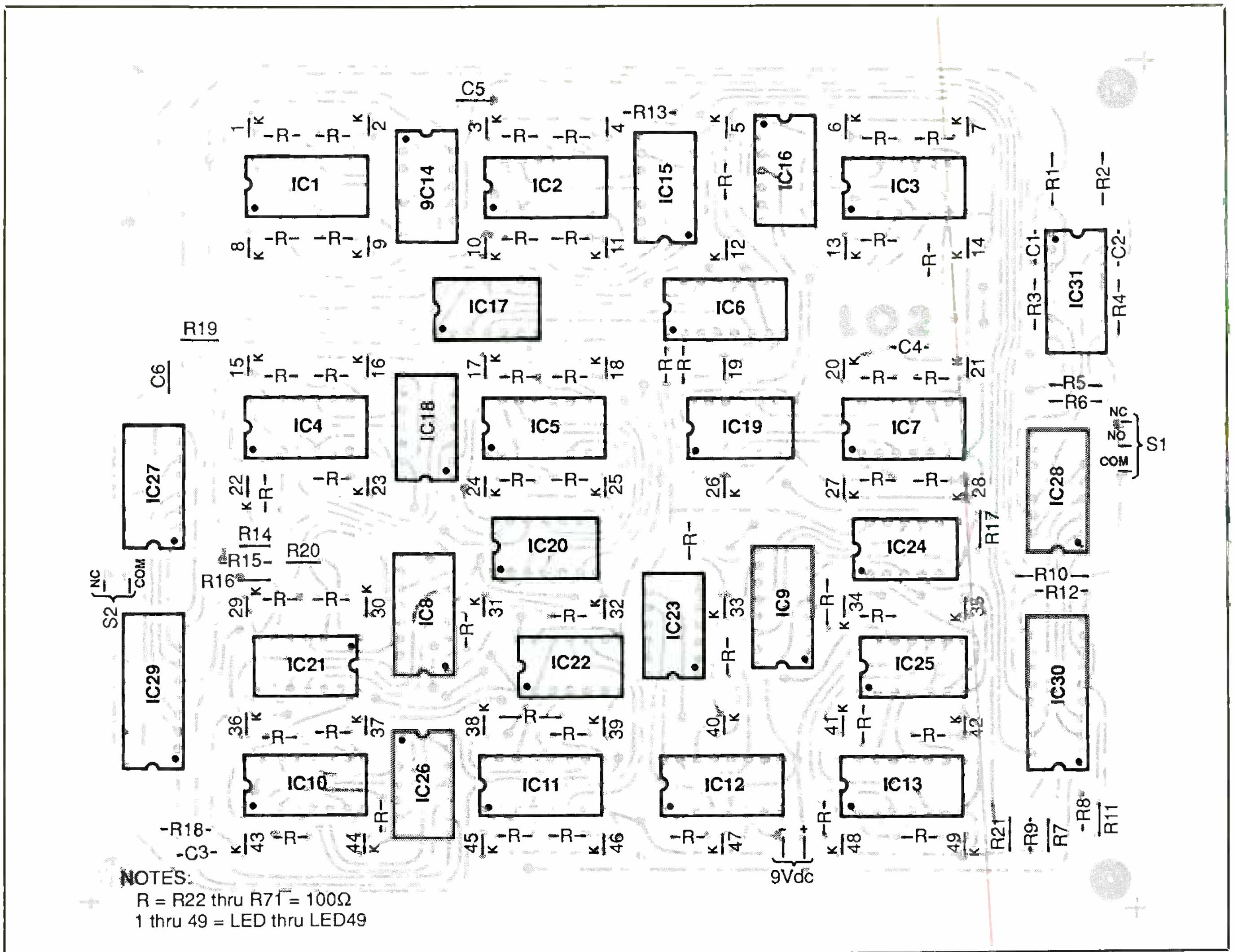


Fig. 3. Wiring guide for pc board. Use this as a rough guide to laying out components if you opt for perforated-board construction instead of a pc board.

circuit construction, orient the board in front of you as shown in the wiring diagram in Fig. 3. (Use this illustration as a rough guide to component placement if you assemble the project on perforated board.) Note that Fig. 3 shows component installations against the conductor pattern on the *top* side of the board.

Begin populating the board by installing and soldering into place the strips of Soldercons. Do *not* install the ICs in the Soldercon "sockets" until after you have performed preliminary voltage tests. Follow with installation of the capacitors and then the resistors. The pc board conductor pattern was laid out to accommodate ⅛-watt resistors, though you can use ¼-watt ones instead if you mount them upright. You will note that there are a number of locations for the resistors identified with an "R." These are the *R22* through *R79* 100-ohm current-limiting resistors for the LEDs.

The light-emitting diodes are simply numbered 1 through 49, with no "LED" identifier preceding them. Mount the LEDs in the locations indicated, making certain that each is properly oriented before soldering its leads to the pads on both sides of the board. As you can see, the cathode lead in each case goes into the hole that is farther away from its associated IC than is the anode hole. Space each LED so that the bottom of its case is about ¼ inch above the surface of the board.

Strip ¼ inch of insulation from both ends of eight 6-inch-long hookup wires. If you are using stranded hookup wire, tightly twist together the fine conductors at both ends of each wire and sparingly tin with solder. Plug one end of these wires into the holes labeled 9VDC, *S1*, *S2* and *S3* and solder into place. Plug the wires into the holes labeled 9VDC from the *bottom* of the board.

At this point, all holes that should have component leads or pins plugged into them should be occupied. Any unoccupied holes—except the four large mounting holes in the corners of the board—must be filled with short wire jumpers. Use cut-off resistor leads or bare solid hookup wire for these jumpers, soldering them to the pads on both sides of the board in each case.

When you finish installing all jumper wires, carefully check all components for proper values and orientations. Also check your soldering against both top and bottom views of the board shown in Fig. 2. Remember that all connections must be soldered to the pads on both sides of the board. Solder any connection you might have missed, reflow the solder on any connection that looks suspicious and remove any solder bridges with desoldering braid or a vacuum-type desoldering tool.

Once you are satisfied that you installed each component in the correct location and in its proper orientation and that all soldering is okay, temporarily set aside the circuit-board assembly.

Now prepare an enclosure in which to house the project. You can use any enclosure that has interior dimensions of at least 6¼ × 5⅛ × 1 to 1½ inches. It can be made of plastic, metal, a mixture of both or even lumber and Masonite or Plexiglas.

Machining of the enclosure requires very little effort. All you need are three holes in which to mount the switches, four holes for mounting the circuit-board assembly in place and as many holes as are needed for mounting the AA-cell holders. Of course, if you are fabricating a wooden enclosure, you might want to add embellishments like insetting the circuit-board assembly into shallow grooves in the walls to eliminate mounting hardware and spacers.

Wire the battery holder into the circuit via the two wires coming from the bottom of the board. You need six cell holders in all for the AA cells that make up the battery. Wire the holders so that all are in series with each other. Then crimp and solder the free ends of the two 9VDC wires to the lugs at the ends of the series string, making sure you observe proper polarity. Temporarily set aside the circuit-board assembly.

Now, use either etching-and-drilling guide in Fig. 2 as a template to mark where the mounting holes for the circuit-board assembly and switches must be drilled in the top panel of the enclosure. This panel should be a sheet of transparent red-tinted plastic that both protects the circuit-board assembly from physical damage and enhances the visible effect of the LEDs when they are lit. Drill appropriate size holes in the marked locations.

Punch 49 ¼-inch-diameter rounds or cut ¼-inch squares of self-stick blank paper. Also, cut three ¼ × 1-inch pieces to use as labels for the switches. Mount the circuit-board assembly to the top panel using ½-inch spacers and suitable machine hardware. Determine where the dividing line for each square, containing a single LED in the center, will be and use ¹⁄₁₆-inch-wide graphics tape to make up a "checkerboard" pattern consisting of seven squares horizontally and seven vertically; this tape is available at many stationery stores.

When you are finished laying out the squares, place a self-adhering paper round or square in the upper-left corner of each square, where it will not interfere with your view of the LEDs. Number the rounds or squares from 1 through 49, starting at the upper-left and ending at the lower-right and working horizontally. Each round or square should bear the same number as the LED it goes with (see Fig. 3). Place the three long labels near the switch holes and label them accordingly.

Checkout & Use

With no ICs plugged into the sockets, power up the circuit-board assembly by flipping the POWER switch to ON. Now, using a dc voltmeter or a multimeter set to the dc-volts function, check out the voltage distribution in the circuit.

Clip the meter's common lead to any convenient circuit-ground point on the circuit-board assembly. Then use the "hot" lead to probe for the presence of +9 volts at the points indicated in the table that accompanies Fig. 1(C). If you do not obtain a reading of +9 volts (or whatever the potential of the battery) at any point in the circuit, power down the circuit-board assembly and check all wiring and soldering.

When checking out the circuit-board assembly, make sure that all connections have been made to both sides of the board, that all connections look okay and that no solder bridges have been created between the closely spaced IC pads and conductors. If you missed a connection, solder it. If a connection looks suspicious, reflow the solder on it. Use desoldering braid or a vacuum-type desoldering tool to remove any solder bridges discovered.

When you are satisfied that the project has been properly wired. Install the ICs in their respective sockets. Make certain that the correct IC goes into any given socket and that it is properly oriented. Also check to make sure that no IC pins overhang the sockets or fold under between ICs and sockets. Handle the ICs with the same precautions you would use for other CMOS devices.

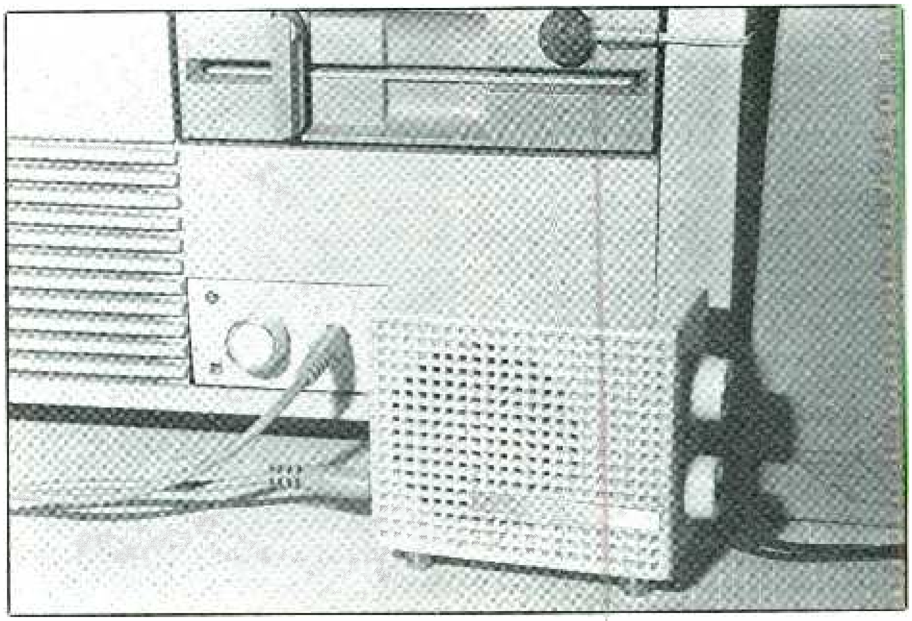
Mount the circuit-board assembly to the top panel with the hardware you previously used to lay out the checkerboard pattern. Then mount the entire assembly inside the enclosure.

To use the project, simply flip the POWER switch to ON, press and release the RESET switch and press and release the PRESS FOR NUMBER switch six times to obtain your six lottery numbers. **ME**

PC Volume Control & Beep Tone Converter

Add-on devices that can make working at your computer a more pleasant experience

By Adolph A. Mangieri



Speakers built into the IBM PCs and compatibles produce a variety of beep tones, musical chords and other sound effects under software control. Unfortunately, the sounds that come from the speaker built into a computer can be just as irritating to listen to as they are utilitarian. Beeps can be too loud for a quiet home or too soft for a noisy office. Few computers provide a volume control for adjusting the tone level to suit different ambient noise conditions, and none permit changing a beep tone without a setup option or utility. Our PC Volume Control permits you to adjust the sound level from the existing speaker in your computer, while our Beep Tone Converter permits you to set the tone of the beep signal more to your liking.

The Volume Control operates just as any other volume control does, allowing you to adjust the sound level over a wide range to suit almost any possible situation. The separate Beep Tone Converter accepts an incoming audio tone from your computer and produces an audio tone of similar duration at a frequency of your choice. The internal speaker and the one you build into the Beep Tone Converter can operate simultaneously to provide a pleasing sound that is reminiscent of two-tone car horns.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the circuitry for the PC Volume Control. At the far left, the speaker plug on the motherboard of the computer is a male four-pin Berg connector that has one unused pin. This connector accepts the mating female speaker shown at the far right. The speaker conductors connect to +5 volts and the speaker signal line from the motherboard.

The 8-ohm speaker is driven by a TTL-level audio output stage in the computer. The Speaker Volume Control circuit patches into the speaker circuit via jack *J4* and plug *PL1*. Potentiometer *R10* in Fig. 1 replaces the original speaker load and permits adjustment of speaker volume from full off to full on. This pot can have any value between 200 and 500 ohms.

For the Beep Tone Converter, the circuit for which is shown schematically in Fig. 2, the audio signal passes through dc blocking capacitor *C1* and to OUTPUT jack *J5*. The square-wave audio-frequency signal drives transistor *Q1*, which amplifies the signal to TTL level for operation of one section of dual retriggerable monostable multivibrator *IC1*.

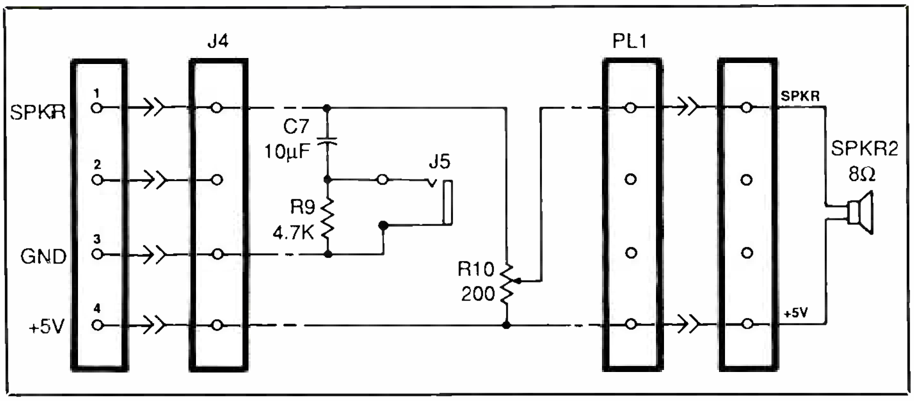


Fig. 1. Schematic diagram of PC Volume Control circuitry.

With pins 2 and 3 of *IC1* pulled up to +5 volts through resistor *R3*, a pulse from high to low at pin 1 causes the *Q* output at pin 13 to go high and subsequently fall low after a period of time determined by the values of *R5* and *C1*. If the INPUT at pin 13 has timed out, the device retriggers and lengthens the output pulse.

By continuously retriggering *IC1* on each cycle of the audio beep tone from the computer, the output at pin 13 is forced high for the duration of the beep tone plus one time-out period. The values of *C1* and *R5* determine the minimum width of the pulse that appears at pin 13 of *IC1*. This was set to about 25 milliseconds to convert very brief and nearly inaudible ticks of a keyboard key click utility to more discernible brief beeps.

The audio output of the Beep Tone Converter is generated by 555 timer *IC2*. This timer is wired to function as a variable-frequency multivibrator that delivers a continuous tone when RESET pin 4 of *IC2* is pulled high by the Q by the output pulse of *IC1*. In operation, capacitor *C2* begins to charge up through timing resistors *R4*, *R6* and *R7*.

When the potential across *C2* reaches 66 percent of the supply voltage, a voltage comparator inside *IC2* senses this condition and switches on an internal transistor to discharge *C1* through *R6* and *R7*. Then when the potential on *C1* reaches 33 percent of the supply voltage, another internal comparator senses this new condition and stops the discharge of *C1*, allowing the charge to rise again to 66 percent of the supply voltage, and the cycle repeats.

With each cycle, a flip-flop in the output stage of *IC1* is toggled and produces a rectangular pulse at OUTPUT pin 13. The output frequency depends on the setting of FREQUENCY control *R7*. The frequency of the output tone varies from about 200 Hz to 4.5 kHz, depending on the setting of *R7*. The rectangular output signal pulses of *IC1* are fed through dc blocking capacitor *C4* to VOLUME control *R8*, which is used to adjust the level of the tone heard.

The Beep Tone Converter circuit is powered from a plug-in wall-type dc source that supplies 9 to 18 volts dc to the power-supply circuit shown schematically in Fig. 3. The dc voltage from the supply is applied to the power-supply circuit through POWER jack *J3*. Rectifier diode *D1* protects the circuit from application of reversed-polarity voltage from the external supply.

Audio output stage *IC2* in Fig. 2 is operated at a potential that can range from 9 to 18 volts dc. Voltage regulator *IC3* in Fig. 3 supplies regulated

PARTS LIST

Semiconductors
D1—1N4001 or similar silicon rectifier diode
IC1—74LS123 dual retriggerable monostable multivibrator
IC2—NE555 timer
IC3—78L05 +5-volt fixed voltage regulator
Q1—HEP730, ECG123 or similar high-gain silicon npn transistor

Capacitors (25 WV or greater)
C1—1-μF tantalum
C2—0.047-μF polyester film
C3—0.01-μF ceramic disk
C4,C5,C6—47-μF electrolytic
C7—10-μF electrolytic

Resistors (¼-watt, 10% tolerance)
R1—300 ohms
R2—12,000 ohms
R3,R4,R9—4,700 ohms
R5—100,000 ohms
R6—1,200 ohms
R7—100,000-ohm panel-mount potentiometer
R8,R10—200-ohm, ½-watt carbon or wire-wound potentiometer (see text)

Miscellaneous
J1,J2,J3,J5—⅛-inch miniature phone jack
J4—4-pin female Berg connector (see text)
PL1—4-pin male Berg connector (see text)
SPKR1—8-ohm miniature speaker (see text)
SPKR2—Existing 8-ohm speaker in computer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware for Beep Tone Converter and suitable enclosure (see text); sockets for DIP ICs; plastic panel or aluminum bracket and aluminum stock for making brackets for PC Volume Control (see text); 9-to-18-volt dc plug-in power supply; pointer-type control knobs for potentiometers; ½-inch spacers; 4-40 machine hardware; hookup wire; solder; etc.

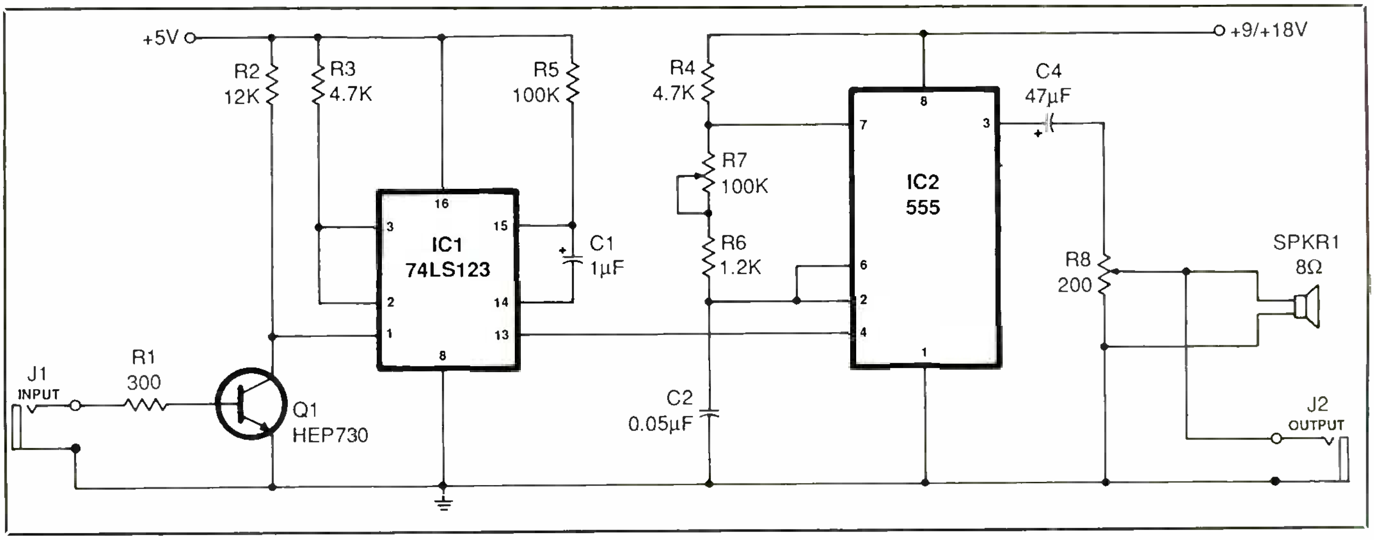


Fig. 2. Schematic diagram of basic Beep Tone Converter Circuitry.

+5 volts for *IC1* and *Q1* in Fig. 2. Optional audio OUTPUT jack *J3* in Fig. 2 provides an audio signal that can be used to drive an external audio power amplifier.

Construction

One way to build the PC Volume Control is to mount the VOLUME potentiometer and OUTPUT jack on a plastic panel that replaces the one on an unused user-accessible disk-drive bay, as shown in the lead photo. Choose a panel that matches the bezel(s) of the other drives mounted in your computer.

If you lack space up front on your computer, you can fabricate a panel that can be bolted in one of the unused connector cutouts on the rear of your computer. This panel can be made from a spare piece of sheet aluminum or a strip of ¹⁄₁₆-inch-thick plastic that has been bent to required shape. Cut it to the same dimensions and shape as a standard bracket for a plug-in expansion board and bend it accordingly.

Assuming you are planning to mount the PC Volume Control circuit on a panel that fits over an unoccupied disk-drive bay, measure the length and height of the existing cover on the bay. Cut the replacement plastic panel to these dimensions.

Before removing the top of your computer, carefully measure the distance from the installed disk drive to the top edge of the cover to be replaced and record your measurement. Unplug your computer from the ac line. Then remove the five screws that secure the cover of the computer in place. Standing in front of your computer, carefully slide the top of the case off and set it aside. Follow the instructions for this detailed in the manual that accompanied your computer.

With the cabinet top removed and set aside, dismount the blank disk-drive cover plate from the front of the chassis by removing the two retaining screws. For safe keeping, replace the screws in the mounting rails from which they were removed and tape the removed cover plate to the floor of the chassis in the open bay.

Fashion a pair of brackets with which to support the new cover plate that will accommodate the components for the PC Volume Control circuitry in the open disk-drive bay from light-gauge sheet aluminum. When you are done, these brackets should look like those shown in the photo of the completed assembly in Fig. 4. The vertical elongated slots in the brackets permit vertical positioning of the panel during installation, using the two retaining screws.

Drill mounting holes for and mount the brackets in place, each with 4-40 machine hardware. Then drill mounting holes for the jack and potentiometer and mount these components in their respective holes. Place a control knob on the shaft of the potentiometer. Then refer to Fig. 1 to wire together the capacitor, resistor, potentiometer and jack. Be sure to properly orient the capacitor. Mount the fixed resistor directly across the two lugs on the jack. The capacitor mounts directly between the "signal" lug on the jack and the lug on the left when viewing the potentiometer from the rear. Do *not* solder any connections just yet.

Determine how long the conductors from *J4* to the + side of *C7*/*R10*, ground side of *R9*/*J5* and *R10* and from *PL1* to the center (wiper) lug of *R10* and right lug of *R10* should be. Cut to length these five wires, using standard (color-coded) stranded hookup wire. Strip ¼ inch of insulation from all wire ends, tightly twist together the fine conductors and sparingly tin with solder.

Crimp the end of one wire to the lug of *R10* to which the + lead of *C7* is connected and solder the connection. Crimp and solder one end of another wire to the ground lug of *J5*. Solder the connections made to both lugs of the jack. Crimp and solder one end of a third wire to the center lug of the potentiometer. Then crimp and solder one end of both remaining wires to the remaining lug of *R10*.

Terminate one of the two wires connected to the left lug of the potentiometer, ground lug of the jack and one of the wires from the left lug of the potentiometer in the four-contact jack. Terminate the other two wires in the four-contact plug. The Parts List specifies Berg connectors for the plug and jack. Difficult to find at best and impossible to find in some locations, these connectors can be home made. For *J4*, I cut down a low-profile DIP socket capable of accepting a Wire Wrap pin to obtain four contacts. For *PL1*, I used a strip of micro board and two Wire Wrap posts. If you do as I did, be sure to use tape to prevent short circuits and double check your wiring.

Trace the pair of wires that run from the speaker in your computer to the Berg strip connector on the motherboard. In an AT or compatible computer that uses a full-size motherboard, this strip connector is most likely located up front near the left wall of the hard disk bay.

When you locate the Berg plug, unplug it from the strip connector and carefully note wire colors. Code both plug and jack in the PC Volume Control circuit with a dot of paint or fingernail enamel to ensure correct replacement.

Use an ohmmeter to verify a resistance of about 8 ohms between the pins at both ends of the unplugged speaker connector. Also verify that pin 3 on the motherboard is electrically tied to ground (the chassis of the computer).

Now plug the line cord of your computer back into the ac outlet from which it was removed and turn it on. Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to circuit ground. Touch the "hot" probe to pin 4 of the strip connector on the motherboard and observe the reading obtained. It should be +5 volts. Exercise caution to avoid shorting pin 3 to pin 4 with the test probe as you take the measurement

After verifying connector pin assignments, power down your computer and unplug it from the ac line. Then slide *J4* from the PC Volume Control assembly onto the Berg strip connector on the motherboard and plug *PL1* onto the end of the speaker cable. Make certain you observe proper polarity.

