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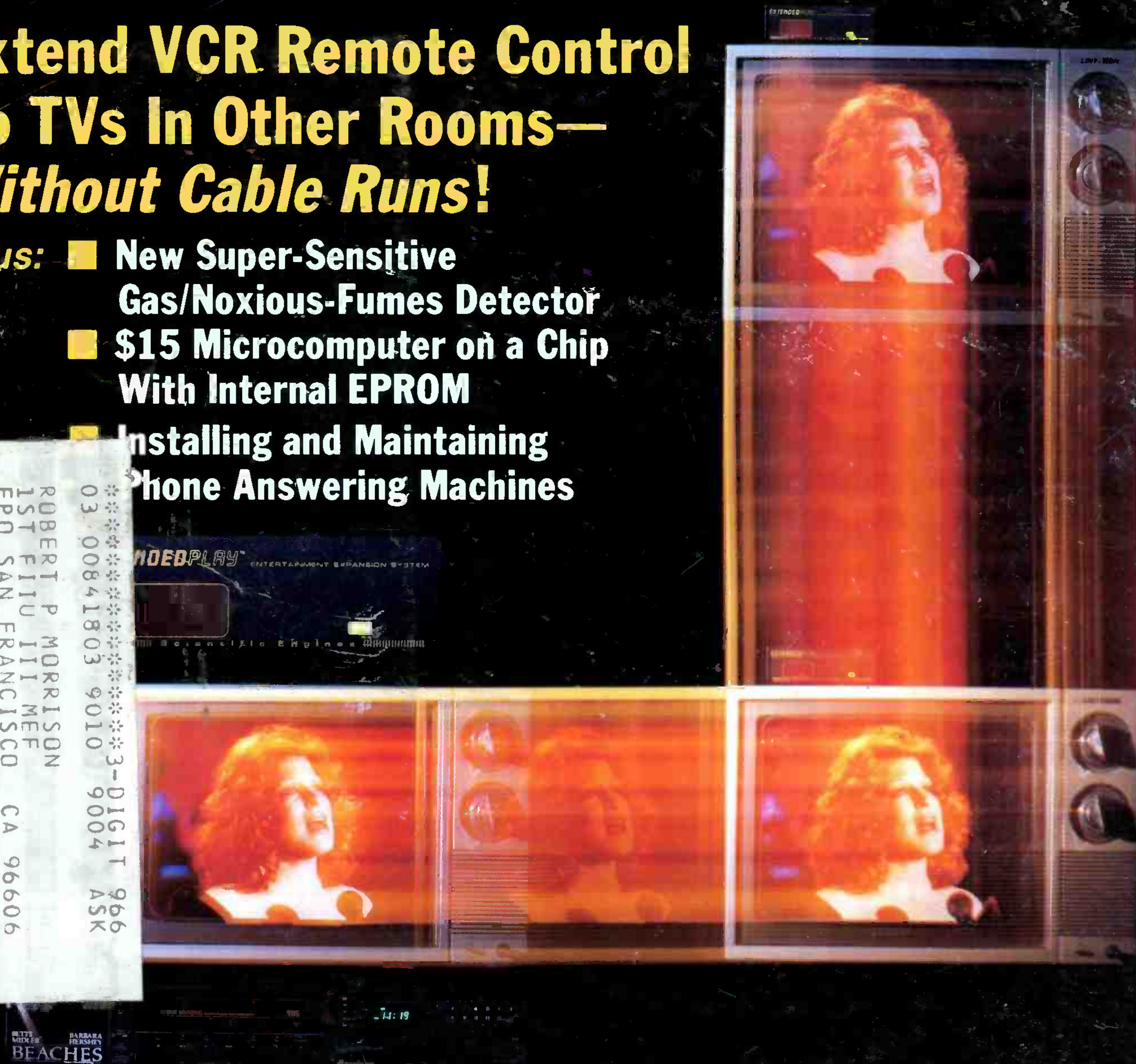

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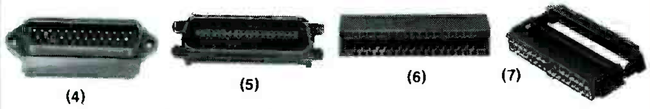

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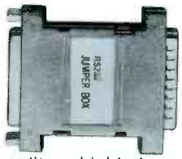

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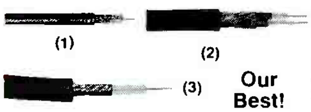

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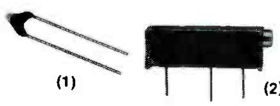

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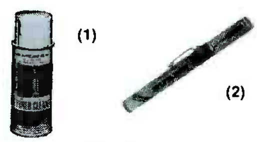

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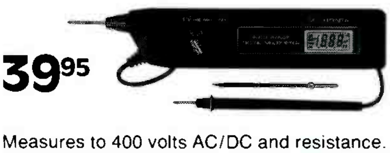

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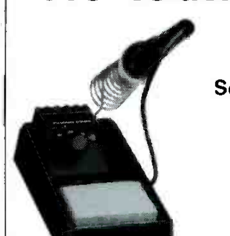

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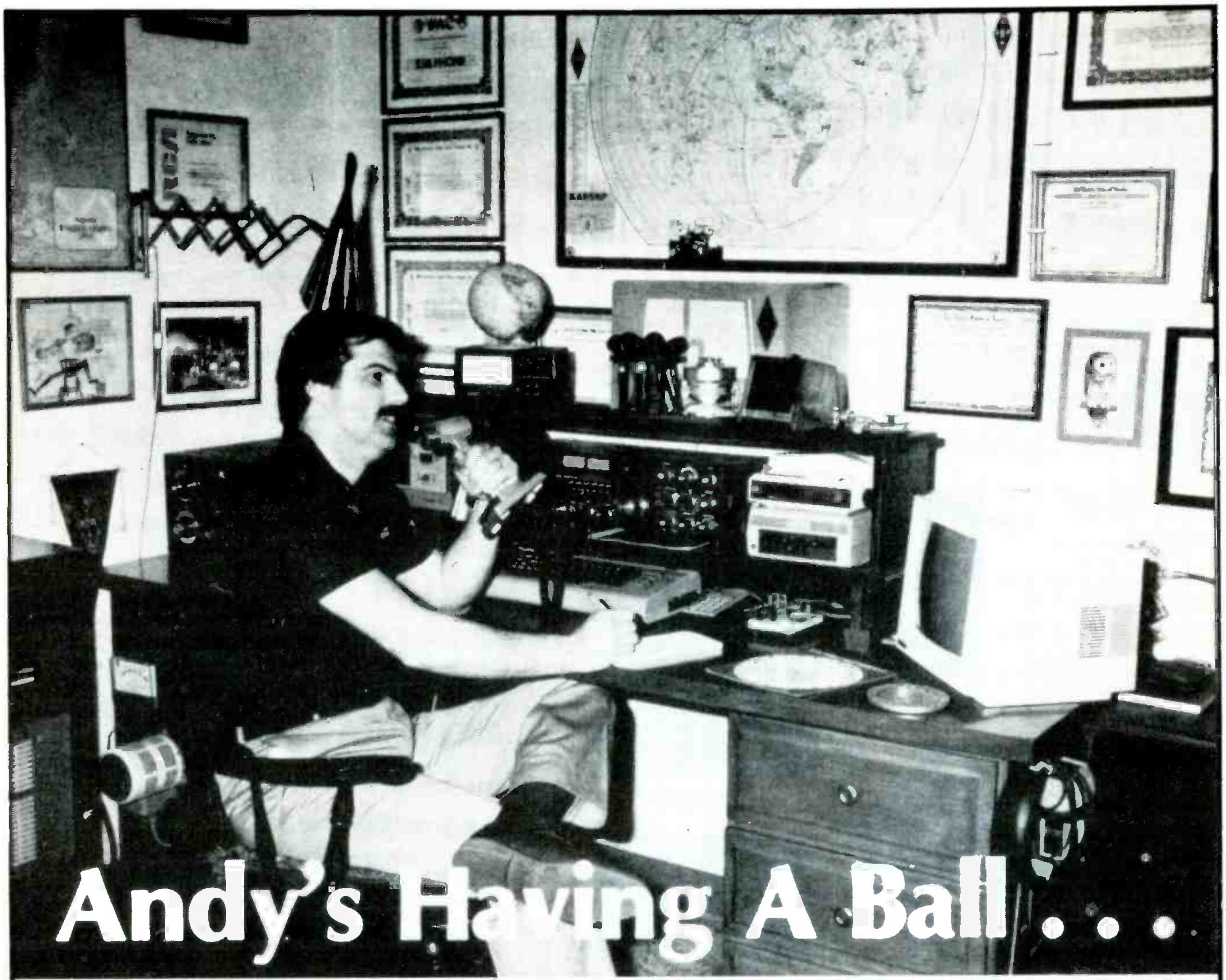