With the speaker connected to the project, turn the knob on potentiometer fully clockwise and use your ohmmeter to verify a resistance of about 8 ohms between pins 1 and 4 of *J4*. Rotate the knob on the potentiometer to its fully counterclockwise position and verify that the resistance reading is now about 200 ohms (or whatever other value you used for *R2*) between pins 1 and 4. You should also obtain a reading of essentially infinity from ground pin 3 to pins 1 and 4 of this connector.

Use cord to tie the speaker cable to a card guide or other convenient place to keep the speaker plug from touching the motherboard. Slide *J4* onto the Berg connector on the motherboard from which you removed the speaker cable.

Now mount the PC Volume Control assembly into place, using the two retaining screws that formerly held the blank panel in place in the drive bay being used for the project. As you do this, adjust the panel of the project horizontally by bending both brackets to the left and right. If necessary, remove the brackets and trim away excess metal to prevent interference with replacement of the top of the computer or later installation of the second disk drive.

Secure the PC Volume Control assembly in place and trial fit the top back on the computer. Note any small adjustments that must be made. After properly positioning the panel assembly in several trial fittings, mark the positions of the brackets to allow you to remove and easily replace the assembly. Dress the cable runs and secure them with cord so that the conductors will not be pinched when you replace the top of the computer.

If you built the project on a bracket that fits into an unoccupied slot on the rear panel, mount the assembly into place. Once again, secure the cable runs neatly to avoid having them interfere with anything else inside your computer, and tie the speaker cable to a point inside the computer

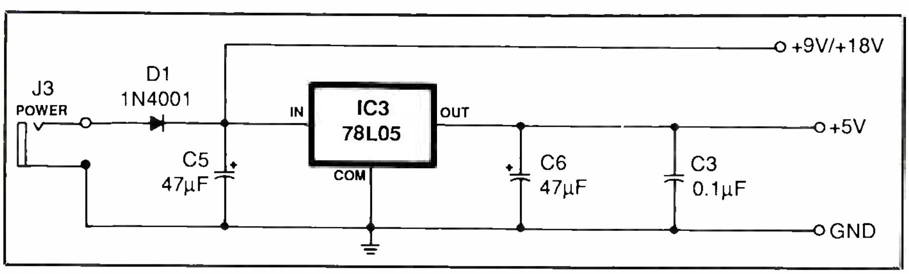


Fig. 3. Schematic diagram of simple power-supply circuitry used to operate Beep Tone Converter.

that keeps the speaker connector from touching the motherboard or anything else inside the computer.

Replace the top of the computer's enclosure and secure it with the five screws you removed earlier. Plug the computer back into the ac outlet, turn it on and boot it up. Do this several times with the potentiometer set for a high and a low volume to check operation of the PC Volume Control circuit. If everything appears to be working as it should, proceed to assembly of the Beep Tone Converter.

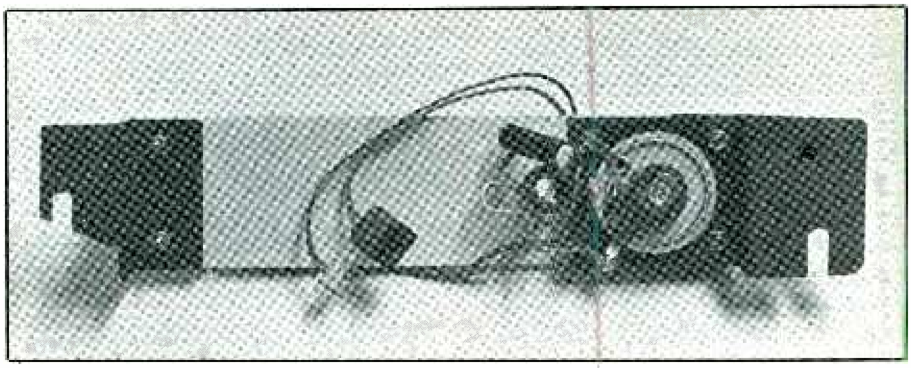


Fig. 4. PC Volume Control unit built onto plastic panel that has user-fabricated aluminum brackets (shown in black) at opposite ends to facilitate mounting panel in open drive bay.

To house the Beep Tone Converter circuit and its dc power supply (not including the external plug-in wall transformer), I used a TV remote speaker unit that included a speaker and 200-ohm wire-wound potentiometer and perforated-board construction, as shown in Fig. 5.

Since component locations and conductor runs in this circuit are not critical, you can use a printed-circuit board of your own design on which to mount and wire together the components of the circuits shown in Fig. 2 and Fig. 3. If you elect point-to-point wiring, use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. It is a good idea to use sockets for the DIP ICs in this project.

When selecting components for the Beep Tone Converter, *Q1* can be any high-gain npn milliwatt transistor. Potentiometer *R8* can have any value between 200 and 500 ohms. Also, the speaker can be any size 8-ohm unit. As you assemble this circuit, wire potentiometer *R7* so that volume increases when the shaft of this control is rotated in the clockwise direction.

When wiring the components onto the selected board, begin with the DIP IC sockets. Do *not* install the ICs in their respective sockets until after preliminary voltage checks have been performed. Once the sockets are in place, install and solder into place the resistors and then the capacitors and rectifier diode, followed by the transistor and voltage regulator. Make sure the electrolytic capacitors are properly polarized and that the transistor and voltage regulator are properly based before soldering their leads into place.

When you finish wiring the circuit-board assembly, set it aside and machine the enclosure in which you will house the project. You can use any type of enclosure that is large enough to accommodate the circuit-board assembly, speaker, jacks and controls without crowding.

To prepare the enclosure, determine where the circuit-board assembly and the various off-the-board components are to be mounted. The best locations for the INPUT and OUTPUT jacks is the front or side and POWER jack is the rear panel. The front panel is the best location for the speaker, while the two potentiometers can mount on one side wall (the one opposite the INPUT and OUTPUT jacks if these are on a side wall).

Machine the enclosure accordingly. Remember to drill a couple of dozen small holes in the front panel to allow the sound from the speaker to escape freely. If you are using a metal enclosure, deburr all holes. When you are done, label the functions of the two potentiometers with a dry-transfer lettering kit or tape labeler. If you use the former, protect the lettering with two or more light coats of clear acrylic spray.

When the enclosure is ready, mount the jacks and potentiometers in their respective holes. Strip ¼ inch of insulation from both ends of six 5-inch-long hookup wires. If you use stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Solder one end of one wire to any convenient circuit-ground point a second wire to wherever the negative (−) lead of *C4* is connected. Similarly, solder one end of another pair of wires into the circuit where *R7* is to install and the final pair to the free end of *R1* and a ground point near this resistor.

Mount the circuit board in place with ½-inch spacers and 4-40 × ¾-inch machine screws, nuts and lockwashers. Crimp but do not solder the free ends of the two wires you just installed to the two outer lugs on VOLUME control *R8*, the ground wire to the right lug and the *C4* wire to the left lug as you view the pot from the rear. Solder the *C4/R8* connection.

Prepare four more 5-inch-long hookup wires as before. Crimp and solder one end of two of these wires to the center lug of *R8*. Similarly, crimp one end of the other two wires to the right lug of *R8* and solder the three wires now connected to this lug into place. Crimp the free ends of the wires connected to the center lug of the potentiometer to the "hot" speaker lug and signal lug of the OUTPUT jack and solder both connections. Then crimp and solder the free ends of the two remaining wires to the unoccupied lugs of the speaker and OUTPUT jack.

Crimp and solder the free ends of the two wires coming from *R1* and the ground near it to the signal and ground lugs, respectively, of the INPUT jack. Strip an additional ½ inch of insulation from the wire connected to *R6* on the circuit-board assembly. Thread this wire through the left and center lugs of *R7* and solder it to both lugs. Then crimp and solder the free end of the other wire to the unoccupied lug of this potentiometer.

Run a thick bead of silicone adhesive around the perimeter of the speaker and press the speaker into place on its panel. Allow the adhesive to cure for at least two hours and preferably overnight.

Checkout

With the ICs still not installed in their sockets, plug the external wall-mount dc power supply into the jack on the back of the project and then into an ac outlet. Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to a convenient circuit ground. Touching the "hot" probe to pin 16 of the *IC1* socket should yield a reading of +5 volts. Touching the probe to pin 8 of the *IC2* socket should yield a reading of +9 to +18 volts.

If you do not obtain the above readings, touch the "hot" probe of the meter to the output pin of *IC3* and note if the reading is +5 volts. If not, touch the probe to the input pin of the regulator, this time noting if the reading is +9 to +18 volts. If you still do not obtain the proper readings, power down the project, troubleshoot it and rectify the problem before proceeding.

Once you obtain the proper readings, power down the project and install *IC2* in its socket. Make sure it is properly oriented and that no pins overhang the socket or fold under between IC and socket. Then bend a small-gauge length of bare solid hookup wire into a U shape and plug it into pins 8 and 13 of the *IC1* socket (this forces RESET pin 4 of *IC2* low on power-up). Set the VOLUME fully clockwise for maximum volume.

Power up the project and verify that no tone is heard from the speaker. If so, power down the project and move the jumper in the *IC1* socket so that it bridges pins 13 and 16 now to pull RESET pin 4 of *IC2* high. Once again, apply power to the project. This time, you should hear a tone coming from the speaker and it should change frequency as you rotate the knob on the FREQUENCY control in both directions, increasing in frequency as you rotate the knob clockwise.

With power to the project disconnected, remove the jumper wire and install *IC1* in its socket. Connect the project to the PC Volume Control unit with a suitable cable plugged into the INPUT jack on the former and the OUTPUT jack on the latter. Power up your computer and the Beep Tone Converter and boot the computer. Verify that the Converter beeps.

After the project beeps, load a BASIC interpreter into your computer and type "10 BEEP." Press function key F1 on your computer to run this one-line BASIC program. You should again hear a beep tone from the speaker in the project.

If the project fails the beep-tone test, feed into the INPUT jack on the

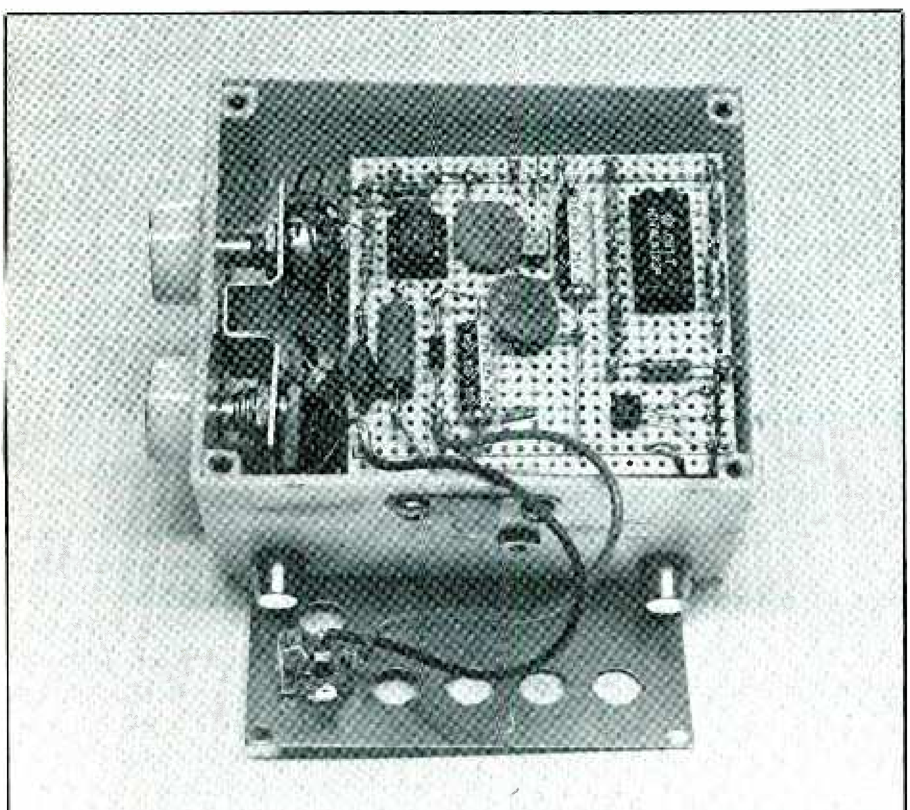


Fig. 5. Interior view of wired Beep Tone Converter circuit built on perforated board and mounted inside a commercial TV extension speaker enclosure.

Converter a source of audio, such as from a sine-, square- or triangle-wave generator. You can also use the sawtooth output from an oscilloscope if you have this handy. Verify the pulse at pin 1 of *IC1* in the project. At input frequencies beyond about 30 Hz, pin 13 of *IC1* should go high and remain there as the project continually retriggers. At lesser frequencies, pin 13 of *IC1* should show positive-going pulses that time out before the next cycle of the input signal can retrigger the monostable multivibrator. If you do not observe this action, check the wiring of *Q1* and *IC1* and replace possible defective devices.

Application

A common complaint is that the beeper in PC and compatible computers is too loud in a quiet environment. If this is so in your case, adjust the audio to any comfortable level, using the VOLUME control in the Beep Tone Converter.

Audio OUTPUT jack *J5* in the PC Volume Control circuit is not intended for earphone use. If you plug an earphone into this jack, you may hear a faint high-pitched tone and random ticks as DOS performs its tasks. Also, the audio output signal at this jack is little affected by VOLUME control *R10*.

The background noise heard through an earphone plugged into *J2* seems to be noise on the +5-volt line or/and crosstalk in the computer circuits. If you wish to use earphones with the project, set *R10* to full counterclockwise to reduce background noise to a minimum.

Several modes of operation are possible with the Beep Tone Converter. For a monotone beep, set the VOLUME control in the PC Volume Control unit fully counterclockwise to silence the speaker in the computer. Execute the BEEP command in BASIC, and adjust the FREQUENCY and VOLUME controls on the Beep Tone Converter for a tone of a frequency and level to your liking.

Lacking distinction, the monotone beep can be enhanced by operating the speaker in the computer and that in the Beep Tone Converter simultaneously to produce pleasant stereo polyphonic chords. To achieve this effect, set the VOLUME control on the PC Volume Control unit to about mid-rotation. Then carefully adjust the Beep Tone Converter for an output beep frequency that complements the tone generated by the speaker inside the computer. Balance the relative sound levels of the tones produced by both speakers. When you find the preferred settings, mark the locations of the knob pointers on the controls with dots on the panel for quick setup.

Key-click utilities generate audible ticks that help to maintain typing rhythm. These ticks tend to "wash out" when a turbo computer is operated at maximum speed. Also, the computer beeper delivers very little power with brief clicks. The Beep Tone Converter alters faint key clicks to louder brief beeps at a tone of your choice. To obtain this function, set the VOLUME control on the PC Volume Control unit for maximum volume, and adjust the settings of the two controls on the Beep Tone Converter to suit. If you prefer to reduce the duration of the brief beep that replaces the click, reduce the value of resistor *R5* in the Converter circuit.

Sound effects produced by arcade-game software run on a computer are often hampered by insufficient power in the audio system of the computer. In many cases, the Beep Tone Converter can liven up these sound effects. For example, you can try running the speakers in the computer and Beep Tone Converter simultaneously for a richer effect. With the power supply that drives the Beep Tone Converter at a level of 18 volts dc, the level of the sound produced by the speaker in the project is great enough to be heard throughout a house. If you want the earth-shaking effect produced by real arcade games, patch from the OUTPUT jack on the Converter into the input jack on a stereo sound system.

Certain "quiet" games like computer chess use a low-frequency tone to signal an error and a high-frequency tone to signal select or move. These tones may not benefit from use of the Beep Tone Converter. Try juggling the settings of the VOLUME and FREQUENCY controls on the PC Volume Control and Beep Tone Converter units for best overall effects. Whatever the situation, though, it is usually possible to improve the audio effects. **ME**

Blackout/Brownout Alarm

Sounds a buzzer when ac line power drops below a certain level or disappears altogether

By Istvan Mohos

Brief power outages and "brownouts" can occur fairly often during periods of peak power demand and severe electrical storms. When either occurs when you could not be aware of it because you are not using electricity apparent to you at the moment or are sleeping, you will appreciate the audible Blackout/Brownout Alarm described here. It will save you from oversleeping because your alarm clock could not do its job, alert you early to the possibility that meat in your freezer could spoil, and so on.

A novel design approach is used in our Blackout/Brownout Alarm. Instead of a battery that must be periodically replaced, the project uses a super capacitor that can store enough energy to power its piezoelectric audible signaling device for a minute or so. This should be long enough to alert anyone who is in hearing range to the fact that a power "emergency" has occurred. Because no battery ever has to be replaced in this project, you have the option of sealing it in epoxy potting compound or building it into a conventional enclosure. All components specified for the Alarm are readily available from Radio Shack or other local sources.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the Blackout/Brownout Alarm circuit. The circuit forms a power loop when *PL1* is plugged into any ac receptacle. When the project is plugged into an ac receptacle and the power loop is interrupted by the contacts of relay *K1*, the Alarm is in its "standby" condition. It is placed in its "armed" condition by briefly pressing and releasing momentary-action pushbutton switch *S1*.

Pressing *S1* causes current to flow through the coil of *K1*. This energizes the relay, causing its upper contacts to latch the relay on and maintain current through its coil even after *S1* is released.

Whenever *K1* is energized, neon indicator lamp *I1* glows to indicate that the Alarm is armed. Full-wave bridge rectifier *RECT1* converts the incoming 117 volts from the ac line and delivers a pulsating-dc waveform between the + and − points of the rectifier. Because peak values of the rectified potential can reach as high as 180 volts, it is important that the bridge rectifier selected for *RECT1* have a rating of at least 200 volts.

As you can see, the lower set of relay contacts is in series with piezoelectric buzzer *PB1* and super capacitor *C1*. With the relay energized, the ground return bus for *PB1* is broken and no driving power appears across the buzzer. Thus, the buzzer is silent.

The pulsating dc voltage is fed through current-limiting resistor *R2* to zener diode *D1*. The avalanche path through *D1* provides a low-impedance sink for any dc potential in excess of 5 volts. The 5 volts dc maintained across *D1* charges super capacitor *C1* at an approximately 0.5-milliampere rate. Thus, several minutes of charging is required for *C1* to assume a full charge.

When a blackout or brownout occurs, ac power is either no longer delivered to the circuit or is too low in amplitude to maintain the relay in its energized condition. This being the case, *K1* deenergizes. The contacts of

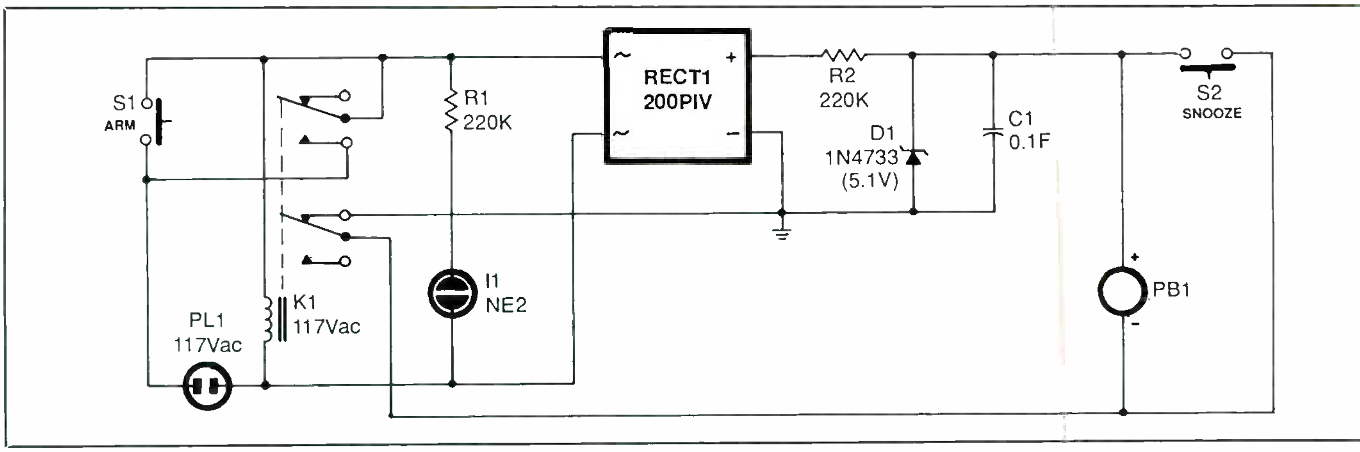


Fig. 1. Complete schematic diagram of the Blackout/Brownout Alarm's circuit.

PARTS LIST

Semiconductors
D1—1N4733 or similar 5.1-volt, 1-watt zener diode
RECT1—200-PIV minimum bridge rectifier (Radio Shack Cat. No. 276-1173 or similar)
Capacitors
C1—0.1-F super capacitor (Radio Shack Cat. No. 272-1440 or similar)
Resistors (¼-watt, 10% tolerance)
R1,R2—220,000 ohms
Miscellaneous
I1—NE2 neon lamp or panel-mount neon-lamp assembly with built-in limiting resistor—see text)
K1—Dpdt, 117-volt ac, 15-mA, 4,500-ohm relay (Radio Shack Cat. No. 275-217 or similar)
PB1—Pulsing piezoelectric buzzer (Radio Shack Cat. No. 273-066 or similar)
PL1—Quick-connect as plug or ac line cord with plug (see text)
S1,S2—Miniature normally-open, momentary-action pushbutton switch
Printed-circuit board or perforated board and suitable soldering hardware (see text); 2-fluid-ounce clear epoxy potting compound or suitable enclosure (see text); materials for making potting frame (see text); hookup wire; solder; etc.

K1 now assume their standby configuration. That is, the latching action of the upper contacts is defeated as the contacts spring open, and *I1* extinguishes. More importantly, the ground-return line of the piezo buzzer is completed and the energy stored in *C1* is applied directly across *PB1*, which then emits an audio tone that serves as the audible alarm. Enough energy is stored in the fully charged super capacitor to cause the buzzer to continue to sound for a minute or so.

When power is restored or comes up to a level that permits normal circuit operation, *PB1* will continue to sound (assuming that the power outage was for a shorter period of time than it takes to deplete the charge on *C1*). The only way to shut off the audible signaling device and restore the alarm to its "armed" condition is to briefly press and then release *S1* to latch the relay on, as detailed above.

Switch *S2* is an option that was added to the circuit to provide a "snooze" capability. Momentarily pressing and releasing this switch short-circuits the super capacitor and silences the piezo buzzer.

Construction

Owing to the fact that there are no restrictions on component placement or conductor routing, you can use any traditional means of wiring to build the Blackout/Brownout Alarm. However, a printed-circuit board, the actual-size guide for which is shown in Fig. 2, is recommended for this project if you plan on potting the finished assembly. If you decide not to pot the circuit-board assembly, you can use perforated board and suitable soldering hardware instead of the pc board.

After etching the printed-circuit board according to Fig. 2, cut the narrow slots at the top for the prongs of the ac plug. One way to do this is to drill a small hole at both ends of each slot and chip out the unwanted board substrate with a sharp safety knife. As you work, periodically plug the prongs of the plug into the slots to check your progress. When the slots are finished, trim the board to size. Then scrub the copper-trace side of the board with scouring powder until the traces are shiny bright, and thoroughly rinse the board and dry it.

You will notice that very little copper has been removed during the etching process. The reason for this is that the epoxy potting compound is a poor conductor of heat. Therefore, by leaving behind the maximum amount of excellent heat-conducting copper on the board, the copper itself will serve as an adequate heat sink for the circuit.

Whichever method of mounting

and wiring together the components, refer to the wiring diagram shown in Fig. 3 for component placement and orientation. Note in Fig. 3 that when wiring the pc board that the components mount on the *conductor* side, using a technique similar to that employed for surface-mount components.

Begin populating the printed-circuit board by trimming the leads of the two resistors and zener diode to appropriate lengths according to the conductor pattern. Carefully bend the leads so that they will safely bridge copper traces they are not supposed to contact. Tack-solder the leads of both resistors to the appropriate points on the copper traces as shown. (Note: if you are planning to house the circuit-board assembly inside a conventional enclosure, you can substitute a panel-mount neon-lamp assembly that has a built-in limiting resistor for the separate *R1* resistor and *I1* lamp called for in the Parts List. If you, do this, do not install *R1* on the circuit board.)

Set the zener diode in place to determine where on the copper traces its leads will touch. Tin with solder both touch points and then tack-solder the diode's leads into place, using heat judiciously and waiting for the first connection to cool before making the second connection. Make sure the zener diode is properly oriented before soldering either lead into place.

Carefully bend all four leads of the rectifier assembly so that they are in line with the rear of the assembly and parallel to each other. When the assembly is laid flat on its back, the leads and rear surface should be in the same plane.

Pretin the copper traces on the board to which the leads of the rectifier assembly are to be soldered. Set the rectifier in place and solder its leads to the appropriate copper traces. Again, make sure the assembly is properly oriented before soldering into place any leads, use heat judiciously and permit the assembly to cool after each soldering operation is performed.

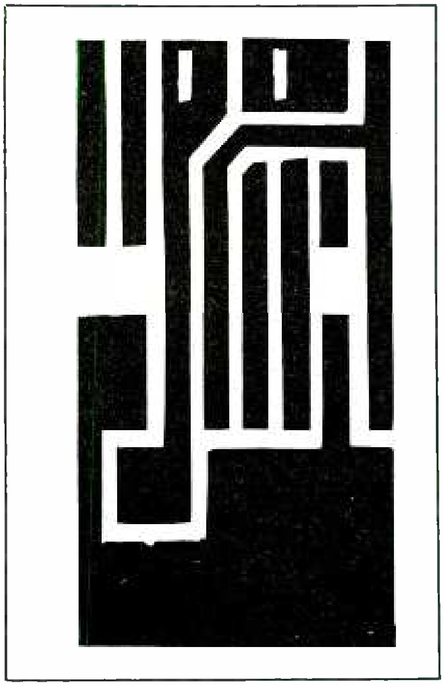


Fig. 2. Actual size etching guide for the printed-circuit board for the project.