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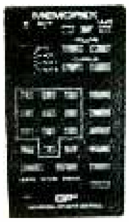

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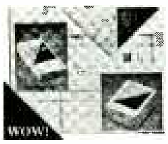

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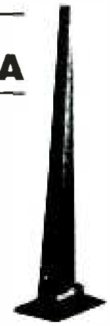

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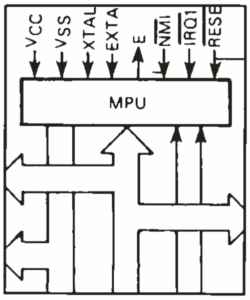

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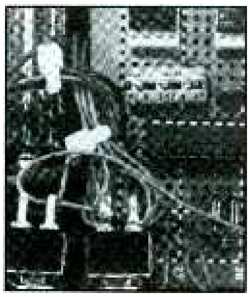

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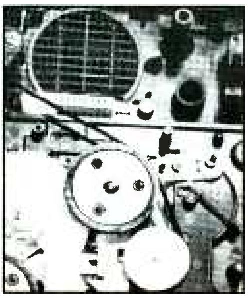

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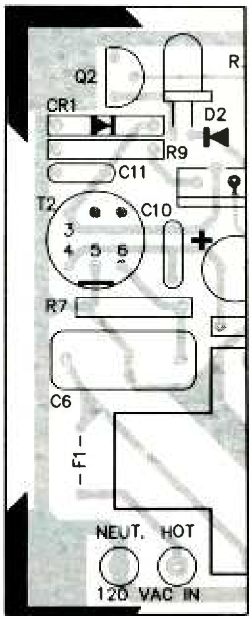

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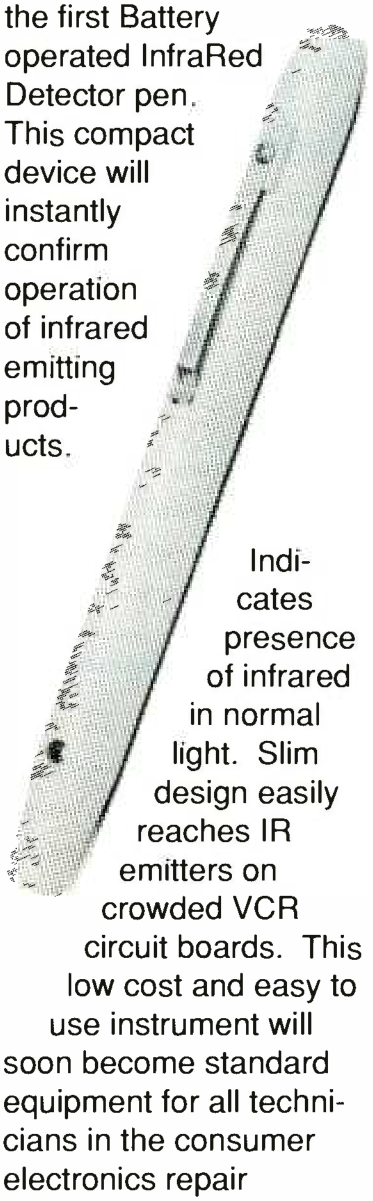

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EDITORIAL

Repair Work

Electronic and computer repairs can be challenging, whether it's a job function or for your personal equipment. Since more than 34% of *Modern Electronics* readers are professionally involved in maintenance/repair work, tackling one's own equipment comes naturally. For others, though, whether design engineer or electronics educator, it's not quite as easy since it is not an everyday task.

Troubleshooting techniques are pretty straightforward insofar as methodology is concerned. The key is isolating the problem to a section, then narrowing it down to a device. In real life, though, it is much more difficult due to both circuit complexity and production methods.

The latter is particularly trying because small seems to be better today and circuits are mounted and spaced tightly onto pc boards, which are often double-sided. Moreover, the growing use of surface-mount devices makes repair life even more difficult. More than anything else, however, is the mechanical side. You might have to disassemble half of the innards to get at what you want to check out.