Bend the leads of the super capacitor outward and clip them so that only about 3/16 inch protrudes beyond the housing. Making sure the capacitor is properly oriented, tack-solder its leads to the appropriate copper traces on the board.

Note in Fig. 3 that a jumper wire is needed, shown just above where *R2* is mounted. Use a suitable length of insulated hookup wire for it.

Strip 1/4 inch of insulation from one end of three 4-inch-long hookup wires. Remove an additional 1/2 inch of insulation from one wire. Thread the stripped end of this wire through the large lug to the specified smaller lug of the relay as shown. Solder both connections. Then crimp and solder the stripped ends of the other two wires to the indicated lugs of the relay.

Strip 1/8 inch of insulation from the free ends of the three wires attached to the relay. Carefully tack solder these wires to the appropriate copper traces near the top of the pc board.

Strip 1/4 inch of insulation from one end and 1/8 inch from the other end of two 2-inch-long hookup wires. Crimp and solder the ends from which the 1/4 inch of insulation was removed to the remaining large and the indicated small lugs on the relay. Then tack-solder the free ends of both wires to the indicated points on the board.

If you are planning to pot the project, tack-solder the leads of the piezoelectric buzzer to the indicated copper conductors at the top-left of the pc board, making sure you observe proper polarity. Leave the leads of the buzzer full length. If you are planning on housing the project inside a standard enclosure, do nothing with the piezo buzzer at this point.

Again, if you are sealing the circuit-board assembly in potting compound, slide over both leads a 1-inch length of plastic tubing to insulate them from each other and the rest of the components on the board. If necessary, trim the leads of the lamp so that only about 1/8 inch protrudes beyond the ends of the tubing. Tack-solder the leads to the two indicated conductors on the board. Otherwise, wait until after the circuit-board assembly is mounted inside its enclosure to connect the lamp to it.

Connection of the two switches (assuming you have decided to include SNOOZE switch *S2*) depends on whether the circuit-board assembly is to be potted or housed inside a conventional enclosure. If the former, you can tack-solder the lugs of each switch directly to the copper traces on the board, making sure that both switches sit perpendicular to the surface of the board. If you are planning on using a conventional enclosure, connect the switches into the circuit via suitable-length hookup wires.

Finish wiring the circuit-board assembly by installing and soldering into place plug *PL1*. If the assembly is to be potted, you need only the insert portion—the part with the prongs—

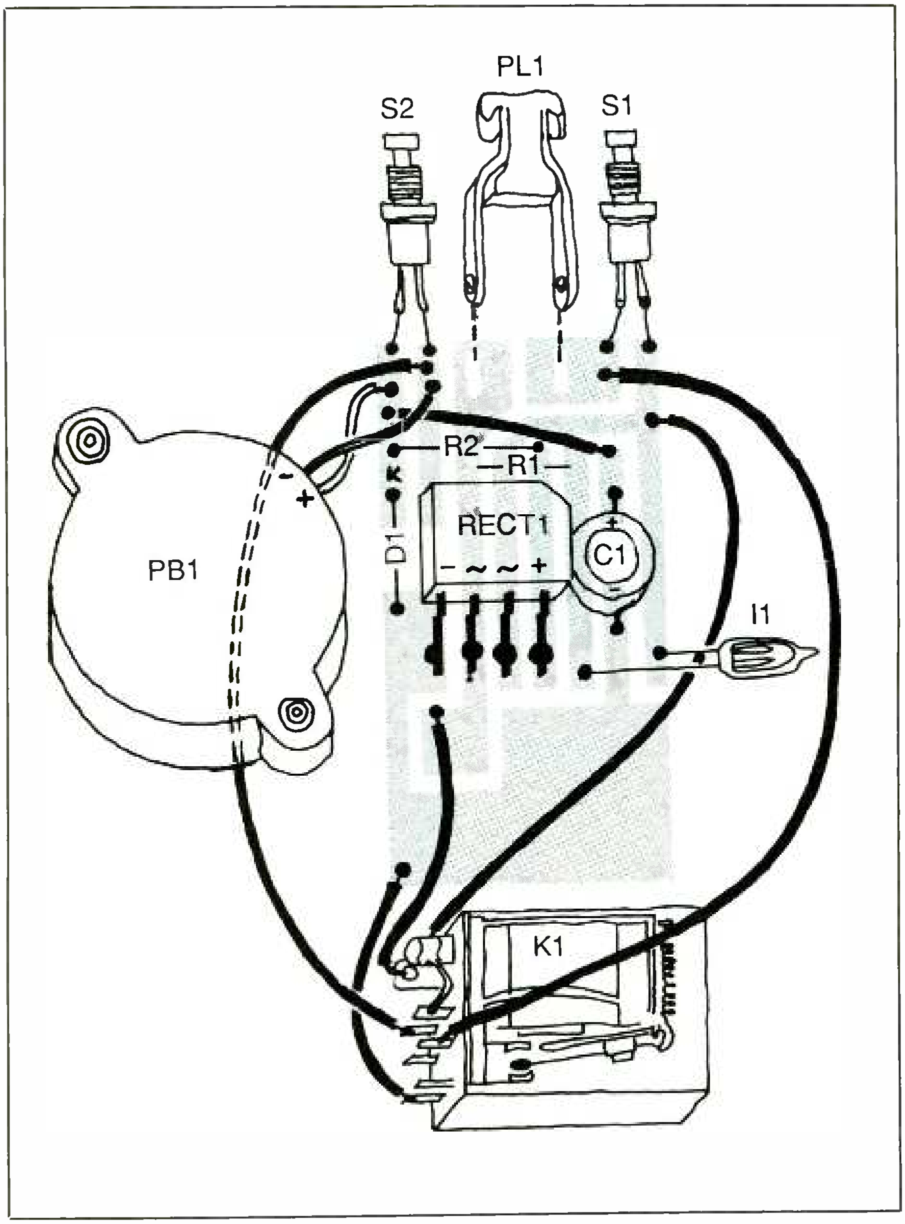


Fig. 3. Wiring diagram for pc board. Note that all components mount on the copper-trace side of the board.

of a quick-connect ac plug here. Discard the shell in this case. If you attempt to use the insert portion as is, the prongs will be shorter by the thickness of the board and may not provide solid plugging action. To offset this, use a saw or file to trim enough of the anvil-like plastic porion between the prongs to restore full length when they are inserted into the slots in the board.

Now insert the prongs in the narrow slots cut for them from the component side of the board and solder the prong sides to the copper conductors along the accessible edges. Make these connections mechanically sound, using as much solder as possible. Otherwise, use a standard ac line cord with plug, which will be wired into the circuit after the circuit-board assembly is mounted inside the selected enclosure.

Should you decide to use a conventional enclosure in which to house your Blackout/Brownout Alarm, you can choose one that is all metal, all plastic or a combination of the two. Machine the enclosure as needed: drill mounting holes for the neon lamp assembly, both switches and the buzzer and the entry holes for the ac line cord and buzzer leads. If you drill any holes through metal, deburr them and line the ones for the ac line cord and buzzer leads with small rubber grommets.

Route the free end of the line cord through its hole and into the enclosure. Tie a strain-relieving knot in it inside the enclosure about 2 inches from the free end. Tightly twist together the fine wires in each conductor and tin with solder. Trim the bare tinned conductors to about ¼ inch long and tack-solder them to the copper traces.

Mount the circuit-board assembly to the floor of the enclosure with thick double-sided foam tape. You can now mount the relay with the same tape, fastening it to the area reserved for it at the bottom of the board or on the wall of the enclosure near the bottom of the board.

It is more convenient to replace the separate *R1* resistor and *I1* neon lamp with a panel-mount neon-lamp assembly with built-in limiting resistor. If you do this, mount the lamp assembly in its hole and secure it with the supplied clip. Tack-solder one lead to the copper trace to which the left end of *R1* in Fig. 3 is shown connected. Then tack-solder the other lead to the trace to which the right lead of the lamp is shown connected. Of course, if you do this, eliminate *R1* from the circuit. Plug the switches into their respective mounting holes and secure them in place with the hardware supplied with them.

Route the leads of the buzzer through their hole and mount the buzzer in place with suitable machine hardware. Tack-solder the positive (+) buzzer lead to the trace at the upper-left of the board and the negative

(–) lead to the trace right next to it.

Readers who wish to encapsulate the circuit-board assembly in epoxy potting compound should first conduct a test to assure that the project has been wired and is working properly. When you conduct this test, practice extreme caution because you will be dealing with potentially lethal 117-volt ac line power.

You will need an extension cord to conduct the operational test for a project that is to be encapsulated but not for one that it to be housed inside an enclosure. Plug *PL1* on the project into the extension cord and place the project on an insulating surface. Plug the extension cord into a convenient ac outlet. The alarm should not sound and the neon lamp should be dark. Carefully press and release ARM switch *S1*. The neon lamp should now be lit but the buzzer should not sound. Allow the project to sit in this condition for several minutes to allow the super capacitor to charge up.

When sufficient energy has been built up in *C1*, pull the plug of the extension cord from the ac outlet. The neon lamp should now extinguish and the buzzer should sound. While the buzzer is sounding, press and release SNOOZE switch *S2*. The buzzer should immediately silence.

When conducting the operational test on a project that is housed inside an enclosure, be sure to have the enclosure closed. Also, plug the project's line cord—without benefit of an extension cord—into the ac outlet. Conducting an operational test on this version of the project requires no special precautions.

If you do not obtain the proper responses from the project, unplug it from the ac outlet and carefully recheck all wiring and component installations. Make certain that zener diode *D1*, bridge rectifier *RECT1* and piezoelectric buzzer *PB1* are all installed in proper polarity.

Check all soldering. If you suspect a connection reflow the solder on it (and add solder if needed). If you discover a solder bridge where there should not be one, use desoldering braid or a vacuum-type desoldering tool to remove it. Do *not* attempt to encapsulate the project or put a nonfunctioning project into service.

When you are certain that the project is operating properly, you can encapsulate the circuit-board assembly in epoxy potting compound. To do so, you will use the "frame-and-pour" method, similar to framing and pouring concrete walkways only in miniature.

A slab of lumber of any type with a hole cut in it for the prongs of the ac plug protruding from the bottom of the circuit-board assembly makes up the bottom of the frame. Lay this flat on your work surface. The walls of the frame are made from four pieces of thin lumber that have been cut to a size to form a surround that has the same inner dimensions as the length and width of the circuit-board assembly and is 1 inch deep. Hold the frame together with rubber bands or tape.

Use double-sided tape to line all surfaces that are to come into contact with the potting compound with strips of clear acrylic or acetate. In a pinch, any transparent plastic film can be used. I have had good results with strips cut from the "bubbles" used on display packages, soft-drink bottles and other plastics. The plastic will not adhere to the epoxy potting compound, allowing the lined strips of wood to easily pop off after about 24 hours as the compound sets.

Once the frame is ready, place the circuit-board assembly inside it, blank side down. The relay now becomes the "cornerstone" of the unit. After mixing a small amount of the two parts that make up the potting compound, pour a thin layer of it in the area in which the relay is to mount and push the relay into it, squaring it up against the lower-right corner of the frame. Work with the epoxy potting compound in a well-ventilated location.

Mix another small batch of the compound and pour it over the rest of the board, positioning the indicator lamp so that it will easily be seen when the project is in operation. Place a strip of tape over the sound-exit hole in the buzzer and use some already setting compound to cover the three small holes in the bottom of the buzzer and allow it to set awhile. This will prevent liquid compound from entering the buzzer and interfering with its operation. Mix some more compound, pour it into the frame and press the buzzer into the liquid compound.

Mix some more of the compound and pour this into the frame. Continue mixing and pouring until you have filled the frame up to the shoulders of the switch frames and the buzzer is encased in what will become a rigid block of epoxy. The process may take as many as 10 mixings and pourings to complete. Use a homemade plastic spatula to smooth each layer of compound as it is poured.

As you approach the end of the potting operation, you will notice that the potting compound tends to run up the sides of the frame, making the surface slightly concave, with ridges at the edges. This does no harm to the finished project but can be less than aesthetically appealing. To correct for this, you can cut a template from some more clear plastic with holes cut or punched for top of the buzzer and switch buttons.

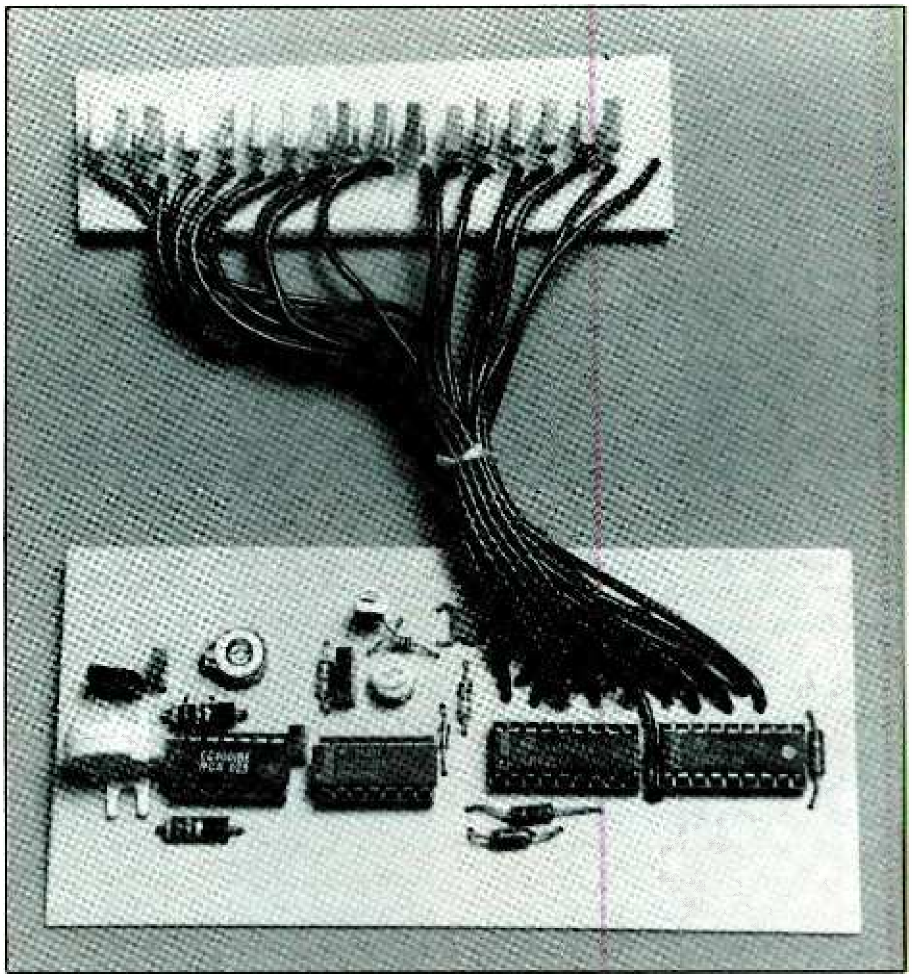
With template in hand, mix and pour the last thin layer of potting compound, smoothing it to the top of the wall. Place the template over this layer, rolling it over the top of the form to avoid trapping any air bubbles between it and the compound.

Allow the assembly to sit undisturbed for at least 24 hours to allow the potting compound to fully cure. When the compound has cured, remove the rubber bands or tape and snap away the wood and plastic strips. The project is now ready to be put into service. **ME**

Relative-Humidity Meter

This all-solid-state instrument measures the relative percentage of moisture in the air and displays it in bargraph or analog meter format

By Anthony J. Caristi



Relative humidity is a measure of the quantity of moisture contained in the air at a given temperature. Higher temperatures can accommodate a greater volume of moisture than can cooler temperatures. Because of its importance to our well-being, it is always a significant factor in any forecast of weather conditions.

Our personal comfort is intimately related to humidity. In the summer, even mild temperatures accompanied by high levels of relative humidity make us uncomfortable because it interferes with one's natural body cooling system—evaporation of perspiration. Conversely, in winter, when indoor air is heated, the natural reduction in relative humidity causes us to feel cold unless the temperature is raised to 72° Fahrenheit or more.

Described here is an instrument that can be used to measure relative humidity with significantly better accuracy than can be obtained by a common low-cost consumer-type device. With it, you can readily determine if you should turn on a humidifier or dehumidifier. The Relative Humidity Meter is also an excellent indicator of any improvement made in humidity level after you take remedial action and helps in determining if your humidifier, dehumidifier or air conditioner is doing its job.

Some Background

The term relative humidity is used to describe the percentage of moisture (water vapor) present in a given volume of air compared to the maximum amount of moisture that can be contained in the same volume of air at the same temperature. A condition of 100 percent relative humidity is said to occur when the air is saturated with moisture and any increase in water vapor will result in precipitation (rain or snow).

Most of us are aware of the effects excessive moisture or lack of sufficient moisture have on our comfort. But our bodies are not the only things that can suffer adverse reaction to too much or too little humidity in the air. For example, wooden drawers and doors tend to expand and jam in hot, humid weather but fit too loose in cold, dry weather. Wood furniture and fixtures may shrink and crack in the winter as well.

Even such things as photocopy machines and computers may fail to perform properly unless the relative humidity in their working environments is held to within certain limits. In extreme cases of humidity coupled with high temperatures, mildew can form everywhere and, when it does, causes significant damage.

There are several ways in which relative humidity can be detected and measured, using a family of instruments called "hygrometers." One way is to detect the rate of water evaporation by an instrument, known as a "psychrometer," that uses two thermometers. One has a continuously moistened cloth covering its bulb and senses the rate of evaporation by the resulting reduction of bulb temperature; the other, against which the cooler temperature is compared, simply monitors the ambient temperature.

Using the psychrometer method of detection, a chart can be consulted to determine the relative humidity level that corresponds to the two temperature readings. While a very accurate indicator of relative humidity, this method may not be convenient to use.

Another way to measure relative humidity is the one used by the many low-cost relative-humidity gauges that have been around for many years. These instruments are designed to respond to the percentage of humidity by monitoring the length of a strand of hair, which lengthens or shortens according to the amount of moisture in the air. It is not surprising that such devices are not very accurate and that any reading of relative humidity given by them may not be very meaningful. This is especially so at very-low or very-high levels of humidity.

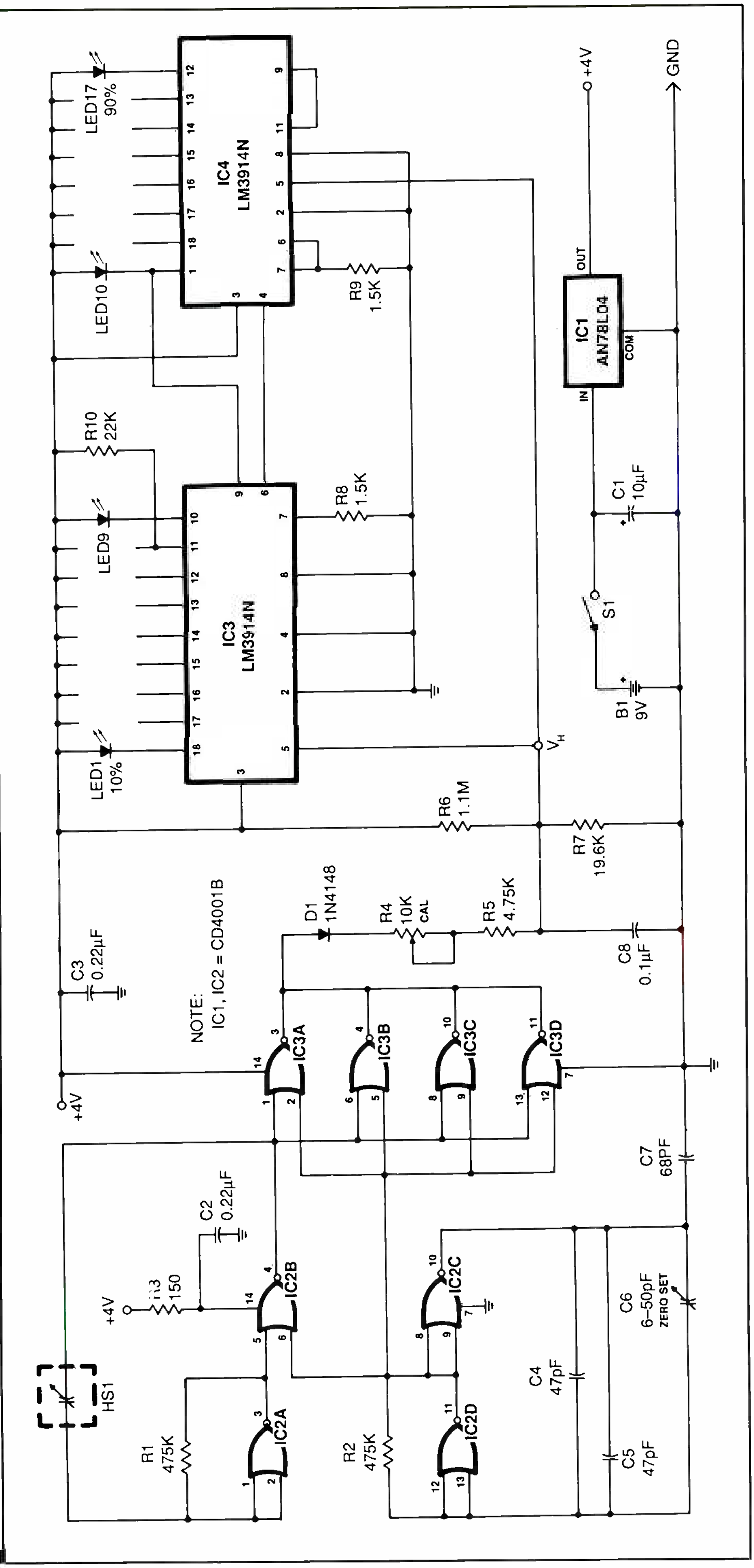


Fig. 1. Schematic diagram of Relative Humidity Meter circuitry.

PARTS LIST

Semiconductors
D1—1N4148 or similar signal diode
D2,D3—1N4004 or similar silicon rectifier diode (optional—see text)
IC1—AN78L04 fixed +4-volt regulator
IC2,IC3—CD4001BE quad-2-input NOR gate
IC4,IC5—LM3914N LED driver
LED1 thru LED17—2-volt, 20-mA light-emitting diode (see text)

Capacitors
C1—10-μF, 16-volt electrolytic
C2,C3—0.22-μF, 25-volt ceramic disk
C4,C5—47-pF, 25-volt NPO ceramic disk
C6—6-to-50-pF trimmer (Radio Shack Cat. No. 272-1340 or similar)
C7—68-pF, 25-volt ceramic disk
C8—0.1-μF, 25-volt ceramic disk
C9—100-μF, 16-volt electrolytic (optional—see text)

Resistors
(¼-watt, 1% metal-film)
R1,R2—475,000 ohms
R5—4,750 ohms
R7—19,600 ohms
R11—23,700 ohms (optional—see text)
(¼-watt, 5% carbon)
R3—150 ohms
R6—1.1 megohms
R8,R9—1,500 ohms
R10—22,000 ohms
R4—10,000-ohm pc-mount cermet trimmer potentiometer

Miscellaneous
B1—9-volt alkaline battery
HS1—Humidity sensor (Mepco/ Centralab Inc., P.O. Box 760, Mineral Wells, TX 76067; specify Part No. 691 90001)
M1—50-μA dc panel meter movement with 1,000-ohm coil (optional—see text)
S1—Spst momentary-action, normally-open pushbutton switch (or slide or toggle switch if using ac-operated power supply; see text)
T1—12.6-volt C.T. power transformer (Radio Shack Cat. No. 273-1365 or similar)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for all DIP ICs; snap connector and holder for 9-volt battery; suitable enclosure (see text); red plastic filter; ½-inch 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 main pc board, $12.95; ready-to-wire display pc board, $4.95; AN78L05 and CD4001BE, $2 each; LM3914N, $6 each; set of four metal-film resistors, $2. Add $2.50 P&H. New Jersey residents, please add 6% state sales tax.

Several electrical methods for measuring relative humidity also exist. One uses a solid-state humidity-detecting device developed by Mepco/Centralab, Inc. of Mineral Wells, TX. This device has the ability to change capacitance in accordance with the percentage of relative humidity in the air. It is this device that is the subject of this project. With this device, you can build a low-cost, accurate hygrometer that provides relative humidity readings ranging from 10 to 90 percent in increments of 5 percent.

Our Relative Humidity Meter uses a set of 17 light-emitting diodes arranged in a single line to indicate in bargraph-style the current relative humidity. A circuit option that permits use of a standard analog microammeter panel meter movement in place of the discrete LEDs will also be described.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the circuitry used in the Relative Humidity Meter. At the heart of the humidity-measuring circuit is sensor *HS1*, which contains a plastic film that is coated with gold on both sides. This film forms a capacitor and its dielectric constant varies with the amount of moisture present in the ambient air. Consequently, the capacitance of the sensor is a function of the percentage of relative humidity.

Figure 2 illustrates the variation in sensor capacitance as a function of relative humidity. As you can see, the response of the sensor to changes in relative humidity is not exactly linear.

Sensor *HS1* in Fig. 1 makes up one element in a multivibrator circuit composed of *IC2A*, *IC2B* and *R1*. Connected between the inputs and output of the NAND gate, the resistor causes this section of *IC2* to be biased in its unstable state. Positive feedback through *HS1* results in oscillation of the circuit at a frequency that is determined by the RC time constant of the capacitance of *HS1* and the value of *R1*. In this particular arrangement, with the specified value for *R1*, frequency of oscillation is about 8 kHz.

In a similar manner, *IC2C* and *IC2D*, also wired in a multivibrator configuration, develop an oscillator signal of a frequency determined by the values of *R2* and the sum of *C4*, *C5* and *C6*. Since pin 6 of *IC2B* is connected to both inputs of *IC2C*, the two discrete oscillator circuits are forced into synchronization. This results in both circuits operating at the same frequency but with different duty cycles.

In Fig. 3 are shown the waveforms that appear at the outputs of *IC2B* and *IC2D*. Note that the duty cycles of the two waveforms are not equal in length. This is because the values of capacitance used in the two oscillator circuits are different.

Referring back to Fig. 1, you will note that the four sections that make up *IC3* are wired in parallel with each other. This is to provide a lower output impedance than can be obtained from just a single section of this chip. The inputs of *IC3* perform a NAND operation on the outputs of *IC2*. As a result, the pulse width of the output waveform is the difference in duty cycles of the two oscillator circuits.

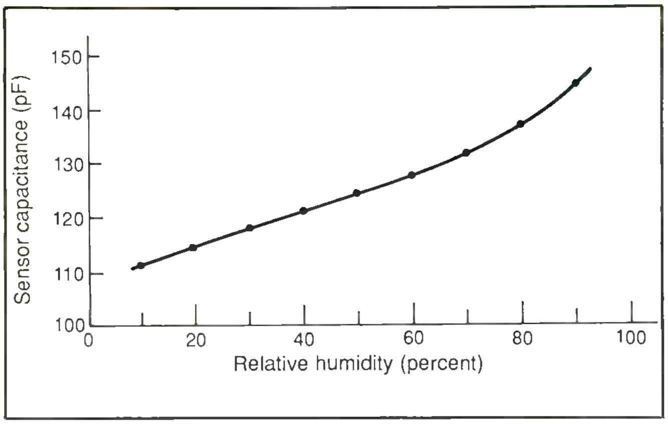
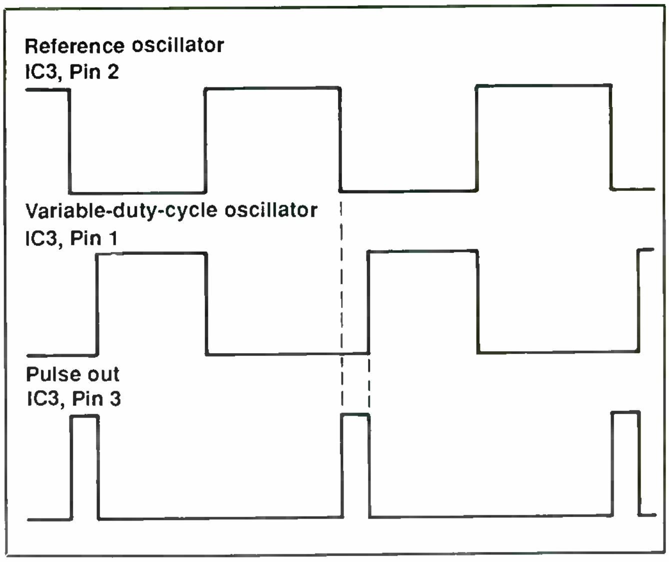


Fig. 2. Variations in sensor capacitance vs. relative humidity.

Fig. 3. The waveforms that appear at the outputs IC2B and IC2D.



Total capacitance of *C4*, *C5* and *C6* is adjusted to equal the capacitance of *HS1*, which is about 118 picofarads when the relative humidity is zero. Under this condition, the duty cycle of each oscillator is essentially equal and the output of *IC2* is a pulse train of very narrow spikes.

When relative humidity is greater than zero, the resulting increase in sensor capacitance and change of duty cycle of the oscillator built around *IC2A* and *IC2B* causes the width of the output pulse from *IC3* to increase. In this manner, pulse duration becomes a function of relative humidity.

The average value of the output pulse from *IC3* is stored in *C8*, which is charged through *D1*, *R4* and *R5*. This dc voltage is calibrated using potentiometer *R4*. It will vary from almost zero at zero percent humidity to about 1.25 volts at 100 percent relative humidity.

Any voltage developed across *C8* can be directly used to drive a 50-microampere analog meter movement through a suitable-value limiting resistor, as shown in Fig. 4. This will provide you with an analog indication of relative humidity with a scale range of zero to 100 percent.

Since sensor *HS1* does not have a straight-line response of capacitance-versus-humidity (see Fig. 2), it is necessary to add a small amount of current, through *R6*, into *C8* to linearize the circuit. This results in the output voltage across *C8* to be a linear function of relative humidity detected by the sensor.

Integrated circuits *IC4* and *IC5* are LED bar and dot driver chips that are capable of each driving 10 LEDs. Each of these ICs contains a voltage-divider string and 10 comparator circuits that provide detection of 10 levels of voltage fed to input pin 5. The two chips are wired in cascade so that 20 voltage levels can be detected and a total of 20 LEDs can be driven. In this project, only 17 LEDs are required to represent levels of humidity from 10 to 90 percent in 5-percent increments. The two chips are programmed to operate in the "dot" mode, which means that only one LED will be on at any given moment.

Pin 7 of *IC5* generates a 1.25-volt reference that is fed to the top of its built-in voltage divider string at pin 6 of *IC5*. The bottom of the string connects to circuit ground at pin 4 of *IC4*. This circuit arrangement permits the cascaded LED driver chips to detect potential levels from 0 to 1.25 volts in increments of 62.5 millivolts. When a voltage is detected, either of the chips lights the LED that most closely represents the voltage fed to pin 5. The illuminated LED then indicates the relative humidity within 5 percent.

The project is powered by 9-volt transistor radio battery *B1*, which frees you from dependency on ac line power. The output voltage from the battery will decrease as time goes by and the project is used. To preserve humidity-reading accuracy of the hygrometer, the terminal potential of *B1* is regulated to 4 volts by means of fixed regulator *IC1*. This means that the circuit will operate properly over the useful lifetime of the battery, which is virtually depleted by the time its terminal voltage decreases to about 5.5 volts. Since the battery is normally called upon to deliver current for only brief periods of time as you take a humidity reading, it should last a very long time.

If you wish to have a continuous display of relative humidity, you will want to power the project from the ac line to obviate having to frequently replace spent batteries. The circuitry for this option is illustrated schematically in Fig. 5.

Construction

With the exception of the 17 LEDs, the entire circuitry of the Relative

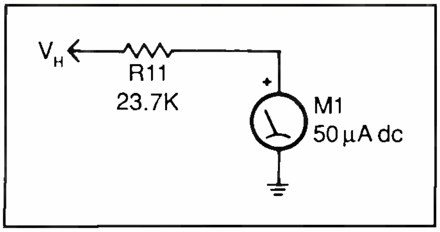


Fig. 4. Optional analog microammeter movement can be used in place of individual LEDs for display.

Humidity Meter wires together on a single compact circuit board. You can use a printed-circuit board for this, home fabricated using the actual-size etching-and-drilling guide shown in Fig. 6, 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 perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Whichever method you choose, be sure to use sockets for all DIP ICs.

From this point onward, we will assume printed-circuit construction. Place the ready-to-wire board on your work surface oriented as shown in Fig. 7. (Note: If you elect perforated-board construction, use Fig. 7 as a rough guide to component placement and orientation.) Begin wiring the board by installing and soldering into place the sockets. Do *not* plug the ICs into the sockets until after you have conducted preliminary voltage checks and are certain that the circuit has been properly wired.

Next, carefully following Fig. 7, install and solder into place the resistors and trimmer potentiometer *R4*. Note that some resistors are precision metal-film types. These are used in the circuit to ensure that calibration of the hygrometer does not change with changes in temperature and component aging. Make sure you install these resistors in the correct locations on the board.

Continue wiring the board by installing and soldering into place the diode and capacitors. Do not use ordinary ceramic-disc capacitors for *C4* and *C5*. The values of these two capacitors affect calibration of the hygrometer. The best choice for *C4* and *C5* is silver mica or NPO ceramic-disc units that have very low temperature coefficients. Before soldering the leads of the diode and electrolytic capacitors into place, make sure each of these components is properly oriented.

Next, install and solder into place voltage regulator *IC1*. Make sure this device is properly based before soldering its leads into place. If you are including in your project the optional ac-operated power supply, install *C9*, *D2* and *D3*. Make sure each of these components is properly oriented before soldering their leads to the copper pads on the bottom of the board. Similarly, if you are including the analog meter-movement option, install and solder into place *R11*.

Do *not* mount or handle humidity sensor *HS1* until you are instructed to do so later during checkout. Keep this fragile component in a safe place until it is ready to be installed.

If you elected to use the analog meter-movement feature, connect the microammeter to the circuit in accordance with Fig. 4. LED drivers *IC4* and *IC5* and the LEDs are not used in this version of the project and should be omitted.

Assuming you are building the version that does include the LED display, you can use 17 discrete light-emitting diodes or LED assemblies that contain five or more individually accessible light-emitting diodes in a single package. The lead photo shows the project built using discrete LEDs.

If you use the LED display, you will need a separate printed-circuit board (or perforated board with suitable hardware) on which to mount the LEDS and to wire to the main board. You can fabricate the board yourself using Fig. 8(A) or buy a ready-to-wire board from the source given in the Note at the end of the Parts List.

When the board is ready, install and solder into place the 17 LEDs. Make sure each LED is properly oriented and that the top of its case is a uniform ½-inch height above the surface of the board before soldering its leads into place.

Interconnect the two circuit-board assemblies as detailed in Fig. 7 and Fig. 8(B), using suitable length light-gauge stranded hookup wires. After cutting all wires to length, strip ¼ inch of insulation from both ends. Tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. Plug one end of the wires into the holes for them in the main circuit board from the component side and solder into place. Then plug the free ends of the wires into the appropriate holes in the display board from the solder side and solder into place.

Tightly twist together the fine wires at the unfinished ends of both leads of a 9-volt battery snap connec-

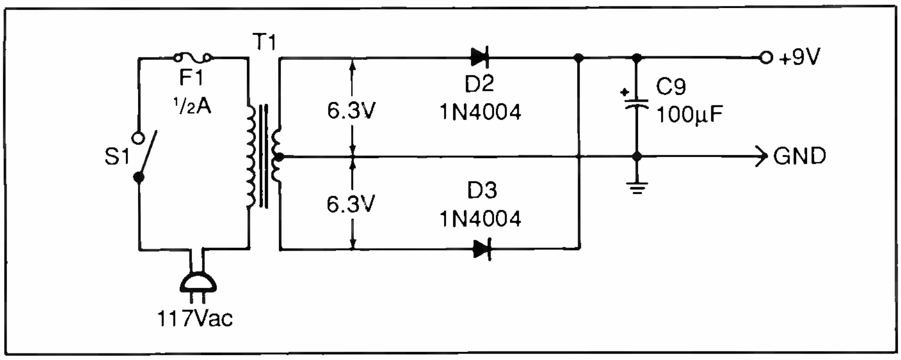


Fig. 5. Schematic diagram of optional ac-operated power supply.

tor and sparingly tin with solder. Plug the leads into the B1+ (red insulation) and B1– (black insulation) holes in the main circuit board and solder into place.

Strip ¼ inch of insulation from both ends of two 5-inch hookup wires. If you are using stranded wire, tightly twist together the fine conductors at both ends of both wires and sparingly tin with solder. Plug one end of these wires into the holes labeled *S1* on the main circuit board. Crimp and solder the other ends of these wires to the lugs on *S1*. This can be a momentary-action, normally-open pushbutton switch for the battery-powered version of the project or a standard miniature toggle or slide switch if you want continuous humidity display when using an ac-operated power supply.

If you plan on using the ac power supply, prepare two more 5-inch-long wires as described above. Plug one end of these wires into the holes labeled *T1* on the main board and solder into place.

You can house the project in any type of enclosure that will accommodate both circuit-board assemblies without interference with each other. Machine the enclosure as needed. That is, drill mounting holes for both circuit-board assemblies (just the main board if you opted for an analog meter-movement display). Then make the cutout for the LED display or meter movement and drill mounting holes for the battery clip and switch.

If you decided to incorporate the ac power supply into your project, also drill a hole for the jack that mates with the plug-in ac wall transformer. Also, drill a dozen or so small holes through the wall of the enclosure near where *HS1* will be when the circuit-board assembly is mounted in place to permit ambient air to enter the enclosure.

If you are using a metal enclosure or have drilled holes through or cut a slot in a metal panel, remove any sharp burrs. Glue a clear red plastic filter over the cutout for the LED display. As the glue sets, examine both circuit-board assemblies for proper component installations, especially orientations.

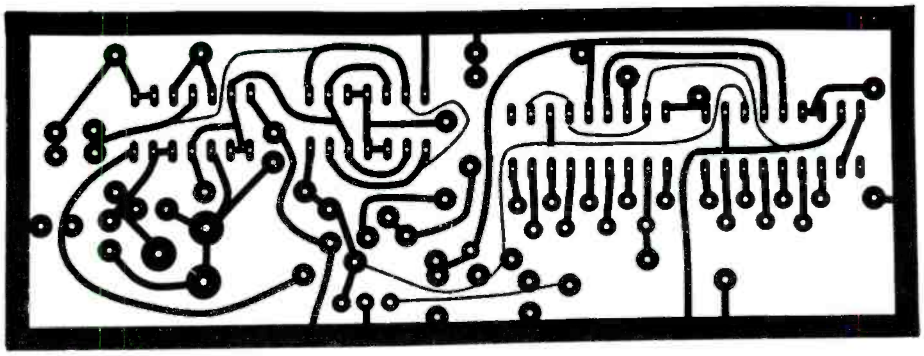


Fig. 6. Actual-size etching-and-drilling guide for the main printed-circuit board.

Turn over both circuit-board assemblies and carefully check all soldering. If you missed a connection, solder it; if a connection looks suspicious, reflow the solder on it and add solder if needed; and if you locate a solder bridge—particularly between the closely spaced IC socket pads—remove it with desoldering braid or a vacuum-type desoldering tool.

When you are satisfied that your wiring and soldering are okay, mount the display in the cutout using ½-inch spacers with a lockwasher at each end and 4-40 × ¾-inch machine screws and nuts. Also use ½-inch spacers to mount the main circuit-board assembly to the floor of the enclosure.

If you are using the ac-operated power supply, mount the jack for it in its hole and crimp and solder the free ends of the wires coming from the T1 holes on the main board to the lugs of the jack. Be sure to observe proper polarity as you do this. Then mount the battery clip with suitable machine hardware via the hole you drilled for it and the switch in its hole with the hardware supplied with it.

Checkout & Calibration

To check out the project, you need a dc voltmeter or multimeter set to the dc-volts function. You will also need 118- and 159-picofarad test capacitors upon which the accuracy of calibration will depend. These are not standard capacitor values, but you can make the capacitors you need by connecting in parallel two or more capacitors of different values. Just

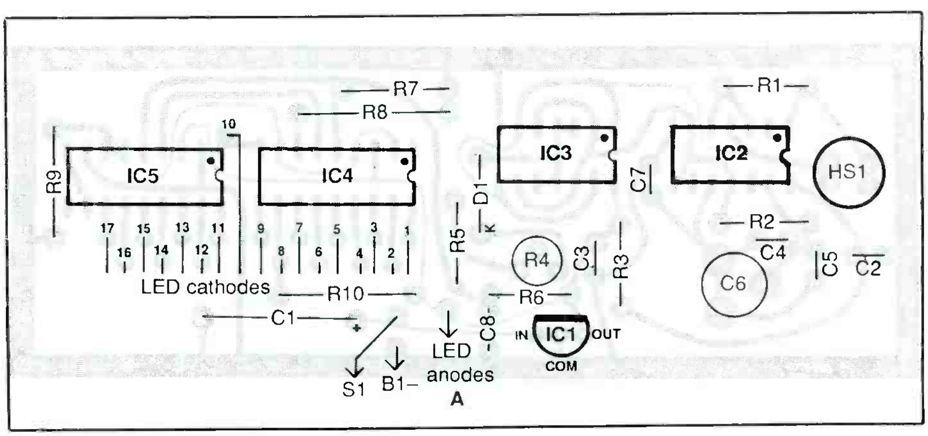


Fig. 7. Wiring guide for main pc board.

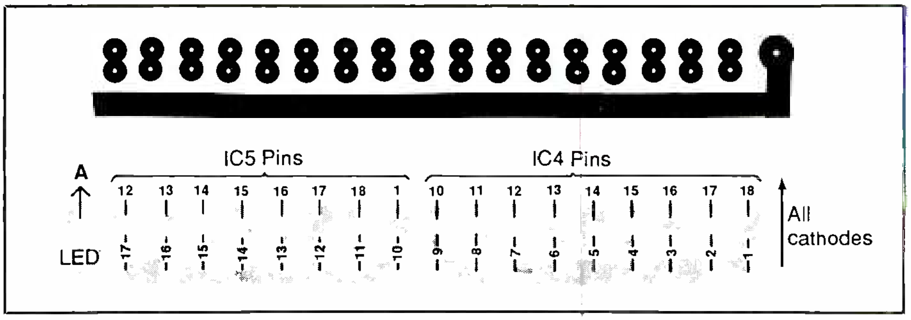


Fig. 8. Actual-size etching-and-drilling guide (A) and wiring guide (B) for display board.

keep in mind that the effective total capacitance of two or more values in parallel is the sum of the values. Use 2-percent precision capacitors for this arrangement.

An alternative method of obtaining test capacitors of the required values is to parallel connect a fixed-value and a variable capacitor. If you have access to a capacitance bridge, you can use it to measure the total value of capacitance as you adjust the trimmer capacitor for the appropriate value.

Connect the 118-picofarad capacitor to the main circuit-board assembly where sensor *HS1* is to be located, using one set of copper pads. The other set of pads is reserved for the sensor, which will be wired into the circuit later on.

Clip the common lead of the meter to any convenient point that is at circuit ground, such as the negative (−) lead of *C1*. Then snap a fresh 9-volt battery into the snap connector or plug the transformer into the project and a convenient ac receptacle.

Apply power to the project and measure the voltage at the OUT lead of regulator *IC1* with the "hot" probe of the meter. Use a jumper lead to temporarily bridge the lugs of the switch to apply power continuously to simplify checkout. You should obtain a reading of +4 volts. If not, power down the circuit and troubleshoot it to isolate the cause of the problem and correct it.

Begin troubleshooting by measuring the resistance between the +4-volt regulated supply rail and circuit ground to make sure that a short circuit does not exist. Then check the orientations of *C1* and *IC1* and measure the terminal voltage of the battery if you are using it to make sure the battery is not depleted. The circuit will operate properly as long as the battery can supply at least 5.5 volts to the regulator, measured under operating conditions.

The next step in the procedure is to check out the display section. For this, it is necessary to plug *IC4* and *IC5* into their sockets. Be sure to observe proper orientation and to avoid having any pins overhang the sockets or folding under between ICs and sockets. You also need a source of positive dc voltage that is adjustable from 0 to 1.5 volts. A suitable regulated dc power supply can be used, or you can temporarily connect a 10,000-ohm potentiometer across *C1* and use the wiper terminal as the variable voltage source.

Connect the positive side of the variable-voltage source to the junction between *R6* and *R7*. This is the pin 5 inputs of the LED driver ICs. Set the voltage of the supply to zero. Then apply power to the project and measure the voltage, referenced to ground, at pin 6 or 7 of *IC5*. You should obtain a reading of about +1.2 to +1.3 volts at this point. Record this reading.

Connect the "hot" probe of the dc voltmeter (or multimeter) to the junction of *R6* and *R7* and very slowly vary the adjustable dc source so that the voltage increases from zero to the potential you recorded. As you do this, the LEDs should light in sequence from 10 to 90 percent.

As the voltage crosses over any two sequential indications, you will note that one LED will fade out as the next one turns on. This feature is built into the driver chips to assure that at least one LED will be lighted at a time over the voltage-detection span of the circuit. You will also note that at the extremes of the voltage excursion no LED will be on since the indicating range of the hygrometer is limited to 10 percent humidity at the low end and 90 percent humidity at the high end.

If you do not obtain the above response, check the LEDs to be sure that all are wired into the circuit in the proper polarity. Check the anodes of the LEDs and pin 3 of *IC4* and *IC5* for the presence of +4 volts. Check pin 5 of the ICs for the variable dc input voltage, and make sure that the ICs are properly oriented in the sockets.

Next, set trimmer capacitor *C6* and scale calibration potentiometer *R4* as follows. Plug the remaining two ICs into their sockets, observing the same details described above for the other ICs. Check to make sure that the 118-picofarad test capacitor is soldered to the circuit board.

Connect the "hot" lead of the voltmeter to the junction formed by *R5* and *C8* and the common lead to the negative lead of *C1*. Set the meter to a low range, apply power to the circuit and adjust *C6* for a minimum reading—about +0.1 volt.

Turn off the hygrometer and connect the 159-picofarad capacitor in place of the 118-picofarad unit. Reapply power to the circuit and set *R4* to obtain a reading on the meter equal to that you recorded earlier.

If you do not obtain the results specified above, it is best to troubleshoot the circuit using an oscilloscope. Examine the circuit waveforms to verify that both multivibrators are oscillating. When *C6* is properly set and 118-picofarad test capacitor is installed, the waveforms at pins 1 and 2 of *IC3* will be approximately square and 180 degrees out-of-phase with each other.

If either or both multivibrators are not oscillating, check the wiring associated with *IC2* and *IC3* for short- or open-circuits. Also, check the values of circuit components to be sure that they are correct, and check the orientation of *D1*. If all check out, try new ICs in the circuit.

For the final adjustment, you need a calibrated source of relative humidity. One way to make this adjustment is to obtain an *accurate* hygrometer to measure the ambient humidity level and calibrate *C6* accordingly. If you use this method, simply install *HS1* on the main circuit-board assembly in place of the test capacitor (*HS1* is not polarity sensitive), apply power to the circuit and adjust *C6* so that the display indicates the relative humidity level as measured by another hygrometer. It is best if you choose a day that has a relative humidity level of 40 to 60 percent to obtain the most accurate adjustment.

A more accurate method of calibrating *C6* is to place the sensor in an enclosed environment that contains a known level of humidity. Remove the test capacitor from the circuit, and connect the sensor into the circuit using about 6-inch-long leads. Dissolve some potassium carbonate in a jar half filled with water.

Place the sensor in the jar, taking care to avoid having it touch the solution. Cover the top of the jar so that the humidity level inside the jar reaches its final value, which will be 44 percent at room temperature. Adjust *C6* so that the 45% LED lights.

Remove the temporary wires that connect the sensor to the circuit-board assembly and place the sensor on the board. Calibration of the project is complete. **ME**

A Smart Weather Monitor

(Part III)

How the project's A/D Memory Expansion and Keyboard modules work

By Tom Fox

In the first two installments of this article, we described operation, construction and initial tests of the CPU and Display/Output modules, the two basic elements that make up this sophisticated stand-alone system. This time around, our focus is on operation and construction of the two modules that remain to complete the system, an A/D (analog-to-digital) Memory Expander and a data-entry/command Keyboard.

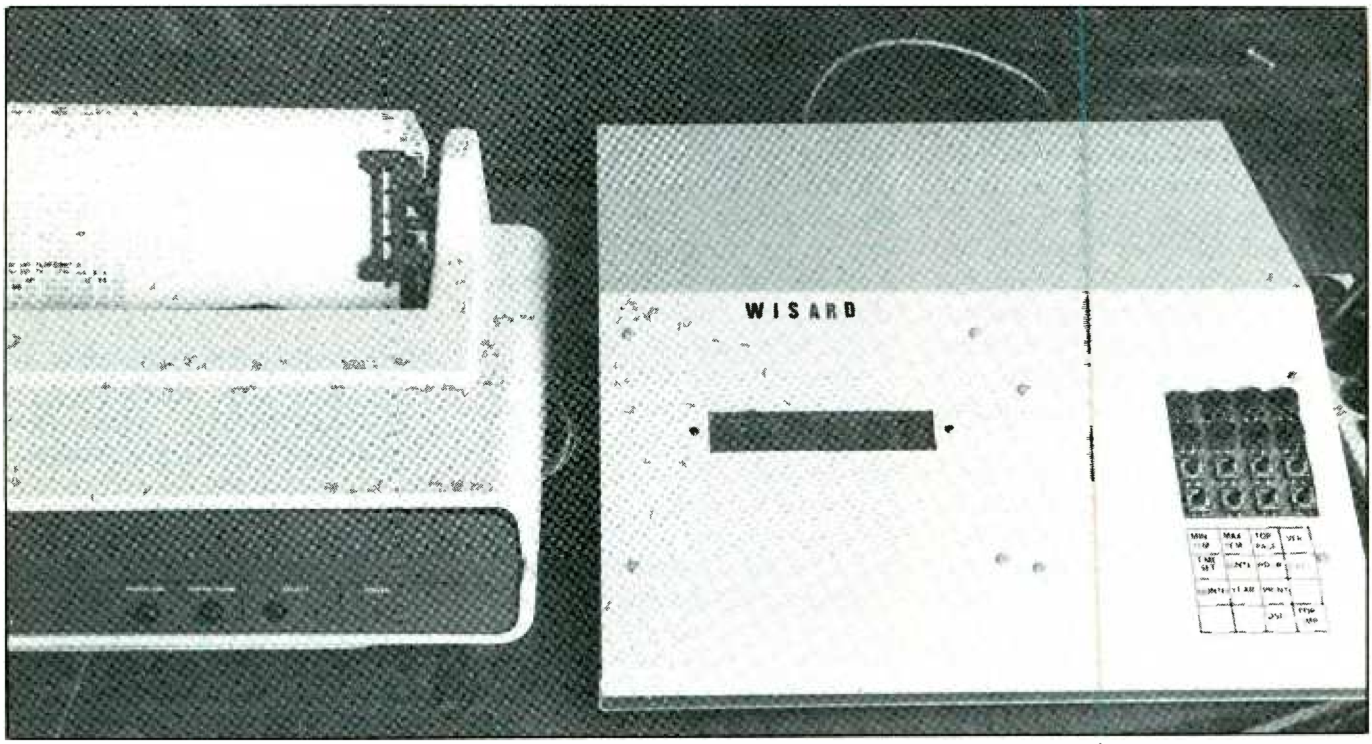
About the Circuits

The primary purpose of the A/D (analog-to-digital) memory-expansion module is to provide the calibration and interfacing circuitry needed to supply the CPU module with temperature information in a form it understands. A secondary purpose of the A/D module is to provide memory expansion. The A/D module can accommodate six general-purpose analog inputs, in addition to the two temperature sensors.