As an example of this, I have a VCR that stopped recording. Additionally, most TV (cable) channels don't play through the VCR's tuner. Without even opening up the VCR, I concluded that the problem lies with the r-f modulator or switch or combination modulator/switch. Removing the VCR's cover revealed that the modulator (which turned out to have an integrated switch) was buried amid a mass of metal that would challenge anyone's ingenuity to uncover. The part itself cost more than $35, to boot. The saving grace is that virtually nothing gets repaired in a service shop for less than $125.

Computer repairs can be a frustrating experience, too. I tackled a memory board problem recently that was both easy and difficult. The monitor's error code indicated that the machine I was working on had a defective RAM. The code pointed to a particular memory bank and even order number of the IC in that bank. Substituting a new RAM chip for that one didn't correct the problem, however, which puzzled me. I tried another new RAM chip just to be sure, but the error code still popped up.

Not wishing to randomly substitute the IC for a host of others, I checked out a manual I had to confirm that I was looking in the right spot. To my surprise, the manual indicated that the defective IC in the same bank was a one other than what the IBM manual indicated. Okay, so I tried the new one in that location. Same thing: an error code. Double-checking my count of the IC's position, I then realized that my number counting was wrong. I had started counting the IC order with the number one instead of zero. Quickly extracting and inserting in the next IC socket to the one I worked on solved the problem. Whew! It could have been worse because the first bank of user memory was unsocketed, which means I would have had to remove all my expansion cards and the motherboard, unsolder a suspect IC, insert the new one, assemble the whole thing again, and continue the time-consuming procedure until I hit the right one.

There are some neat devices to speed servicing, of course. For example, there are extender boards that allow you to test an expansion card that's typically mounted vertically with no room to check things out. I just got a news release about one such device, called the PC-EXT. Made by ICS Datacom (San Jose, CA), it's an active card that buffers the computer from damage and allows the printed-circuit card to be removed or reinserted without powering down the PC. The service accessory can be left plugged into the PC; a two-position toggle switch is used for powering up the device or the card under test.

If you service electronic or computer equipment for a living, it generally pays off to invest in devices that shorten servicing time (which is money).

Art Salsberg

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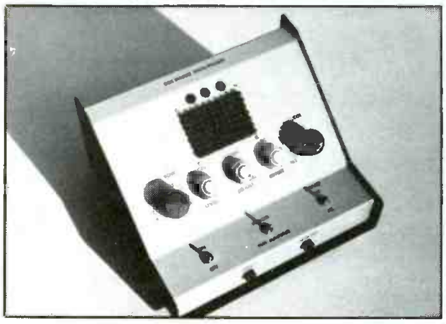
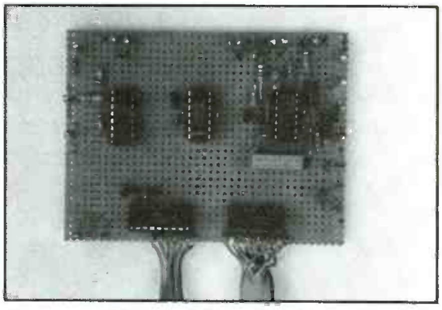
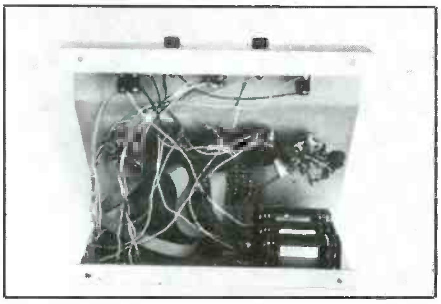
A Fun Learning Experience

• I thought you might like to see the finished product from your "Solid-State Oscilloscope" project featured in the November 1989 issue of *Modern Electronics*. Thanks for this very interesting project. I must admit that there was one point that had me stopped for a couple of days. In the wiring of the LM3914, pin 9 has two alternatives. One is as was shown for bargraph mode. Using individual LEDs instead of bargraph displays, I noted that all LEDs in each row lit, in-







cluding the ones that should light when a sine-wave input was applied to the project.

After checking and rechecking my wiring and locating no errors, I turned to an IC handbook and discovered that, for an individual LED array, pin 9 of the LM-3914 should be left unconnected. This was a good learning experience and a fun project to build. Along with my many other interests, I enjoy working with solid-state electronic projects.

D.B. Lones
Palos Verdes Estates, CA

A Myth

• "Down Memory Lane" in the February 1990 issue of *Modern Electronics* stated that David Sarnoff started Radio Corporation of America. That's nonsense! The book *Men and Volts*, which is the history of the General Electric Company, gives the correct information on the origin of RCA.