Shown in Fig. 9 is the complete schematic diagram of the circuitry used in the A/D memory-expansion module. Temperature forecasting firmware for the project is programmed into 2732A EPROM *IC207*. Optional "user" EPROM *IC202* can be employed *without* having to modify the other firmware in the system. To make it possible to use the 2716 EPROM, position 1 of DIP switch *S1* must be set to OFF. This permits simple and inexpensive customizing of WISARD and permits some educational possibilities.

A back-up battery is provided for 2K CMOS static RAM *IC201*. When it is installed in the project, this chip expands WISARD's non-volatile user RAM from its basic 8K to a total of 10K.

Notice that *IC210* in the A/D circuit is an eight-bit ADC0809 analog-



to-digital converter with an eight-channel multiplexer. Though this chip can accommodate up to eight different analog inputs, it can handle only one analog input at a time because it contains just one A/D converter. Nevertheless, being able to convert all eight inputs into digital form in less than a hundredth of a second, operation of the multiplexer is invisible in human terms.

Response of the A/D converter chip is to addresses 5000H through 5007H, decoding for which is accomplished primarily by *IC203*, *IC204* and *IC206*. The A/D converter has an internal three-bit address decoder that selects a particular input channel. (Address lines A0, A1 and A2 are connected to the internal address latch and decoder of *IC210*. A write operation to address 0101 0000 0000 0001 or 5001H, for example, selects pin 27, connected to the calibration circuit of temperature sensor *TS1*.)

Operational amplifier *IC209* provides the reference and supply voltages for the A/D converter. (The ADC0809 requires only 1 milliampere of current for operation.) Operated here as a voltage-follower, the LM301 op amp is over-compensated to assure operating stability.

Precision voltage source *D209*, an LM239 device, provides an extremely stable 6.9 volts for use as a standard. The output of the voltage-follower is set by the trimmer control *R229*. (During calibration, this control is set to produce + 5.00 volts at pin 6 of *IC209*.)

Integrated circuit *IC210* is wired in this module for continuous A/D conversion. This is accomplished by connecting START input pin 6 to END-OF-CONVERSION output pin 7. To assure start-up, an external pulse is applied on power-up. This external pulse is

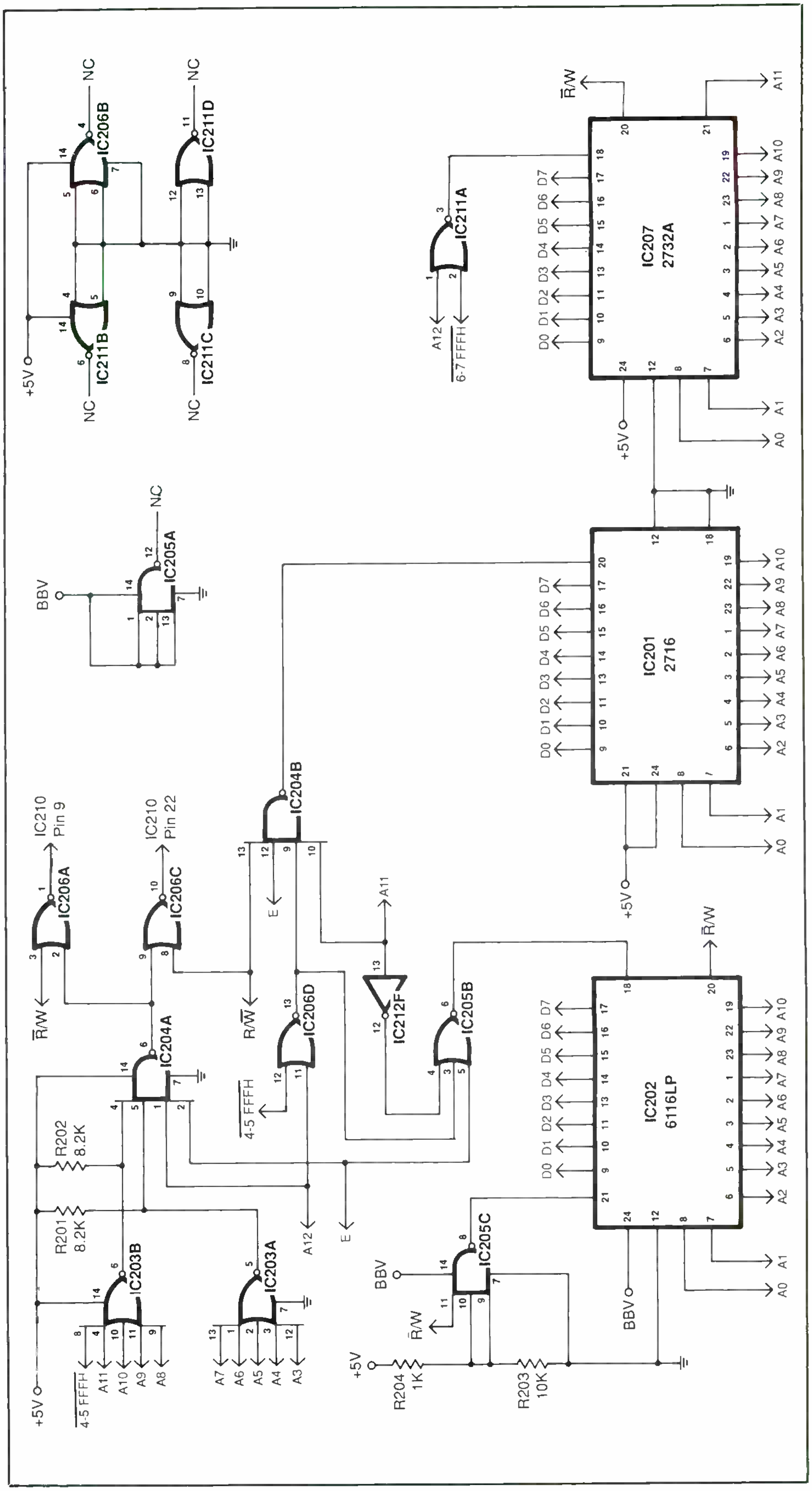
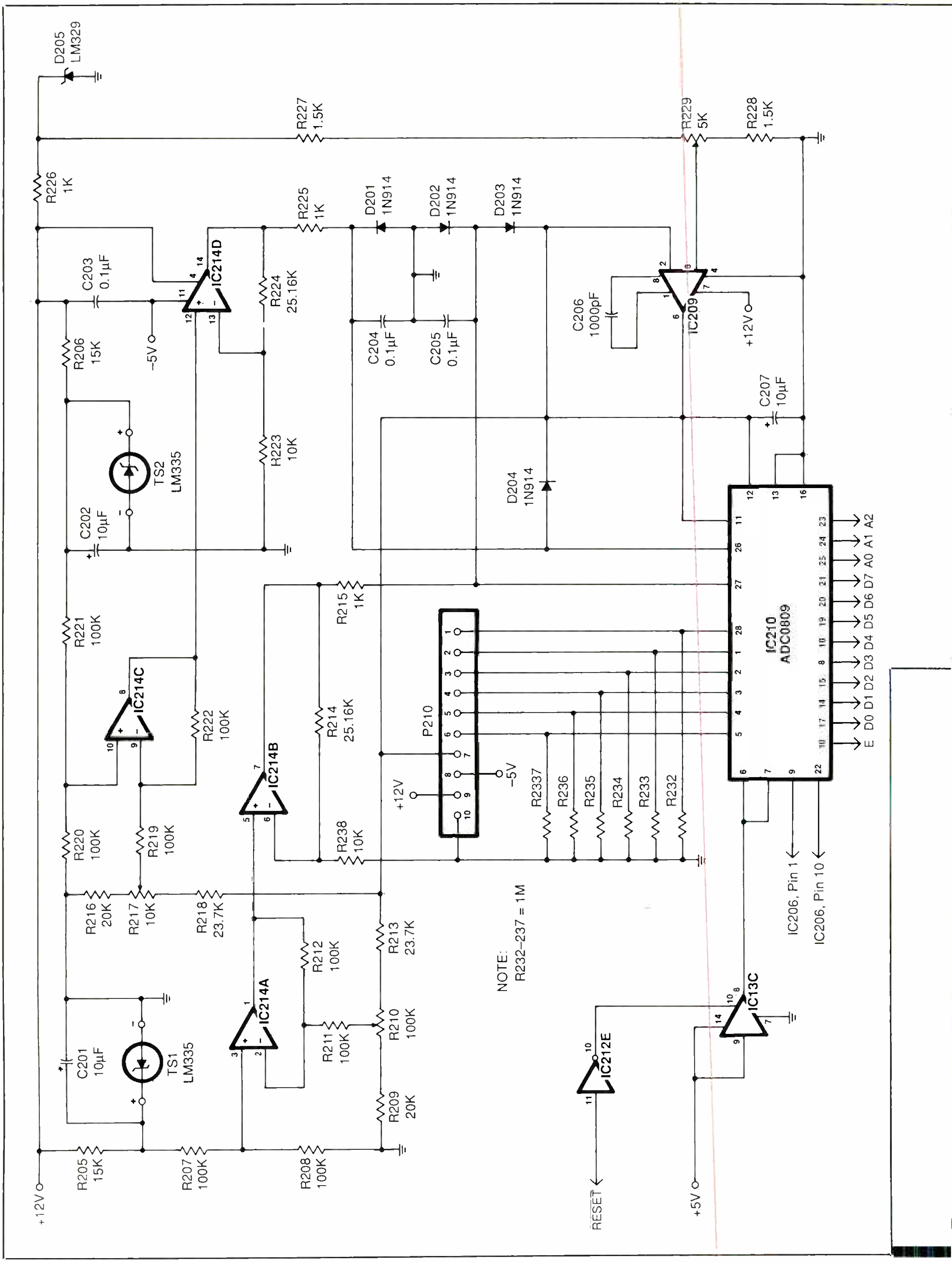
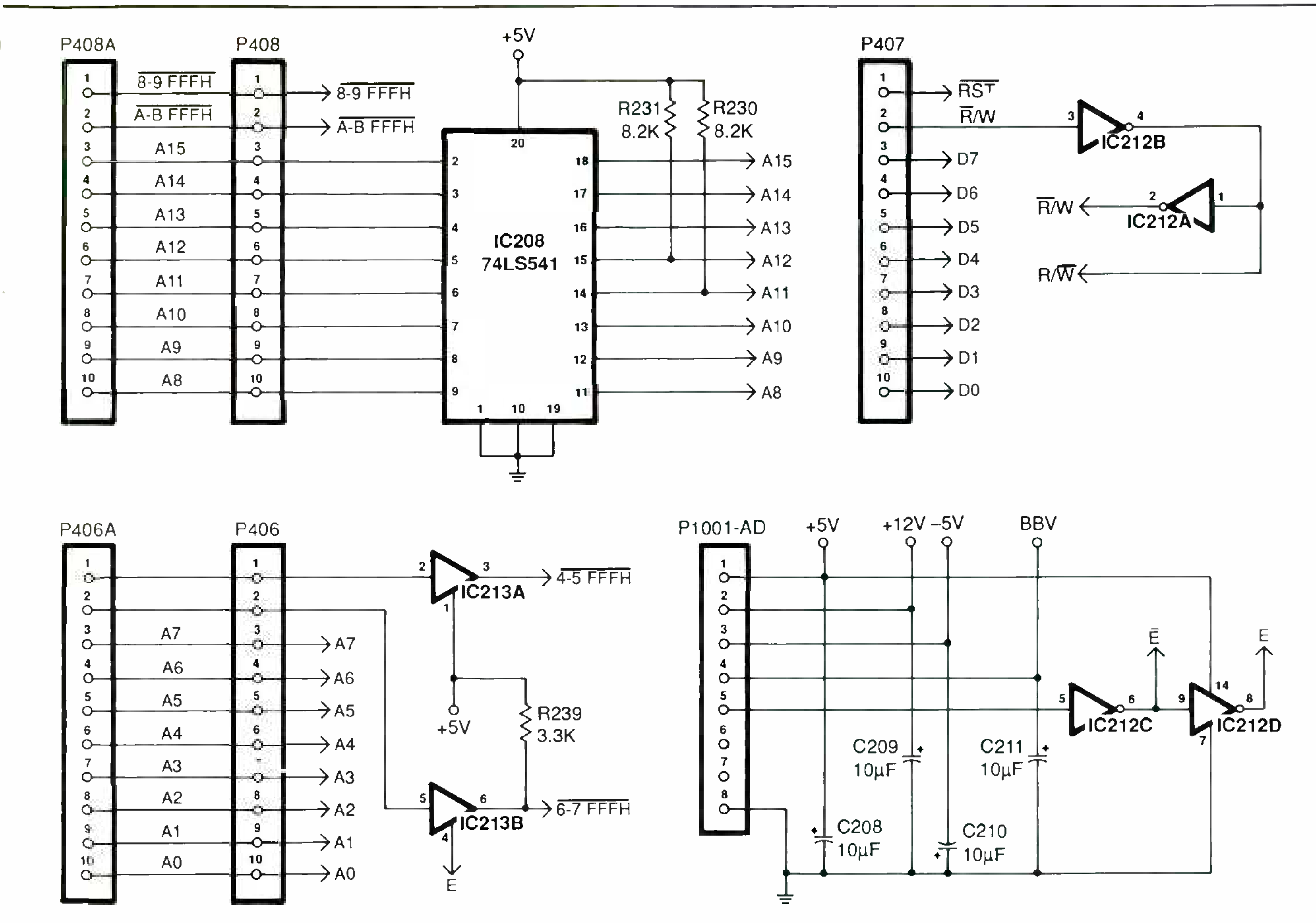


Fig. 9. Complete schematic diagram of A/D Memory Expansion module circuitry.


D205 LM329
R227 1.5K
R229 5K
R228 1.5K
R226 1K
R225 1K
D201 1N914
D202 1N914
D203 1N914
C203 0.1µF
IC214D
R224 25.16K
C206 1000pF
IC209
+12V
C204 0.1µF
C205 0.1µF
R206 15K
-5V
C207 10µF
TS2 LM335
R223 10K
D204 1N914
C202 10µF
R221 100K
R215 1K
IC210 ADC0809
IC214C
R222 100K
R214 25.16K
P210
IC214B
-5V
+12V
R2337
R236
R235
R234
R233
R232
A2 A1 A0 D7 D6 D5 D4 D3 D2 D1 D0 E
R220 100K
R219 100K
R238 10K
R216 20K
R217 10K
R218 23.7K
R212 100K
R213 23.7K
NOTE: R232–237 = 1M
IC206, Pin 1
IC206, Pin 10
IC214A
R211 100K
R210 100K
IC13C
C201 10µF
TS1 LM335
R209 20K
IC212E
R205 15K
R207 100K
R208 100K
+12V
RESET
+5V



obtained by connecting the inverted reset pulse to the ENABLE pin of three-state buffer *IC213*. The "normal" input of this buffer is connected to the + 5-volt rail.

The 614.4-kHz ENABLE line from the CPU module connects to CLOCK input pin 10 of *IC210*. You can use the A/D module to convert up to six analog inputs of your choice to digital form. These "freebie" inputs wire to connector to *P210*. One-megohm resistors identified as *R232* through *R237* reduce the possibility of an electrical charge building up on an unused input. If external inputs are made to the inputs, these resistors can be eliminated.

Also connected to *P210* are the − 5V and + 12V supply lines, circuit ground and the + 5.00V reference lines. These lines make life a bit easier for those people who wish to expand the basic project.

Two reference pins are available on *IC210*. These are pins 16 and 12, which are the $-V_{ref}$ and $+V_{ref}$ inputs. In this circuit configuration, pin 16 is tied to ground (0.0 volt) and pin 12 is tied to pin 11, which is connected to a stable and accurate + 5.00-volt source. With this arrangement, an input of + 5.00 volts will result in a binary 11111111 or decimal 255 or hex FF output. An input of 0.0 volt results in a digital output of 00000000, or simply zero. The smallest standard step the A/D converter circuit can make is one LSB, which corresponds to 5/256 or 0.001953 volt.

Temperature sensors *TS1* and *TS2* are precision integrated-circuit LM-335 devices. They can be viewed as zener diodes whose "zener potential" is linearly related to temperature. Though MCU-based instruments aren't fussy about linearity (they can compensate for nonlinearities in their firmware), using an intrinsically linear sensor does help in simplifying matters. In addition to outstanding accuracy, the LM335 is commonly available and inexpensive.

While the LM335 is a simple component around which to design, it isn't so simple that you just hook one up to an A/D converter and expect the firmware to do all the rationalization! A bit more is needed to give WISARD a full temperature range capability. With a $-V_{ref}$ at circuit ground potential, the lowest temperature to be measured is converted to 0.00 volt. Also, with a $+V_{ref}$ set at + 5.00 volts, the maximum temperature is converted to + 5.00 volts.

According to published specifications, the LM335 has an operating temperature range from −40° to 100° C (−40° to 212° F). Consequently, if 1 LSB is specified to correspond to 1° F and the lowest tem-

PARTS LIST (A/D Module)

Semiconductors
D201 thru D204—1N914 or similar diode
D205—LM329 precision voltage reference
IC201—2716 EPROM (optional—see text)
IC202—6116LP static RAM (optional—see text)
IC203—74LS260 dual 5-input NOR gate
IC204—74HC20 dual 4-input NAND gate
IC205—74HC10 triple 3-input NAND gate
IC206—74HC02 quad 2-input NOR gate
IC207—2732A EPROM (programmed, see Note below)
IC208—74LS541 octal buffer with 3-state outputs
IC209—LM301 operational amplifier
IC210—ADC0809 8-bit A/D converter with multiplexed inputs
IC211—74HC32 quad 2-input OR gate
IC212—74HCT04 TTL-compatible CMOS hex inverter
IC213—74LS126 quad buffer with three-state output
IC214—LM324 quad low-power operational amplifier
IC215,IC216—LM335Z precision temperature sensor

Capacitors
C201,C202,C208 thru C211—10-μF, 25-volt electrolytic
C203,C204,C205,C212 thru C218—0.1-μF, 50-volt monolithic ceramic
C206—1,000-pF, 100-volt monolithic ceramic
C207—10-μF, 25-volt solid tantalum

Resistors (¼-watt, 5% tolerance)
R201,R202,R230,R231—8,200 ohms
R203—10,000 ohms
R204,R215,R225,R226—1,000 ohms
R205,R206—15,000 ohms
R207,R208,R211,R212,R219 thru R222—100,000 ohms
R209,R216—20,000 ohms
R227,R228—1,500 ohms
R232 thru R237—1 megohm
R239—3,300 ohms
R213,R218—23,700 ohms, 1% tolerance
R214,R224—25,160 ohms, 1% tolerance
R223,R238—10,000 ohms, 1% tolerance
R210,R217—10,000-ohm vertical pc-mount trimmer potentiometer
R229—5,000-ohm, 15-turn pc-mount trimmer potentiometer

Miscellaneous
P210,P406A,P408A—10-pin single-row male header with 0.1-inch spacing (Digi-Key Part No. 929834-01-36)
P406,P407,P408—10-pin single-row male header with 0.1-inch spacing (Digi-Key Part No. 929834-03-36-solder or 929647-03-36-gold
P1001AD—8-pin 0.156-inch center header (Digi-Key Part No. WM4406 or WM4606)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware; suitable enclosure (see text); cable and connectors for power-supply hookup (see text); sockets for all DIP ICs; cables and connectors for temperature, moisture and light sensors; heat-shrinkable tubing; machine hardware; hookup wire; etc.

Note: The following items are available from Magicland, 4380 S. Gordon, Fremont, MI 49412: complete No. ADME1 kit of A/D module parts, including pc board, 6116 RAM, 2715 without programming, all ICs, sensors, DIP IC sockets and connectors but not including programmed 2732A EPROM, \$65; Set No. PRAD89 of 16 precision resistors, \$5; programmed 27128 EPROM, \$18, programmed 2732A EPROM, \$12, (both programmed EPROMs, \$25); No. 680-ADM double-sided A/D pc board with plated-through holes, \$22.00; for part number 680X-ADM-2.

perature to be measured is −40° F, the maximum temperature (in Fahrenheit) that can be measured with a single byte of data is 256° − 41° + 215°. This is just a shade beyond the recommended maximum of 212° F. (Actually, the specs state that the sensor can take temperatures up to 257° F for short periods of time.) Therefore, −40° to 215° F appears to be a common-sense choice for the temperature range.

The data sheet for this device also reveals that 0.01 volt corresponds to 1° Kelvin, which is the same as Celsius. So 2.73 volts corresponds to 0°C, which implies −40°C (−40°F) corresponds to 2.73° − 0.40 = 2.33 volts. Using this information, the first step is to design a circuit that has a 0.00-volt output when its input is 2.33 volts. This can be done with a symmetric unity-gain differential amplifier that has 2.33 volts applied to its inverting input.

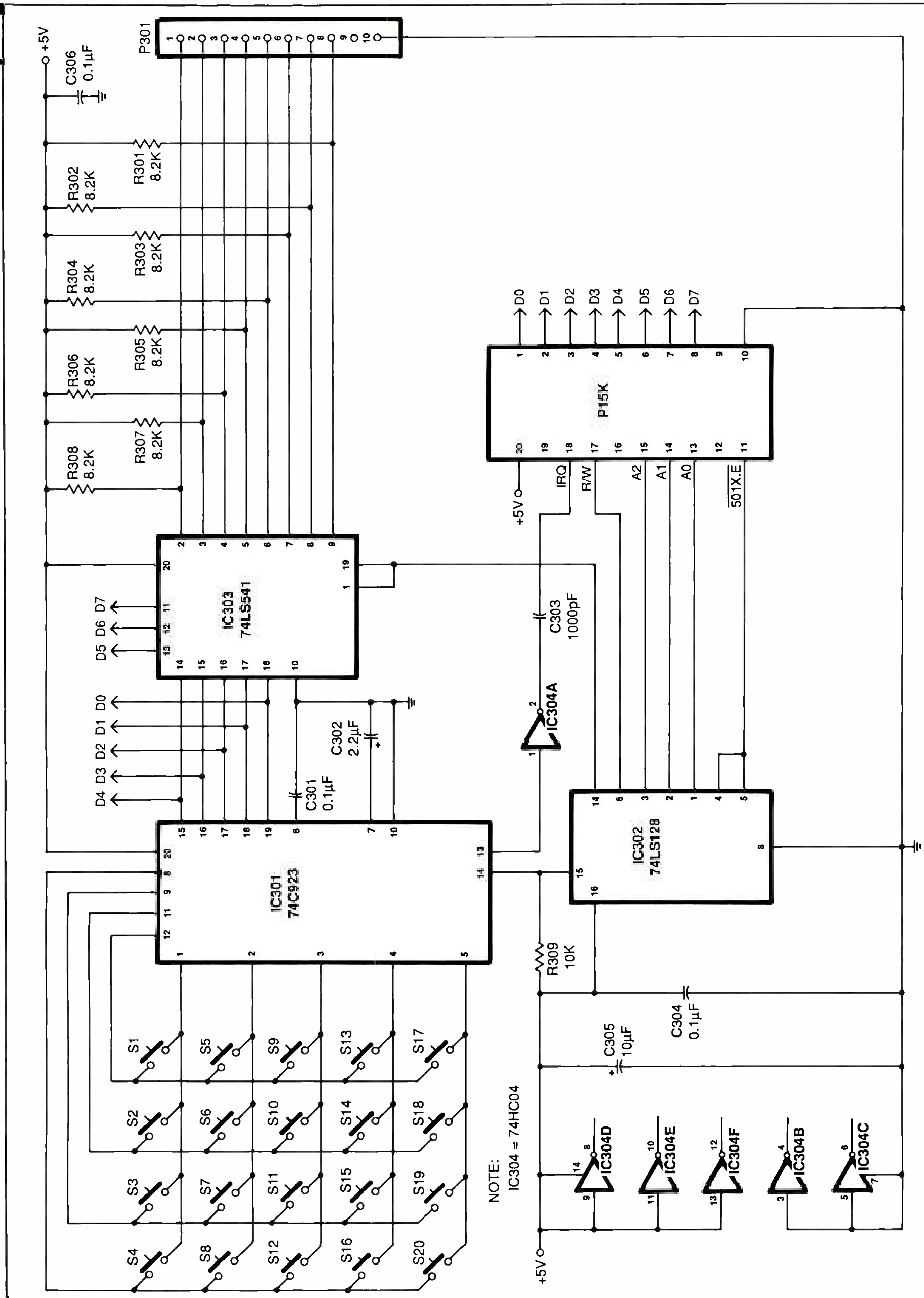
The circuitry for the above for *TS1* is shown in Fig. 9 as one op amp in *IC214* and resistors *R207* through *R213*. When *R210* is properly adjusted the voltage at its wiper terminal should be close to 2.33 volts referenced to ground.

The next step is to design a circuit that multiplies this referenced-to-ground voltage by a factor that has an output of 5.00 volts when *TS1* is heated to 215° F. A non-inverting amplifier with a gain of 3.516 accomplishes this admirably. Such a circuit is made up of another op amp in *IC214* and precision resistors *R214* and *R238*.

Circuitry for temperature sensor *TS2* is handled in an identical manner as that for *TS1*. Diodes *D201* through *D204* protect the inputs of *IC210* from extremes of voltages, while capacitors *C204* and *C205* reduce electrical noise noise.

Address decoding for optional

Fig. 10. Complete schematic diagram of Keyboard module circuitry.


P301
+5V
C306 0.1μF
R301 8.2K
R302 8.2K
R303 8.2K
R304 8.2K
R305 8.2K
R306 8.2K
R307 8.2K
R308 8.2K
D0 D1 D2 D3 D4 D5 D6 D7
P15K
IRQ
R/W
A2
A1
A0
501X.E
IC303 74LS541
C303 1000pF
IC304A
C302 2.2μF
C301 0.1μF
IC302 74LS128
IC301 74C923
R309 10K
C304 0.1μF
C305 10μF
NOTE: IC304 = 74HC04
IC304D
IC304E
IC304F
IC304B
IC304C
S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17 S18 S19 S20

PARTS LIST (Keyboard)

Semiconductors

IC301—74C923 20-key keyboard encoder

IC302—74LS138 3-of-8 decoder

IC303—74LS541 octal buffer with 3-state outputs

IC304—74HC04 hex inverter

Capacitors

C301,C304,C306—0.1-μF, 50-volt monolithic ceramic

C302—2.2-μF, 25volt tantalum

C303—1,000-pF, 100-volt monolithic ceramic

C305—10-μF, 25-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R301 thru R308—8,200 ohms

R309—10,000 ohms

Miscellaneous

P15K-K—20-pin dual-row male header with holes on 0.1" centers (Digi-Key Cat. No. 929836-01-36, solder plated, or No. 929665-01-36, gold plated

P301—10-pin single-row male header with 0.1" hole spacing (Digi-Key Cat. No. 929834-01-36)

S1 thru S20—Momentary-action s.p.s.t. switch (pc board accommodates Panasonic Part No. EVQ-PYR12K, Digi-Key Cat. No. P9952; only 13 switches are used by ME1 firmware); cable to connect Keyboard to CPU board (Digi-Key Cat. No. R8322-18-ND); printed-circuit board; sockets for all ICs; machine hardware; hookup wire; solder; etc.

Note: If you have any questions about WISARD, write to: Tom Fox, Magicland, 4380 S. Gordon, Fremont, MI 49412; include a self-addressed stamped envelope for reply.

2716 EPROM *IC201* is carried out by *IC204*, *IC206* and *IC212*. This EPROM responds to addresses 4800H through 4FFFH. (Recall that the 4-5FFFH address line that originates in the CPU module is low whenever hex addresses 4000 through 5FFFH appear on the address bus).

The temperature-forecasting firmware is contained in *IC207*. This 2732 EPROM responds to addresses 6000H through 6FFFH. Address decoding for this chip is accomplished with *IC211*. Integrated circuits *IC205*, *IC206* and *IC212* perform the required address decoding for the optional 2K CMOS static RAM. NAND gate *IC205C* and resistors *R203* and *R204* make up a write-protection circuit that eliminates the possibility of an erroneous write to *IC202* during a power shutdown.

Having dealt with the A/D Memory Expansion module, turn now to the schematic diagram of the Keyboard Module circuit shown in Fig. 10. The simplicity of this circuit is due primarily to *IC301*, a 74C923 20-key encoder chip that uses the IRQ pin of the MCU to "announce" a switch closure.

When a key is pressed DATA AVAILABLE line pin 13 of *IC301* goes high. After inversion by *IC304A*, the signal couples through *C303* to the IRQ line. In essence, a negative pulse appears at the IRQ pin of the MCU when a key is first pressed. Upon receipt of the Interrupt Request, the MCU program jumps to a switch routine that reads the data at address 5010H, assigned to *IC301*.

The program checks data lines D0 through D4 to determine which switch was pressed. The program continues from there. Capacitor *C301* determines the "scan" rate of the chip. With the specified 0.1-microfarad value for *C301*, the scan rate is about 800 Hz. Capacitor *C302* sets the debounce period of the circuit at about 35 milliseconds.

Three-state octal buffer *IC303* provides additional switches that are polled by the MCU and do not make use of the Interrupt Request line. Connected to *P301*, these switches can be used as supplementary option switches. When a read calls address 5011H, pins 1 and 19 of *IC303* go low, enabling all of the buffers in this integrated circuit. When this occurs, the data at *P301* transfers to the data bus. Address decoding for *IC301* and *IC303* is accomplished by 74LS138 3-to 8 line decoder *IC302*.

Function assignments for each of the keys that make up the keyboard are detailed in Fig. 11. Notice that only 13 keys are used by WISARD. This leaves seven keys for future growth of the project.

S4 VERSION 3	S3 TOP PAGE 2	S2 MAX. TEMP 1	S1 MIN. TEMP 0
S8 DAY 7	S7 HOUR 6	S6 MINUTE 5	S5 TIME SET 4
S12 * B	S11 PRINT A	S10 YEAR 9	S9 MONTH 8
S16 FORECAST TEMP F	S15 DISPLAY E	S14 * D	S13 * C
S20 * 13	S19 * 12	S18 * 11	S17 * 13

Fig. 11. Drawing shows functions assigned to each key in Keyboard module. Keyswitch locations shown with asterisks have no assigned functions and can be eliminated for sake of economy.

Coming Up

This completes our discussion of the operation of the A/D Expansion and Keyboard modules. Next month, we will present details on wiring of these two circuit-board assemblies and fabrication of the light and heat sensor/cable arrangements used with the project. We will also give details on chassis construction.

In the concluding installment of this series, which will be presented in the October issue, we will discuss placement of the sensors to obtain the most accurate and reliable readings, getting WISARD up and running and expansion of the basic project with hardware and software modifications. **ME**

More Piezoelectric Experiments

By Forrest M. Mims III

Last month's column covered basic piezoelectric principles, materials and applications. In addition, we experimented with a unique piezoelectric fan that has no rotating or frictional parts. This month, we'll conclude this two-part examination of piezoelectronics by experimenting with piezoelectric high-voltage trip hammers and sound disks. We'll also take a close look at a remarkable piezoelectric clear plastic film.

Piezoelectric High-Voltage Sources

Piezoelectric trip hammers provide ignition sparks for gas heaters, cigarette lighters, outdoor gas-type barbecue grills and gas lanterns. Hand-held piezoelectric sparkers are used to ignite pilot lights in gas furnaces and stoves and even the burners of hot-air balloons.

You can perform many interesting experiments with a piezoelectric high-voltage trip hammer. Trip hammers made by Vernitron Piezoelectric Division for use in outdoor barbecue grills generate about 18,000 volts when tripped. The active element is a small cylindrical slug of piezoelectric ceramic that measures only about ⅝ × ³⁄₁₆ inch. This slug is installed at one end of a plastic cylinder, the remainder of which contains a plastic rod, a pair of springs and a cam and hammer.

When a push button at the end of the rod is pressed, the upper spring is compressed against the hammer. Initially, a small pin resting against a plastic shoulder holds the hammer securely in place. As the button is pressed farther down, however, a cam gradually moves the pin away from the retaining shoulder.

When the pin moves off the shoulder, the hammer is released. It then strikes the piezoelectric slug with great force to produce an 18,000-volt spike. The second spring in the igniter, compressed by the downward motion of the hammer, pushes the hammer back to its resting position when the push button is released.

You may be able to purchase replacement piezoelectric igniters from stores that sell or/and service outdoor gas cookers. (Another possible source is your local Sears store—Ed.) A cheaper alternative is to salvage the piezoelectric trip hammer mechanism from a cigarette lighter that is equipped with a piezoelectric igniter.

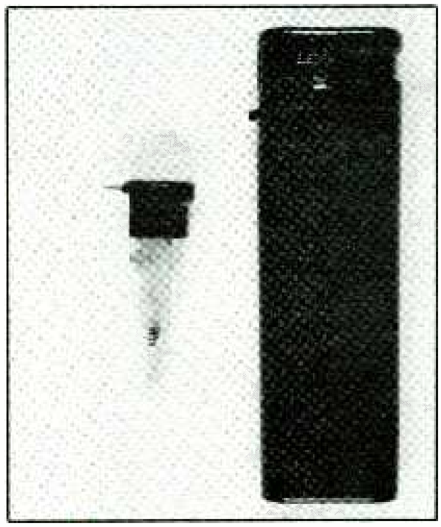


Fig. 1. A disposable cigarette lighter shown alongside the piezoelectric trip hammer that supplies the ignition spark.

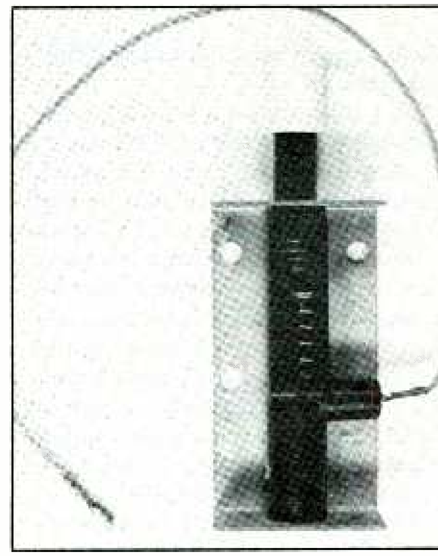


Fig. 2. A Vernitron piezoelectric sparker for outdoor gas barbecue grills.

Figure 1 is a photo of a Scripto Electra cigarette lighter alongside the piezoelectric trip-hammer mechanism that it contains. The piezoelectric slug inside the trip hammer measures less than ³⁄₁₆ inch on a side yet is capable of producing around 15,000 volts!

Shown in Fig. 2 is an older piezoelectric pushbutton with which I have experimented for several years, the Vernitron Model 3652. Figure 3 identifies the main components of this device. Note that this sparker is equipped with a single wire lead. A spark is generated between the end of this lead and the metal frame that holds the pushbutton assembly.

Piezoelectric igniters used in cigarette lighters have small metal terminals instead of leads. Be sure to use wire with high-voltage insulation if you connect an additional lead or leads to a piezoelectric pushbutton.

You can easily view the high-voltage arc produced by a piezoelectric igniter like the one pictured in Fig. 2. Mount the discharge wire so that its bare end is within ⅛ inch of the frame of the igniter. For best results, operate the device in subdued light, and place dark paper behind

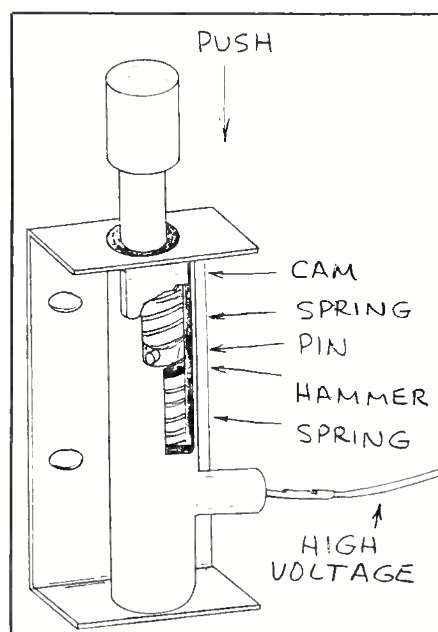


Fig. 3. Annotated drawing of the piezoelectric sparker shown in Fig. 2.

the discharge point to obtain a better view of the spark.

Each time you press the trip-hammer button, a spark should jump between the discharge wire and frame. Try moving the discharge wire farther away from the frame to increase the length of the spark.

You may have to modify this procedure for other kinds of trip hammers. For example, the miniature units used in cigarette lighters have no wire leads. You can use ordinary alligator-clip leads to make connection to the discharge point at the top end of the hammer and the metal terminal along the side of the hammer. The leads must not touch each other.

An interesting experiment to perform is to discharge a piezoelectric trip hammer through a xenon flash tube. Use clip leads to connect the discharge terminals of the tube to the trip hammer. When you actuate the trip hammer, a thin violet arc will discharge between the two electrodes inside the tube. There is no need to apply a voltage to the trigger terminal of the tube since the voltage produced by the trip hammer far exceeds the breakdown potential of xenon.

Caution: Be careful when experimenting with any high-voltage source, including piezoelectric trip hammers! The discharge from a piezoelectric trip hammer can produce a potent tingle. While this in itself may cause no harm, it may startle you or cause an involuntary muscle reflex action. Protect yourself from an accidental shock by working on an insulated work surface and using well-insulated connection wires. If you use only one hand at a time, you'll avoid a shock through your body.

Piezoelectric Sound Sources

Such piezoelectric sound transducers as phonograph pickups and microphones have been in use for many years. The high-frequency audio drivers known as "tweeters" often have a piezoelectric driver element. Various kinds of buzzers, warblers and sirens have become by far the most common users of piezoelectric audio transducers.

Most of these piezoelectric sound sources are made by bonding a thin disk of piezoelectric ceramic to a circular metal plate. When an alternating voltage is applied to the element, the ceramic becomes alternately concave and convex. This mechanical movement is amplified by the metal plate. The result is a sound wave that has the frequency of the applied signal.

Piezoelectric sound sources weigh only a few grams, but they can produce sound levels of from 60 to 90 decibels. When housed inside an enclosure that directs the sound into a directional beam, the sound pressure level can exceed an audibly painful 110 decibels.

As you might expect, piezoelectric sound generators have a particular resonant frequency at which they produce their highest sound level. They often resonate well at harmonic frequencies, and even at non-resonant frequencies can produce substantial sound pressure levels.

Figure 4 shows the output from a typical piezoelectric sound generator, MuRata's No. PKM11-4AO. As expected, this graph shows that the sound generator works much better over some narrow frequency ranges. It also shows that the device produces usable sound over a wide audio spectrum.

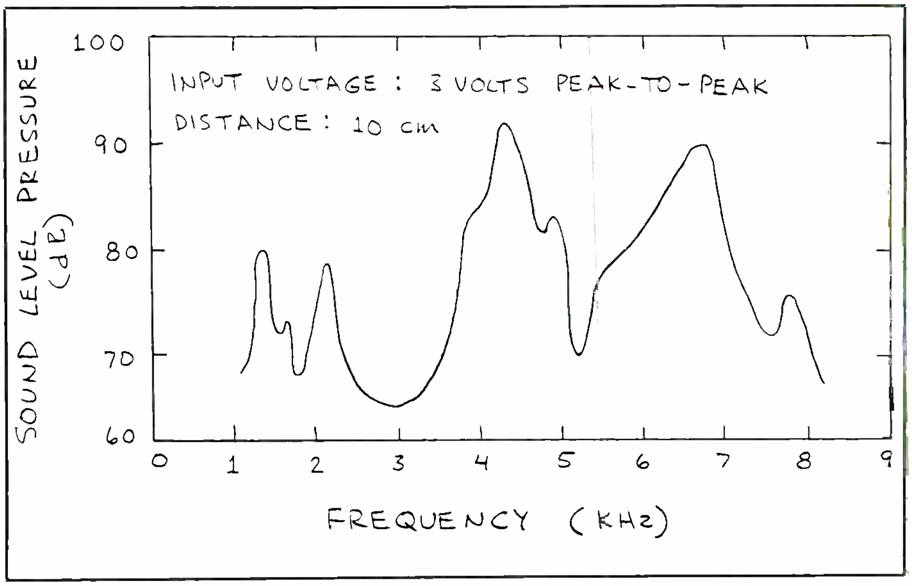


Fig. 4. Sound pressure output of MuRata No. PKM11-4AO piezoelectric disk.

If you have experimented with piezoelectric sound sources, you've probably noticed that they can produce a very long pure tone. While this tone is ideal for warning and notification purposes, it can be annoying. Moreover, very pure audio tones can establish regions of constructive and destructive interference within a room that has smooth walls and little sound-absorbing material.

As you walk through such a room in which a piezoelectric sound disk is operating, you'll notice distinct changes in the amplitude of the sound. In regions of destructive interference, the sound level is substantially lower than in other areas. These regions can have very sharp boundaries and can be very small. Many times, I've noticed that moving my head a small fraction of an inch will cause a substantial change in the sound pressure level produced by a sound disk.

For optimum results, it is important that you mount a piezoelectric sound generator properly. To illustrate why this is so, I made a series of photographs of a sound disk that I connected to a signal generator. First I poured some white beach sand over the disk, as shown in Fig. 5(A). I then switched on the signal generator and noticed that, almost immediate-

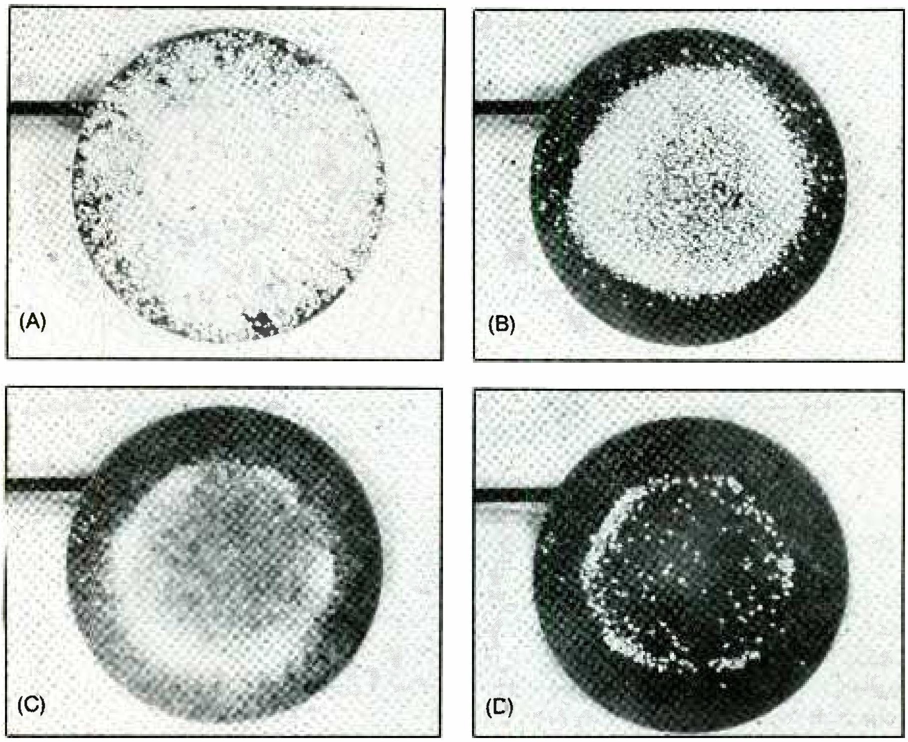


Fig. 5. A piezoelectric disk (A) silent and covered with sand; (B) a few moments after the driving signal is applied; (C) with sand vibrating away from center; and (D) the ring of sand that marks the annular mode of the disk.

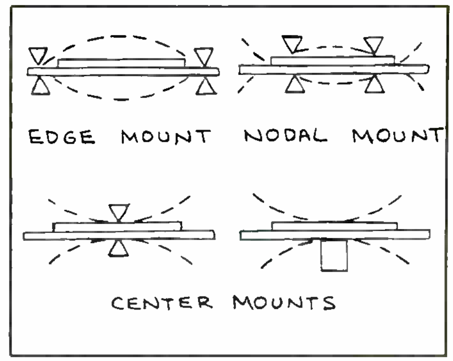


Fig. 6. Mounting arrangements for piezoelectric buzzer elements.

ly, the sand around the perimeter of the disk flew up and away from the disk, as shown in Fig. 5(B).

When I increased the amplitude level of the drive signal, the sand at the center of the disk began violently bouncing, as illustrated in Fig. 5(C). After several seconds, most of the sand in the center of the disk had bounced away, leaving behind the thin ring of sand shown in Fig. 5(D). This ring marks the annular node of the disk. This is the region of the disk that doesn't vibrate when the disk is driven by an oscillating frequency. This region can serve as one of several mounting points for the disk.

It is very important to mount a piezoelectric disk properly. If the vibrating portion of the disk is cemented or attached to a mounting support, the sound produced will be severely attenuated.

Shown in Fig. 6 are several methods that can be used to mount a piezoelectric sound disk. The nodal mount takes advantage of the non-vibrating, circular node shown in Fig. 5(D). The edge mount permits the entire disk to vibrate. The two center mounting methods illustrated in Fig. 6 permit the outer rim of the disk to freely vibrate.

Many different circuits can be used to drive piezoelectric sound disks. The nature of the drive circuit is dependent upon the design of the the sound disk's electrodes. Figure 7 shows both a standard sound disk and a disk that has a third electrode known as a feedback tab. The feedback tab produces a small voltage when the disk moves in response to a signal applied to the main electrodes.

Shown in Fig. 8 is the schematic diagram of a single-transistor driver circuit that can be used to drive disks that have a feedback electrode. Figure 9 is the schematic diagram of a standard oscillator built around a 555 timer chip that will drive both standard sound disks and disks that have feedback tabs.

You can better understand the operation of the feedback electrode with the help of the circuit whose schematic diagram is shown in Fig. 9. Connect the anode of a light-emitting diode to the unused feedback tab of the sound disk. When the driver circuit is switched on and the sound disk is emitting sound, the LED will emit a dim glow.

If you try this experiment, remember that the anode of the LED connects to only the feedback tab. There is *no* electrical connection between the feedback tab and the other electrodes on the sound disk. The LED is powered solely by the piezoelectricity generated by the ceramic in the vicinity of the feedback tab. This simple demonstration shows how a piezoelectric slab can be used as a solid-state signal isolator or transformer.

You need to be aware of some basic operating precautions that must be observed as you work with or use piezoelectric sound sources. The very high sound level produced by many of these devices can be annoying at best and dangerous to hearing at worst. You can reduce the sound level of a piezoelectric disk by reducing the amplitude of the drive signal. If the sound disk is installed inside a plastic housing, you can reduce the level of the sound by blocking the opening with tape, putty or clay.

A second precaution that must be observed is based upon the fact that piezo-

ELECTRONICS NOTEBOOK...

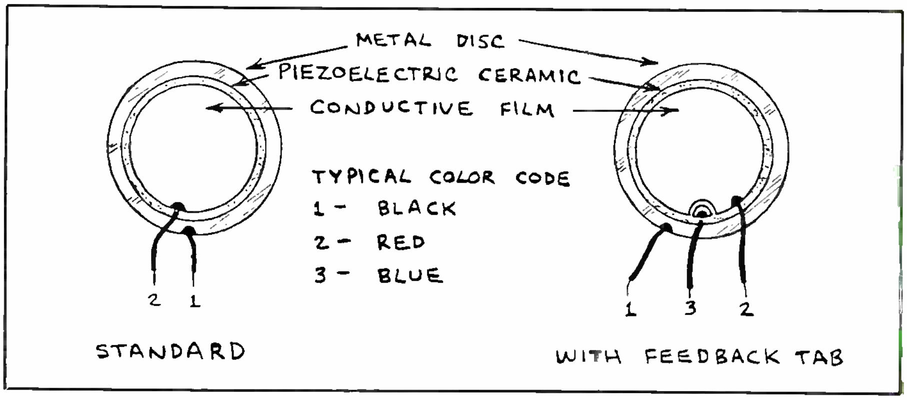


Fig. 7. Typical piezoelectric sound disks.

electric sound disks can produce a substantial voltage when they are subjected to mechanical shock or vibration. If great enough, this voltage can damage the drive circuitry. Proper mounting of a sound disk will reduce the chance of a mechanical shock of the kind that may produce a high-voltage spike. Connecting a zener diode across a sound disk will short-circuit any voltage that exceeds the breakdown voltage of the diode.

Piezoelectric Plastic Film

Piezoelectric plastic film is used in switches, microphones, speakers, earphones and in guitar and other stringed-instrument pickups. The material is also used in sensors that detect pressure, vibration, impact, liquid level and infrared radiation. It is also used to make motorless fans, ink-jet pumps and optical shutters. In fact, piezoelectric film has so many potential applications that it's impossible to describe all or even most of them in these pages.

As the sheet of piezoelectric plastic film shown in Fig. 10 clearly reveals, piezoelectric plastics and ceramics have little in common. Ceramics are rigid, brittle and restricted in size. Plastic films are flexible and can have very large surface areas. These films can be cut or stamped into many different shapes, and they can easily be laminated or incorporated into many different materials, including fabrics, plastics, wood and metal. Piezo-

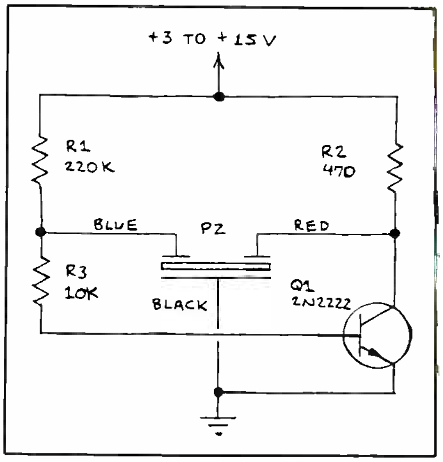


Fig. 8. Schematic diagram of a single-transistor piezoelectric buzzer driver.

electric ceramics produce greater voltages than do films, but the latter is more sensitive to pressure and can withstand higher voltages.

The Kynar Piezo Film Department of the Pennwalt Corp. (P.O. Box 799, Valley Forge, PA 19482) manufactures polyvinylidene-fluoride (PVDF) piezoelectric film under the Kynar registered trademark. Kynar film is tough, flexible and transparent.

Pennwalt manufactures Kynar film in continuous sheets up to 3,000 feet in length and in various complex shapes. The company supplies the material with various kinds of screen-printed and sputtered conductive electrodes.

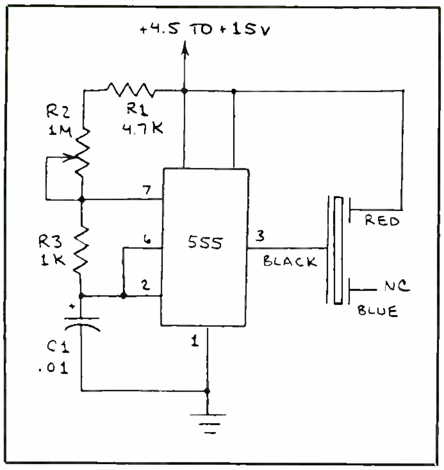


Fig. 9. Schematic diagram of a piezoelectric buzzer driver circuit built around the popular 555 timer chip.

Pennwalt sells many different kinds of piezoelectric components, including small rectangles of Kynar with and without attached wire leads, vibration detectors and bimorphs. A 15 × 20-mm sheet of Kynar without wire leads, which can be added for $2, costs only 50 cents. A bimorph with attached leads costs $15. The company also sells a variety of demonstration kits that include complete instructions and Kynar components. Shown in Fig. 11 is the Basic Design Kit made by Pennwatt.

For detailed information about these and other components and kits, write the company at the address given above. If you decide to place an order with Pennwalt, keep in mind that the company has a $50 minimum.

Experimenting With Kynar Film

Shown in Fig. 12 are some samples of Kynar film with which I have experimented. The small sample that has no electrodes was included in some literature sent to me by Pennwalt. It was taped to a card that describes several experiments that can be performed to quickly convince even a skeptic that Kynar has lots of potential applications.

The simplest experiment that can be conducted involves connecting the Kynar sample to an oscilloscope with a pair of clip leads. When you touch the film or press it against something, the scope indicates a fluctuating voltage waveform. When you breathe on the film, the scope also displays a fluctuating voltage waveform. This illustrates the pyroelectric property of the film.

A xenon strobe or flashbulb produces a much greater output. I used a plastic infrared Fresnel lens purchased from Edmund Scientific Co. to increase the detection range of the film. It detected my hand at a distance of several feet.

Another simple experiment that can be conducted with the sample piece of Kynar film involves connecting it to the output of a signal generator. In this experiment, the film will emit a clear tone as the generator is swept across the audible range of frequencies. If you don't have a signal generator, you can use a radio. Alternatively, you can build a simple oscillator using a 555 timer chip and use this to drive the Kynar sample.

You can obtain greater sound levels by taping the Kynar sample to an index card or even an inflated balloon. Another way to boost the level of the sound emitted by the Kynar film is to connect a step-up transformer between the signal generator and the Kynar sample. I've used a standard 117-to-6.3-volt power transformer for step-up purposes with good results.

A miniature high-voltage dc-to-dc converter transformer like those used in photographic strobe lights also works well as a step-up device. You can salvage dc-to-dc converter transformers from defective strobe units. Otherwise, you can purchase a brand new one for only $2 from The Electronic Gold Mine (P.O. Box 5408, Scottsdale, AZ). With this company, your minimum purchase order is $10; so get the company's catalog before you decide to place an order.

Incidentally, even very small pieces of Kynar film will function as sound sources. For example, I used scissors to cut a 0.25-inch square of Kynar film and used this to generate sound. Of course, the sound level was not nearly as great as that emitted by a larger sample, but the tiny piece of film did produce audible sound.

Another experiment you can conduct involves attaching the Kynar sample to an index card or a credit card with double-sided tape. In this experiment, the Kynar sample will generate a voltage when the

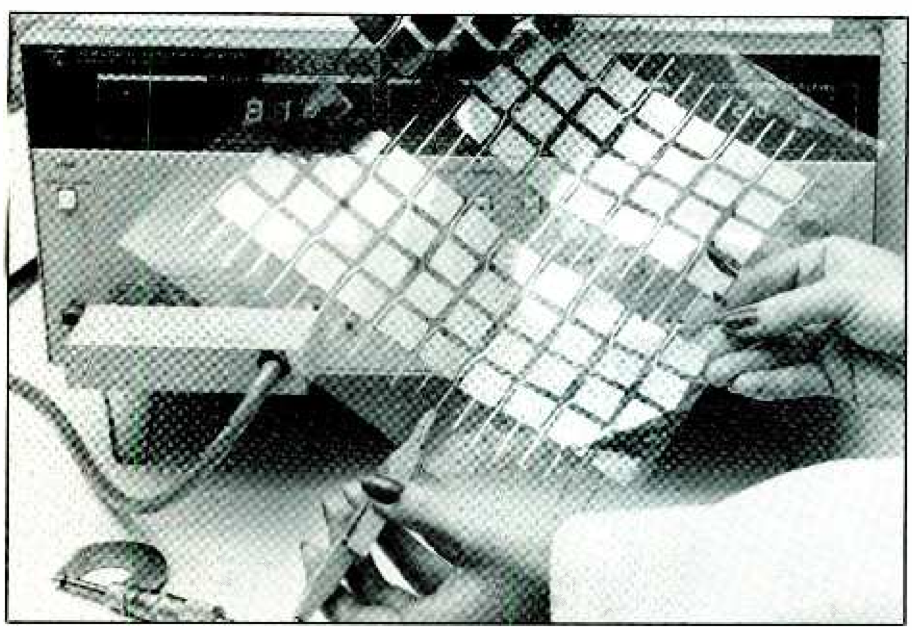


Fig. 10. Kynar flexible piezoelectric film. (Photo courtesy of Pennwalt Corp., Inc.)

Fig. 11. Kynar film demonstration kit. (Photo courtesy of Pennwalt Corp., Inc.)

card is bent in either direction. The polarity of the voltage depends on the direction in which the card is bent. This application illustrates how Kynar can be used as a strain gauge.

It's easy to make a Kynar microphone. Just connect a Kynar sample to the microphone jack of a small audio amplifier or tape recorder. If you want to be formal, tape each end of the Kynar sample to a business card, allowing the center of the sample to bow upward. Alternatively, simply allow the Kynar sample to hang from a pair of clip leads. In either case, the Kynar sample will function as a microphone.

You can increase the level of the signal generated by a Kynar microphone with a step-up transformer, as described above. The literature from Pennwalt suggests attaching the Kynar element to the bottom of a foam plastic drinking cup with double-sided tape.

You can make various kinds of switches with Kynar film. Kynar will generate a signal amplitude of up to 10 volts when it is struck by a domed snap button. Simply touching the film with a finger will also generate a voltage, though a smaller one.

Pennwalt's Kynar literature describes several interface circuits you can build. The material will directly drive liquid-crystal displays (LCDs) and CMOS circuits. It can also be connected to the inputs of operational amplifiers and comparators to serve as a drive signal source.

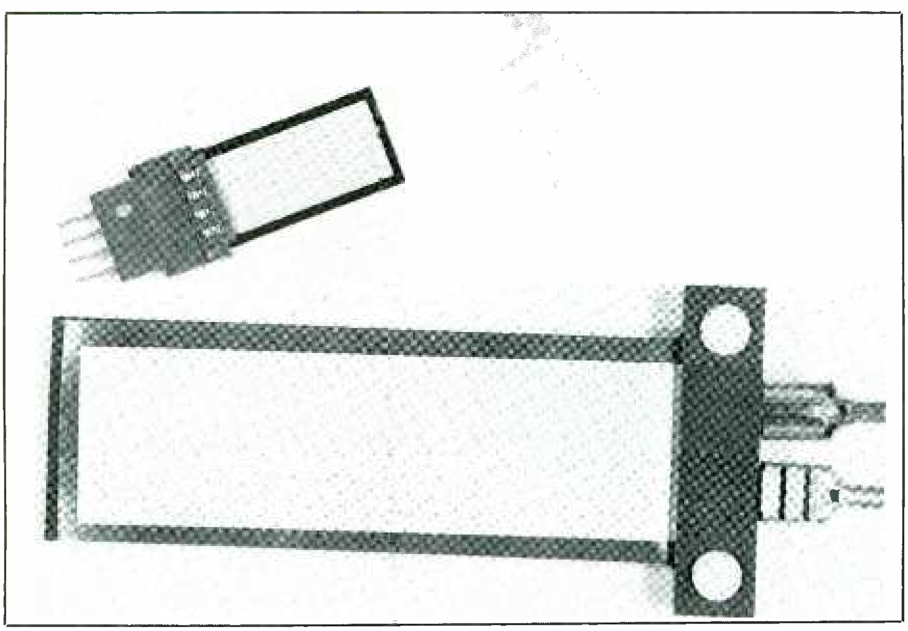


Fig. 12. Typical Kynar piezoelectric elements.

Going Further

If this two-part series about piezoelectricity has stimulated your interest, you'll undoubtedly want to read more on the subject. If you do, I direct you to the excellent literature on the subject available from some of the companies that manufacture piezoelectric materials. Literature published by Pennwalt, the manufacturer of Kynar plastic film, is particularly good. So are the various brochures and booklets published by Vernitron Piezoelectric Division (232 Forbes Rd., Bedford, OH 44146) and Burleigh Instruments (Burleigh Park, Fishers, NY 14553).

Many of the manufacturers of piezoelectric sound disks publish literature about their products. Especially good is the literature published by MuRata Erie North America, Inc. (2200 Lake Park Dr., Smyrna, GA 30080) and Projects Unlimited, Inc. (P.O. Box 14538, Dayton, OH 45414-2539).

Finally, more experimenter applications for piezoelectricity are included in *Forrest Mims' Circuit Scrapbook II* published by Howard W. Sams & Co., Inc. (1986); see especially pages 215 through 229 of this book. ME

SOLID-STATE DEVICES

Pyroelectric Infrared Sensors & a Power Operational Amplifier

By Joseph Desposito

A passive infrared detector works much like the human eye in that it is a one-way receiver. At the heart of this type of device is something called a ceramic pyroelectric infrared sensor. The sensor consists of an infrared detecting element and a low-noise impedance-matching circuit, both contained in a metal package with an infrared transmitting window.

The sensitive element is an electrically polarized ceramic slice with infrared transmitting metallic electrodes deposited on opposite faces. The pyroelectric nature of the ceramic causes the electrodes to produce an electrical output signal in response to changes in temperature. Sensors intended for movement detection have a daylight filter that ensures that the device is insensitive to short wavelength infrared, as emitted by the sun.

Electrically, a sensor can be represented by one or two capacitors (depending on whether it is a single- or dual-element device), an n-channel FET, and a non-linear network, connected as shown in Fig. 1. The dual-element devices have two differentially connected sensitive areas with a single impedance-converting amplifier to provide immunity from common-mode signals such as those generated by variations in ambient temperature, background radiation, and acoustic noise.

The pyroelectric ceramic material used in sensors developed by the Amperex Electronic Corp. (Smithfield, RI) is a doped lead zirconate titanate, which is optimized for infrared applications. It is insensitive to water, is rugged, and can be handled by mass production techniques similar to those used in the manufacture of conventional semiconductor devices. The material has a high Curie temperature, and can operate up to 70 degrees Fahrenheit. Furthermore, responsivity is only slightly temperature dependent.

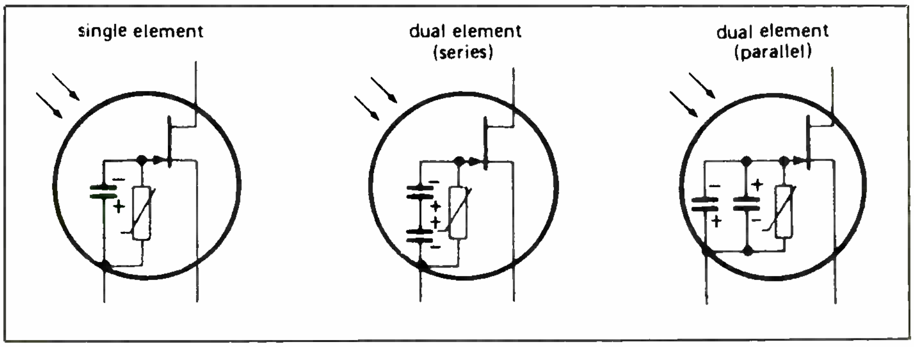


Fig. 1. An infrared sensor can be electrically represented by one or two capacitors, an n-channel FET and a non-linear network.

What is Pyroelectricity?

A pyroelectric ceramic is composed of a mass of minute crystallites, each of which behaves as a small electric dipole. Above a certain temperature, known as the Curie temperature, the crystallites have no dipole moment. Below the Curie temperature in freshly manufactured material, the electric dipoles are randomly oriented (see Fig. 2A). If the material is heated to just below the Curie temperature in an electric field, the dipoles tend to line up with the applied field (see Fig. 2B). After the material has cooled and the field has been removed, the dipoles remain in the "poled" position, giving rise to a remanent polarization of the ceramic.

The pyroelectric effect arises because of a change in polarization with temperature and may occur in several ways. For example, the individual dipoles may shorten with increasing temperature, or the total dipole moment may be reduced by increased randomness of the orientation of the dipoles due to thermal agitation. Thus, when the temperature of the material increases, the captive surface charge is reduced. This leaves a surfeit of induced charge on the electrodes. The excess charge gradually leaks away through the circuit to which the pyroelectric element is connected. This leakage effect means that a pyroelectric sensor cannot be used in a dc mode. However, it can be operated at very low frequencies down to less than 0.1 Hz.

The pyroelectric element will only produce an output signal if the infrared radiation incident on it changes. This may be achieved either by moving the object of interest into and out of the field of view,

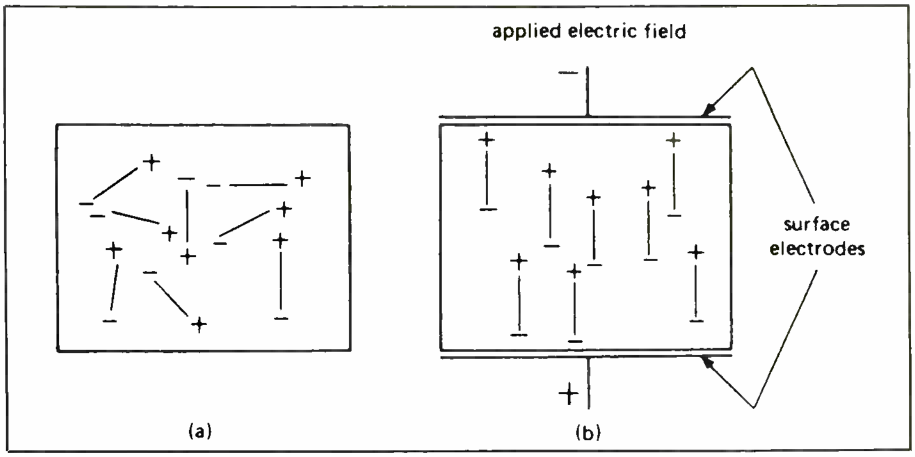


Fig. 2. A pyroelectric ceramic consists of a mass of minute crystallites, each of which behaves as a small dipole, that are randomly oriented (A) below and are aligned (B) when heated to just below the Curie temperature and an electrical field is applied.

or by interrupting the radiation incident on the sensor.

Passive IR Detection

Each person, object or animal emits infrared energy as a function of its surface temperature and size. For temperatures around ambient, the maximum radiated energy is in the region of 10 microns (20 times the wavelength of visible light). Radiation changes produced by a moving object can be detected by a pyroelectric infrared sensor.

A pyroelectric infrared sensor can be used as the basis for a passive infrared (PIR) alarm system. This type of system detects the presence of an intruder within a protected area when movement modulates the radiation incident on pyroelectric sensors that respond only to changes in radiation. An intruder will emit a steady infrared radiation. One way that radiation can be collected is by a Fresnel lens array (a Fresnel lens is a thin polyethylene sheet that is essentially equivalent to thick conventional lenses).

Discrete fields of view from each element ensure significant changes in incident radiation when an intruder passes from an unmonitored gap to a monitored zone or vice-versa. A Fresnel lens array is suitable for most general-purpose moving-sensing PIR applications. It provides high sensitivity, monitoring up to at least 12 meters with 90° angular coverage.

Figure 3 shows the block diagram of a simple passive infrared intruder alarm system. The output from the PIR sensor with its Fresnel Lens array is amplified by two bandpass amplifier stages. A window comparator with positive and negative threshold then drives a logic circuit. This performs simple signal processing and drives the output alarm relay circuit.

For detailed information and a sample device, write on your company letterhead to Amperex Electronic Corp., A North American Philips Co., George Washington Hwy., Smithfield, RI 02917.

Long-Range Detection

Eltec Instruments, Inc. (P.O. Box 9610, Daytona Beach, FL 32020-9610) manufactures the Eltec IR-EYE 862, which can detect people outdoors to a distance of 500 feet (vehicles can be detected to even greater distances).

A person or vehicle will always have a temperature contrast in respect to the background, producing a change of radiation within the field of operation of the sensor when passing through it. For the IR-EYE 862, this temperature contrast can be as little as 1 degree centigrade or less (either positive or negative) for a person at a nominal distance of 150m to trigger an alarm. A precision mirror focuses the radiation onto a parallel opposed dual pyroelectric detector. This will produce a defined signal from a moving object while canceling common mode signal received simultaneously by both sensing elements.

Two-stage optical filtering restricts the radiation to the so-called atmospheric window (8-14 microns). Here the effects of normal constituents of the atmosphere (particularly humidity) least affect the transmission of infrared radiation. This double optical filtering blocks all unwanted radiation from sunlight and headlights, which otherwise may produce false alarms.

Sophisticated signal processing within the eye is used to discriminate even very weak signals caused by a moving target from unwanted signals caused by wind, clouds and precipitation.

Eltec has produced a brochure that describes the principles of operation, functioning, detectability considerations, and installation of non-imaging passive infrared telescopes. Copies of the brochure are available from Eltec Instruments, Inc. at the address given above.

Power Op Amp

A versatile and forgiving power operational amplifier is now available from the

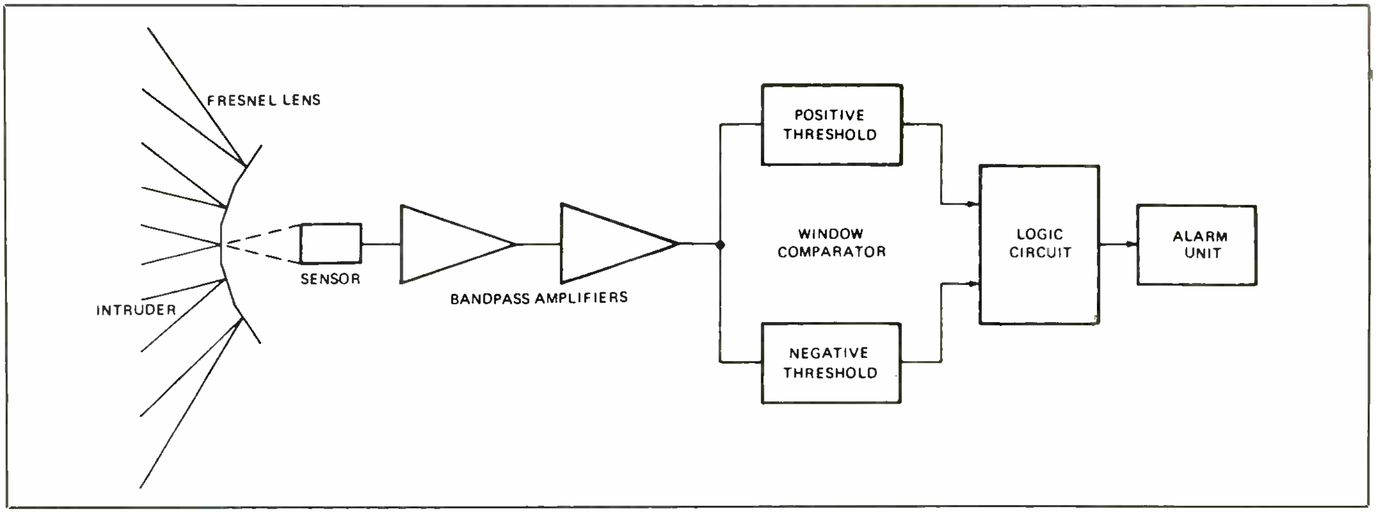


Fig. 3. Block diagram of a simple passive infrared intruder alarm system.

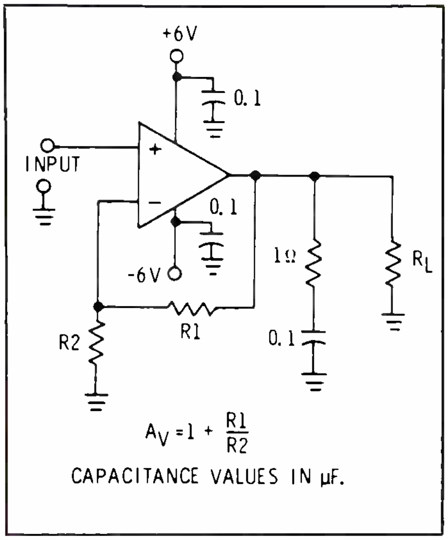


Fig. 4. Typical application of the ULN-3751Z operational amplifier as a non-inverting power amplifier.

Semiconductor Group of Sprague Electric Co. (41 Hampden Rd., P.O. Box 9102, Mansfield, MA 02048). Operating with power supply voltages of ±3 volts to ±13 volts or 6 volts to 26 volts, the ULN-3751Z delivers peak output current levels to ±3.5 amperes. This integrated circuit is ideal for use in servo systems, robotics, audio and deflection amplifiers, and software programmable voltage or current regulators.

The amplifier requires no external components for loop compensation and maintains a stable, oscillation free operation for all values of gain in the inverting or non-inverting mode, and under all specified load conditions. Low input current and voltage offsets of 10 nA (typical) and ±10 mV (maximum) make the device simple and convenient to use. A self-resetting shutdown circuit powers down the amplifier at a junction temperature of 160 degrees centigrade (typical).

Common-mode rejection of 85 dB (typical), open-loop gain of 80 dB (minimum), and a gain-bandwidth product of 3.5 MHz (typical) endow the ULN-3751Z with the characteristics required by its intended applications. A typical application as a non-inverting power amplifier is shown in Fig. 4. **ME**

PC CAPERS

A Disk-Optimizer Software Package & Something Special For Your Computer

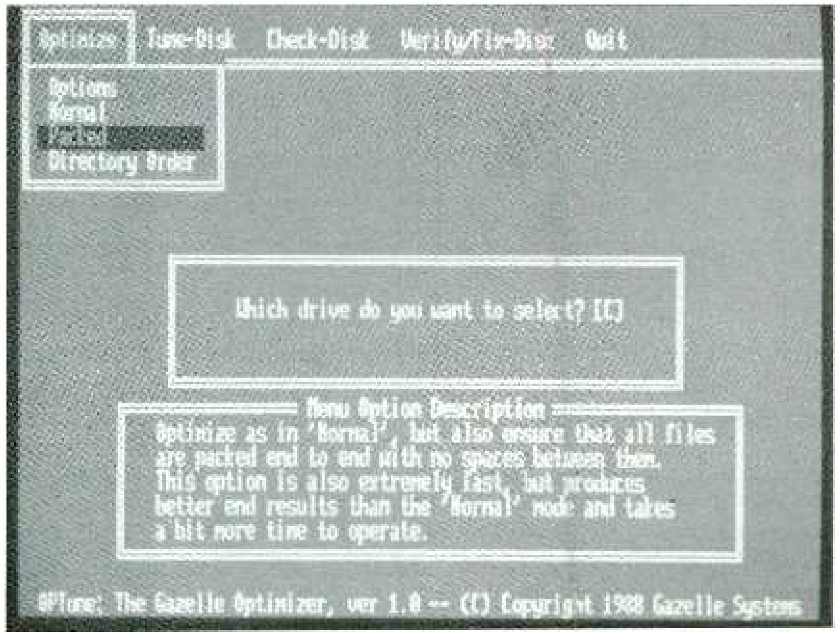
By Ted Needleman

This month, we'll be talking about a disk performance booster, as well as a computer product that is neither hardware or software. Before I get to the actual products though, it might be helpful to briefly review how disks, both floppy and hard, are organized. That way, the product discussion will make a bit more sense. If you already have a fair idea of disk organization, please feel free to skip ahead.

All disks, whether they are "hard" or "flexible" (that is, floppy), have certain things in common. They consist of a magnetic recording surface that is bonded to a supporting substrate. In the case of a hard disk, this substrate is usually aluminum. Floppies generally use a Mylar substrate. Both sides of the substrate are covered with the magnetic covering, though with some floppy disk drives, only one side (or surface) is used. Hard disks with capacities over 10 megabytes usually contain several of these magnetic-coated aluminum disks, called platters. The platters are mounted on a common spindle, and each surface of each platter has its own read/write head. On both the floppy and hard disk drives the heads move linearly from the edge of the disk toward the center and back.

As the disk's read/write head steps in toward the center from the outer edge, a circular swath of the disk surface, which is being rotated, sweeps underneath it. At any one position, this swath is known as a track. The entire disk's surface is divided into these tracks, which vary in number from 40 up, depending on the formatting method, track width, and whether the disk is a floppy or hard disk.

Each track is further subdivided into sectors. The number of sectors in a track again varies, usually according to the density that the sector can be recorded at. Sectors are located physically adjacent to each other, but are not usually labeled or addressed sequentially. Therefore, Sector 2 is not usually the sector immediately following Sector 1. It may be two, three, or even more sectors down the track. This skippage will always be the same number of sectors for a particular disk. If Sector 2 is offset by 2 sectors from Sector 1, then Sector 3 will also be offset by 2 sectors from Sector 2. This offset is called the disk interleave, and is often given in the form of a ratio such as 1:3. This particular ratio indicates that there are three physical sectors between each sequential logical sector.



OPTune features pull-down menus and on-line help.

This is a very confusing state of affairs until you understand the reason for it. Interleaves exist because of two characteristics of disk drives—rotational speed and data transfer rate. To visualize what's happening, let's first imagine that you want to read two sequential sectors from a floppy disk that is interleaved at 1:1; that is, each sequential sector is physically located immediately following the previous one. Most floppy disks spin at either 300 or 360 rpm, which means that the disk surface is passing beneath the read/write head at a pretty good clip. Hard-disk platters spin even faster, usually at a rate of 3,600 rpm.

When you go to read from this disk, the computer issues a read instruction to the disk controller. The controller then positions the head to the correct track and starts looking for the desired sector. When it finds it, it reads the sector, transferring the data first to the disk controller, then into RAM memory within the computer. It then goes through this process again for the second sector. In the meantime, the disk has continued to rotate under the disk head, most likely a fair distance past where the second sector is located, depending on how fast the disk controller functions.

By the time the controller implements the second read request, the sector it wants to read has already passed by the head, and the controller must wait most of an additional revolution to read the second sector. Multiply this process by thousands of reads, and you begin to get an idea of how slow this type of sectoring scheme can be.

Now, if you move the second sector a bit further down the track, you give the disk controller a bit more time to set up for the second read operation. This is the function of a disk interleave, and the actual interleave implemented is a function of both how fast the disk rotates and how fast the disk controller is capable of setting itself up for multiple reads.

In some of the fastest hard-disk and controller combinations, the controller is so fast that, when coupled with very high access speeds on the hard disk head positioning mechanism, the combination is capable of operating efficiently at 1:1 interleaves (where the logical sectors are also physically adjacent). A more common hard disk interleave is 1:3.

Sometimes, however, the disk interleave specified for a particular brand and model of disk and controller is not really optimum for the specific units you have. Factory specifications are based on averages, while the particular units can vary enormously from this average (on either side of the performance curve). What this means is that your disk may not be operating at its most efficient interleave. By changing the interleave (discussed a bit further on), you can sometimes substantially improve the performance of your hard disk.

Another performance factor, especially in hard-disk operations, is how the files on your disk are organized. MS-DOS was designed to allow you to re-use disk space formally taken up by files you no longer need. When you DELete or ERAse a file, you are not really physically removing the file from the disk's surface. What DOS is doing is removing the location of that file from a special index on the disk called the File Allocation Table, or FAT. The FAT contains the names of all the files on your disk, along with other file information, called attributes.

It also contains the starting address of each file (that is, the first sector of the file). Each sector in the file contains a pointer to the next (the sector address). To enable the most efficient use of disk space, files are not usually made up of contiguous sectors (sectors that sequentially follow each other, either physically or logically). Instead, as new files are written, DOS places these records in whatever sectors it happens to have free and writes a pointer to this new part of the file in the previous end of the file.

What this results in are files that are located all over the disk, one part here, another part there. This is particularly prevalent with files that are constantly being updated and rewritten, such as databases and word processing files. This file fragmentation results in a gradual deterioration in performance over time. By reorganizing the files, so that they reside in logically contiguous sectors, you can sometimes gain substantial access performance.

OPTune

Gazelle Systems is pretty well known for its Q-DOS DOS shell and Back-It disk backup and restore utility. Their newest product, OPTune, addresses two of the disk performance problems mentioned above, interleave optimization, and file reorganization. This inexpensive ($99.95) utility helps you determine the best interleave for your specific disk and controller combination and, if necessary, allows you to reset the interleave on your disk without destroying existing data resident on the drive.

The program does the above by reading an entire track into a RAM memory buffer area, performing a low-level format on the track it just read, re-interleaves the disk sectors on that track, and then writes the sectors it is holding back onto the disk. It does this for each of the tracks on the disk. When you've finished using OPTune to reset the disk interleave, you can then use another of its functions, disk reorganization, to further improve performance.

Using OPTune is easy. It installs itself on your hard disk by just placing the program disk in drive A: and typing "OPSTART." This creates a subdirectory named OPTune on drive C: (or any other drive you specify) and transfers all the files to this subdirectory. If you want to modify the display colors, you can then run a program called OPCOLOR. You are then ready to run OPTune.

OPTune's main menu uses pull-down menu bars. The Selections across the top are to OPTIMIZE, TUNE-DISK, CHECK-DISK, VERIFY/FIX-DISK, and QUIT. The usual sequence that you will use is to first run CHECK-DISK to lock out bad sectors, use the TUNE-DISK selections to test and possibly reset the disk interleave, then run OPTIMIZE to reorganize the files.

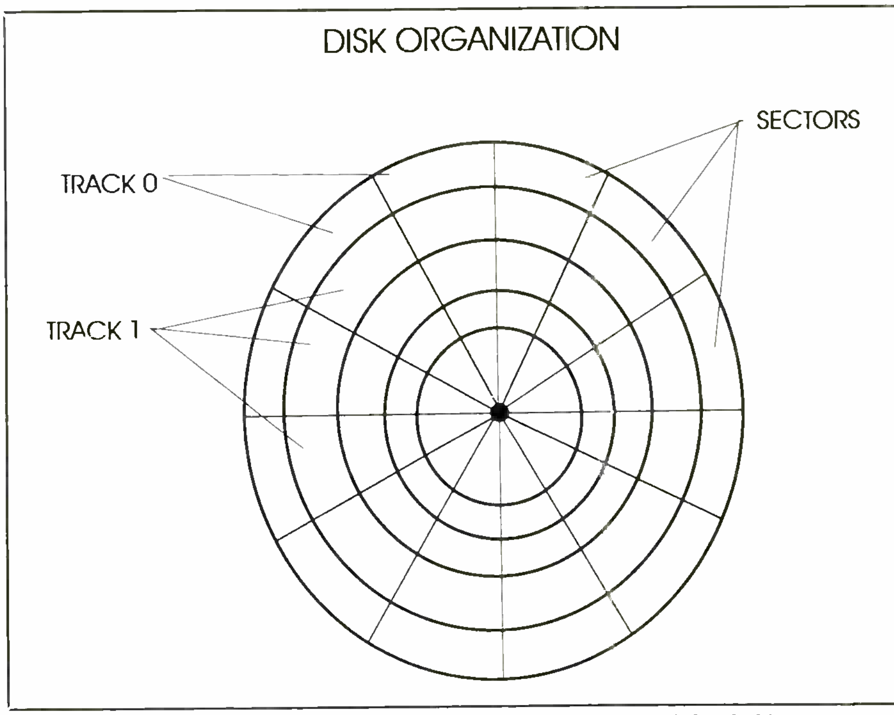
VERIFY/FIX-DISK performs controller/disk level testing at one of three confidence levels. This can take between 20 minutes and 6 hours for a 20-MB disk, depending on what level is selected. Gazelle recommends that these tests be performed at least twice a year, as at the very least, they re-magnetize areas of the disk which may be slightly weak. This makes sense—as not every bit on the disk's surface has the same magnetic retentivity.

If a particular bit on the surface contains data that is not re-written fairly often, and if it is slightly magnetically "weak," there is a chance that the information may just, for all purposes, "fade away." As a result, a sector or cluster of sectors containing data can go bad on you, corrupting a file. By re-writing the sector every several months, you can ensure that the sector has not gone bad, or if it has, increase your chances of recovering the data.

OPTune also accomplishes this function to some extent when you reset the interleave. Every specific disk and controller has an optimum interleave, and this is determined only by actually changing the interleave on the disk and measuring the data transmission rate. OPTune determines the optimum interleave for your specific combination by exactly this method, using an unused track for the interleave change.

Once it has determined the best interleave, you can tell it to reset the interleave across the entire disk. It does this across a logical, rather than a physical drive. For example, my PC has a 40-MB drive with one 32-MB partition, named Drive C: and one 8-MB partition, Drive D:. When

PC CAPERS...



A disk is organized by concentric tracks that are further subdivided into sectors.

OPTune was run, it reset the interleave only on the portion of the drive designated as Drive C:. To reset the interleave on the rest of the physical disk unit, I had to tell OPTune to perform the operation on Drive D:.

The software also offers three levels of reorganizing fragmented files, or optimization. Each offers a slightly higher level of performance, but also takes more time to perform. At the most basic level, "NORMAL" de-fragments all of your files, sorts the files according to your setting (ascending or descending alphabetical order), and squeezes erased files out of your directories. It is the fastest of the three options offered, but does not offer some of the performance gains that the next two levels do.

"PACKED" is the next option. It performs the above tasks, but also places your files on disk so that they are end-to-end. Because there are no open spaces between files, DOS will most likely write new files at the end of all the used space. This option takes a few minutes more to perform, and could provide slightly better performance. In actual use, I saw a significant improvement in speed using NORMAL, but not much apparent improvement between NORMAL and PACKED.

"FILE REALIGNMENT" is the most comprehensive of the three. It works much the same as PACKED, but also arranges the files in the same order they appear in the directory. If you generally access files in sequential order, this will be the most efficient method to reorganize your files, but it also takes the longest time. Again, with my particular applications and files, I did not notice an appreciable improvement over "NORMAL" reorganization.

The first time you run OPTIMIZE, it takes a while to straighten everything out. For the 32-MB partition on my PC, this was 20 minutes and 45 seconds on the first run through. Daily "tune-ups" with OPTIMIZE, however, are averaging only between one and three minutes, depending on how extensive the previous day's use has been.

I haven't benchmarked before and after results, but resetting the interleave from 3:1 to 2:1 and reorganizing the files have produced a noticeable improvement in file access times on my 386 PC. On an 80286 or 8088 system, I imagine the improvement would be even more noticeable. I like OPTune and I'm glad I installed it on my PC. I should warn you, however, that the disk interleave reset does not work correctly on the Compaq DeskPro (and possibly several other esoteric controllers). This is because the disk controller itself contains cache memory to speed up data transfer. Because of the cache, the controller/interleave tests that OPTune performs do not deliver consistent results. Other than this problem, OPTune has worked perfectly for me for several months, and is an inexpensive way to squeeze additional performance from your PC (even if it is a fast 386) at a reasonable cost.

STABILANT 22

At last November's COMDEX show, there was one exhibit that really caught my eye. It was a gentleman playing with Microsoft's Fight Simulator, and the computer he was using was underwater! Having grabbed my attention, the booth's personnel were quick to point out that the substance the computer was submerged in was not water, but STABILANT 22, a liquid that has some very unusual properties.

STABILANT 22 is a liquid polymer that, when not under direct mechanical pressure, is non-conductive. When it is placed under pressure, however, it becomes conductive, but only in the area where direct pressure is being applied. This property makes STABILANT 22 perfect for the application D.W. Electrochemicals promotes it for—contact enhancement.

One of the most prevalent causes of intermittent operation in any piece of electronic equipment, whether it is a computer or audio system, is a deteriorating contact. This can be between an IC and its socket, an expansion card and its socket, or between a plug and jack. This can occur even in computers that use gold-plated contacts. In fact, one of the first things most experienced troubleshooters do when confronted with an intermittent problem is re-seat all the ICs that are socketed, and burnish the edge contacts of peripheral boards with a pencil eraser. Often, this will clear up the problem, at least for awhile.

STABILANT 22 can be applied to the edge connectors of a board with a swab, or squirted into the IC socket with a syringe, where it flows down between the IC's pins and the socket, then becomes conductive where the pins do not make good contact.

I tried STABILANT 22 on a PC that had experienced intermittent problems with the hard disk; sometimes the PC recognized the disk was there, sometimes it didn't. I treated all of the socketed ICs in the disk controller, the edge connector of the card, and the two ribbon cables on both the controller and disk ends. This was several weeks ago, and so far the disk has been behaving itself. Of course, this isn't proof positive that STABILANT 22 works since the very act of taking the board out and putting it back could very well have cleared up a contact problem, as could the act of removing and replacing the cables.

But at $36 (plus shipping) for a 15-ml container of dilute STABILANT 22A, I'd certainly recommend that you have a bit of this stuff on hand. While 15 ml is a small container, a little goes a long way. And as one who has done his share of pencil-eraser burnishing of contacts, STABILANT 22 makes good sense to me. In fact, I intend to "STABILANT-ize" each of my computers as I have occasion to open them up.

STABILANT isn't readily found in audio or computer stores yet, but the company is into setting up various distribution methods. If you drop them a card or call, they'll let you know where you can purchase the product. Or, you can order directly from them. Though they generally prefer to deal in large quantities, they have assured me they will be glad to accommodate *Modern Electronics* readers.

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Nemesis GO!

By John McCormick

Familiar to most computer enthusiasts only in the extremely limited Go-moku version, GO is an Oriental game with rules as simple as checkers and strategic play more complex than chess.

In fact, GO is so difficult to master that there is only one significant GO game machine in the United States competing for the $1-million prize to be awarded to the one game to play at a Master level.

After 17 years in development (starting with a National Science Foundation artificial intelligence research grant), an American is now marketing both a powerful GO software package for several computers and the world's first GO game capable of actually playing the game (rather than merely recording moves). The hand-held Nemesis game computer offers both a training opportunity for beginners and stiff competition for all but the highest-ranking players.

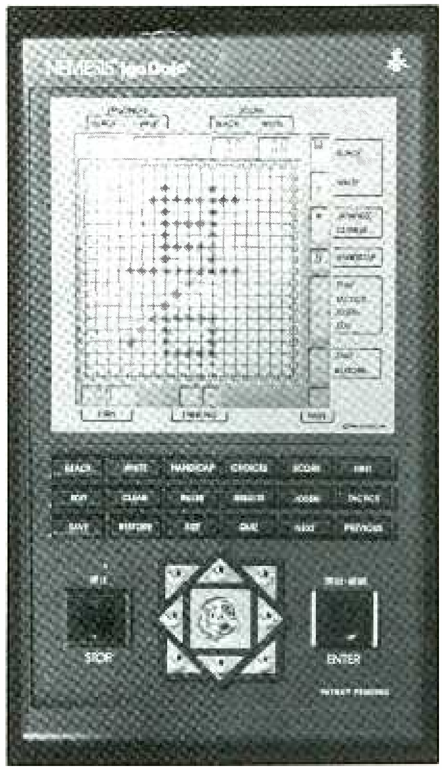
This flexibility is possible because GO is a game traditionally played in a handicap mode. When two players of different abilities wish to play, the weaker player is given a one- to nine-"free"-move handicap advantage. This makes it much easier for GO players to match up on an equal basis than chess players, where fair handicapping is much more difficult to achieve.

The rules of GO are simple. Two players alternately place markers (traditionally small stones) on a board's intersections formed by 19 horizontal and 19 vertical lines: a small board game for quick play has 9 by 9 lines. The winner is the person who controls the most area at the end of the game. Each player has 18 stones, black or white.

Pieces are captured when an enemy group is completely surrounded and has no pair of "open" intersections inside its group. The end is reached when neither player can see another advantageous move or when all the stones have been placed on the board.

Sounds simple, doesn't it?

Actually, it is nearly this simple to start with, which explains much of GO's popularity in the Orient. It is the simplest of



games to start playing, but when two experienced players are facing each other, the strategic complexity of the game starts to become apparent.

Research has shown that many of the best chess players actually have phenomenal memories and can play so well because, no matter what the board position, they have played a similar game before. With the far less restrictive rules of GO, there are so many permissible moves that no one can memorize a useful fraction of the possibilities. This leads to a game that is both easy to start playing and impossible to completely master. Yet, unlike such complex games as backgammon, the game of GO involves pure logic with no room for bad luck.

In both the software and hand-held versions, Nemesis allows you to choose a small board for a quick game or the 19 by 19 world-standard game board along with the handicap and the skill with which the game computer plays.

As with some chess games, Nemesis will offer hints; the software version will even give an explanation of why it made each move.

Since this program is also intended to teach how to play GO, you can back up during a game and replay a section, edit a game in progress, and pause to explore a library of set strategy (called Joseki) for corner moves (only the restrictions imposed by corners allow set strategies).

To play the Nemesis GO program or game computer you select color (software only) and players (one, two, or no human players), play level, Chinese or Japanese rules, and handicap. The major difference between Chinese and Japanese rules is that in Chinese play you can commit "suicide" by moving to a position where you are instantly captured by your opponent, while the Japanese rules simply make this move illegal.

This can make a difference because the number of captured pieces also counts in determining the winner. In general, though Chinese rules are a bit simpler, they are largely restricted to use in China. Japanese rules are in force in the rest of the world. Of course, there are a *lot* of Chinese, so this variant can be important for some GO players.

Alternating moves are selected by moving the flashing cursor with the arrow keys. One hurdle to overcome in playing GO is scoring or calculating which areas of the board are controlled by each player. This alone is enough reason for many players to use Nemesis because you can pause to see who is ahead at any time. This is more important than it might seem because play can get so complex that inexperienced players just can't tell if a certain move was good or not.

The software version of Nemesis plays at the same level as the hand-held computer. However, it offers the advantage of being easier to upgrade as well as explanations for its moves.

This explanation option ranges from practical tactical analysis to jokes, and you can even have a mix of the two to lighten up a session.

Level Play

GO players are ranked in a way similar to judo competitors. Bruce Wilcox, the designer of Nemesis, for example, is ranked six-dan, making him one of the top United States players.

Below first-dan, a professional rank, a pretty good amateur player might have a rating of one kyu or degree, from which he or she can move up to the first-dan ranking. Beginners are rated at 35 kyu. Each kyu rating typically earns a one-stone handicap.

The range from the rank amateur to the best GO player in the world, according to Bruce, is a 45-stone handicap. This is about twice the range between the worst and best chess players.

Nemesis currently plays at a maximum of 15 kyu. It is intended for players up to 10 kyu (using handicapping) and even provides useful practice for players up to one-dan.

AI and Games

For those of you who might be thinking of programming their own GO game, you can get a hint of the difficulty (and possible rewards) from the fact that the Multitech Industrial Corp. of Taiwan has offered a $1 million prize for the first GO game to beat a human master.

After 15 + years of work, some of it on a National Science Foundation Grant, Bruce clearly intends to obtain this prize. But the fact is that, at the moment, there is not a program that comes even close to meeting that goal. This is in contrast to many good available chess games that can consistently beat all but the best human players.

There is also a big difference between the way chess games and the Nemesis software tackle the games. Chess-playing software takes a look at every possible move and tries to pick the best. The longer it takes to make a move, the more plys or "layers" ahead the program can look before choosing a move.

Even when playing at the higher levels, however, Nemesis normally takes less than 30 seconds to complete its next move. With computerized chess games, it's not unusual for a program's move to take many minutes when played at the higher levels.

One would think that the opposite playing times would prevail. Just consider that in a chess opening you can select from only 20 possible first moves and your opponent is limited to the same. (Eight pawns can move one or two squares ahead and either knight can move to one of two squares.)

In comparison, there are 361 possible opening moves in GO (19 by 19 intersections) with 360 possible, perhaps, for the second move, so there is no possible way to test every move in an acceptable amount of time.

Even after chess pieces are spread out during the middle game, there are fewer squares, fewer pieces, and lots of complicated restrictions on how pieces can move, as compared to GO.

With GO, however, no matter how far you analyze the games, there's always a vastly larger number of possible moves (the total can reach 10 to the power of 750). Given the foregoing, the only way a computer program can play GO efficiently is to make extensive use of artificial intelligence to eliminate weak or impractical moves. In real life, playing GO usually takes a lot of time. A single move can take a half hour.

Conclusions

I applaud Toyogo's non-copy protection and its policy of posting a $10 reward for the first purchaser to locate any specific bug and bring it to their attention. The company also has a liberal upgrade policy to let players move up to more sophisticated versions as their skills improve and the program advances.

GO games will probably never catch on as well as portable chess games have. Nevertheless, there are already an estimated 10-million GO players worldwide, with about 50,000 in North America and Europe. The availability of a training game such as Nemesis will help many (including myself) who found it impossible to locate enough competition to improve their game.

If you are looking for a captivating game suitable for children or mathematicians (I first encountered GO in the Math Department of Northeastern University), I strongly recommend you try the Nemesis software. I think that many who get hooked on the challenging game may want the portable version too.

Membership in the American Go Association costs $20/year. Contact AGA, P.O. Box 397, Old Chelsea Station, New York, NY 10113.

Nemesis costs $79 for the game; Joseki Tutor is $49, or both for $128. Toyogo, Inc., 76 Bedford St., #34, Lexington, MA 02173. (617) 861-0488. It requires an IBM PC or compatible with 256K, one disk drive, and DOS 2.1 or higher. The new color version will support EGA color. (Also available for Macintosh.) ME

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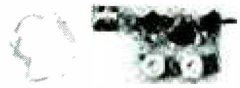

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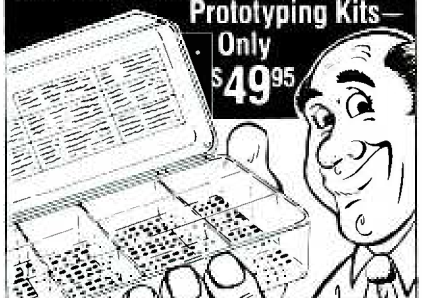

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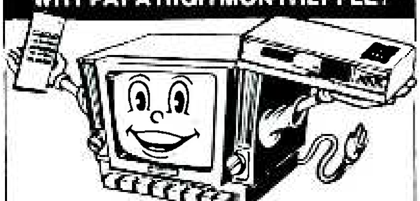

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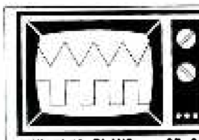

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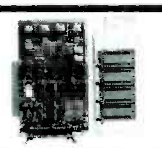

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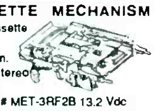

Alpine cassette transport mechanism. Includes stereo tape head, Mitsubishi # MET-3RF2B 13.2 Vdc motor, belt, pulleys, capstan, fast-forward, rewind and eject actuator. Does not include amplifier section. 6 1/2" X 5 1/4" X 1 3/4".
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PN3569	NPN	TO-92	5 for 50¢
2N3904	NPN	TO-92	5 for 75¢
2N3906	PNP	TO-92	5 for 75¢
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Grayhill 56P36-01-1-10N-C
Mini rotary switch. Non-shorting 1 deck, 10 positions. .125" dia. shaft X .375" long. .377" behind the panel depth. P.C. pins
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MICROSWITCH# 4BE3
Slanted keyboard switch with hall effect sensor. Snaps into 5/8" square chassis hole. Hall effect sensor slides easily from switch and can be used in other applications.
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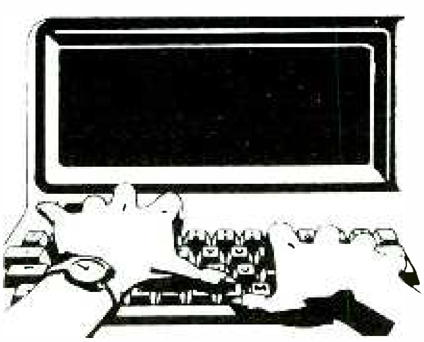

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Practical Printed Circuit *(from page 17)*

wait longer to populate the board, if you wish.

When working on a double-sided pc board you made yourself, keep in mind that the holes are not plated-through. Therefore, you must solder component leads and pins to the copper pads on *both* sides of the board and install bare wires in each hole that signals continuation of a conductor on the other side of the board. Also, if you are building a project that uses DIP ICs and wish to use sockets, do not use ordinary sockets that offer soldering access on only one side of the board. Instead, use Molex Soldercon® socket strips instead.

Some Caveats

The size and complexity of any printed-circuit board you attempt to fabricate using the method detailed above will depend on your persistence, dexterity and experience with this procedure. Do not try to make several of the same board, microwave inductors or computer motherboards with this technique. If you do, the attempts will be destined to fail. Such applications are jobs for the photographic technique.

As you work with the procedure described here, keep in mind that it is best to perform Steps 2, 3 and 4 at one sitting, if at all possible. The reason for this is that the adhesive on the plastic sheeting has a tendency to "grab" after a few hours, making removal much more difficult.

Making a printed-circuit board by the method described above is more dependable and no more difficult or time-consuming than other fabrication techniques. It is easy to master and requires no expensive and temperamental chemicals (other than the etchant of your choice, of course). **ME**

NEW PRODUCTS ... *(from page 13)*

mits the camcorder to control a compatible VCR to put together an edited tape of selected scenes.

A fun feature built into the new camcorders is animation recording capability. With this feature, one can animate toys, dolls and drawings by moving them and shooting one "frame" at a time and playing the tape back at normal speed to view the "action." Other features include: time-lapse recording that permits one to compress (speed up) slow-moving action; index recording; 8:1 power zoom lens; automatic focus; macro focus; constant automatic white balance; high-speed shutter with AE (Automatic Exposure); on-screen viewfinder display graphics; built-in microphone with wind-noise filter; and earphone speaker.

Both models feature all of the above, and the Model CC320 adds a

built-in titler/character generator for superimposing information on a tape in eight different colors and two sizes of characters. The CC320 also has a recording capability that changes normal video into a "negative" image and two-speed record/playback that permits a maximum recording time of 8 hours using a T-160 tape in SLP mode. $1,595 Model CC320; $1,495 Model CC310.

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(The VHF converter options must be used in the R-5000 and R-2000.)

R-2000

The R-2000 is an all band, all mode receiver with 10 memory channels and many deluxe features such as programmable scanning, dual 24-hour clocks with timer, all-mode squelch and noise blankers, a large, front-mounted speaker, 110 volt AC or 12 volt DC operation (with the DCK-1 cable kit), and 118-174 MHz VHF capability with VC-10 option.

R-5000

The R-5000 is a high performance, top-of-the-line receiver, with 100 memory channels, and direct keyboard or main dial tuning—makes station selection super easy! Other useful features include programmable scanning, large, built-in speaker, 110 volt AC or 12 volt DC operation (with optional DCK-2 cable), VHF capability (108-174 MHz) with the VC-20 option, dual 24-hour clocks with timer, and even voice frequency readout with the VS-1 option.

RZ-1
Wide-band scanning receiver

The RZ-1 wide-band, scanning receiver covers 500 kHz-905 MHz, in AM and narrow or wideband FM. The automatic mode selection function makes listening easier. One hundred memory channels with message and band marker, direct keyboard or VFO frequency entry, and versatile scanning functions, such as memory channel and band scan, with four types of scan stop. The RZ-1 is a 12 volt DC operated, compact unit, with built-in speaker, front-mounted phones jack, switchable AGC, squelch for narrow FM, illuminated keys, and a "beeper" to confirm keyboard operation.

Optional Accessory
- **PG-2N** Extra DC cable

Optional Accessories

R-2000:
- **VC-10** VHF converter
- **DCK-1** DC cable kit for 12 volt DC use.

R-5000:
- **VC-20** VHF converter
- **VS-1** Voice module
- **DCK-2** for 12 volt DC operation
- **YK-88A-1** AM filter
- **YK-88SN** SSB filter
- **YK-88C** CW filter
- **MB-430** Mounting bracket.

Other Accessories:
- **SP-430** External speaker
- **SP-41** Compact mobile speaker
- **SP-50B** Mobile speaker
- **HS-5** Deluxe headphones
- **HS-6** Lightweight headphones
- **HS-7** Mini-headphones.

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