William D. Hibbard
Wautatosa, WI

You're correct, of course. The Federal government carved out RCA from its parent company. Sarnoff led the fledgling company to its heights.—Ed.

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COMMUNICATIONS. Cellular telephone ownership continues to rise rapidly. According to a NYNEX spokesman, it will increase almost 50% in 1990, reaching 5-million by year's end. It's predicted that it's current 3.4-million base will triple to 10-million by the end of 1993, The average user in the New York metropolitan area is said to conduct more than 880 phone calls via cellular phone every year. The industry is expected to adopt standards for digital cellular technology in 1990 to allow servicers to handle the burgeoning calls. To illustrate how quickly cellular phones are taking hold, NYNEX's average customer is now 39 years old with an annual income of $40,000, compared to a 1986 average of 55 years old with an annual income of more than $90,000 (not adjusted for inflation).

CBS transmitted the Super Bowel on a switched fiber-optic video network, the first time such a nationwide network has been used for television. It demonstrated an alternative to satellites. The advantage of fiber optics is that there is little to no signal degradation, whereas satellite transmission is subject to higher signal loss and interference due to weather phenomena such as rain or snow, and has redundant physical paths.

General Instrument announces it will offer an upgrade program for its new VideoCipher II-Plus de-scrambling system. Current VCII modules will be able to be upgraded for $129 plus shipping/handling.

Telephones will soon be available that display the caller's phone number. Northern Telecom, Inc. displayed such a phone, the Maestro, with a caller identification built-in screen, at a recent consumer electronics trade show. For $136, you'll be able to know who's making the call to you before answering it.

BATTERY ADVANCES. Duracell introduces the first 9-volt alkaline battery pack for use in camcorders. Its battery-pack cartridge holds six alkaline batteries that provide up to two hours of continuous recording time. Its main advantage is, of course, easy and quick replacement instead of recharging time for standard rechargeable Ni-Cd batteries commonly used....Gates Energy Products, the largest maker of sealed, rechargeable batteries, introduced its own line of rechargeable batteries to the consumer retail market with a lifetime guarantee against failure to accept a charge for as long as the purchaser owns them.

MOTOROLA'S 040 MICROPROCESSOR. Motorola's new 32-bit 68040 CPU answer's Intel's 80486, claiming 20 MIPS (millions of instructions per second) performance at 25 MHz compared to the 486's 15 MIPS. The 1.2-million-transistor chip has been endorsed by 35 leading computer manufacturers, including Apple, Bull, Hewlett-Packard/Apollo, NCR, Unisys and Nixdorf, among them. The 040 is a complete redesign of the company's 68000 architecture while maintaining complete software compatibility with preceding 68000-family processors. It includes an integer unit, floating-point unit, dual memory management units and data and instruction caches on a single chip. Its expected to be used in desktop computers, graphics workstations and multi-user computers. The 179-pin device is priced at $795 in sample quantities.

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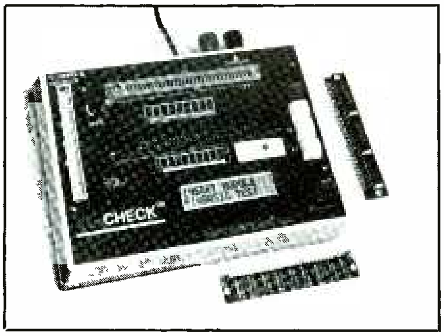
NEW PRODUCTS

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.

Portable SIMM/SIP Memory Tester

Innoventions Inc.'s (Houston, TX) SIMCHECK automatically tests all standard 30-pin SIMM and SIP memory modules that contain eight or nine bits of 256K, 1M, 4M or 16M on-board. The portable tester is said to offer features previously available only in very expensive large desktop testers. Its built-in high-speed 16-bit processor in a proprietary architecture is optimized for fast testing.



An automatic digital speed synthesizer tests access time down to 20 ns. Programmable voltage sources permit advanced testing, including voltage bounce and voltage cycling. A unique Chip-Heat mode warms the modules to ready them for temperature-dependent measurements.

Automatic functions include measurement and display of module type, size and speed; testing of all memory module data bits without the need to switch from bit to bit; and Auto Loop Test that generates complex proprietary test patterns. The tester has a 50-pin expansion slot to accommodate future add-ons. Its test program can easily be upgraded by replacing the on-board EPROM.

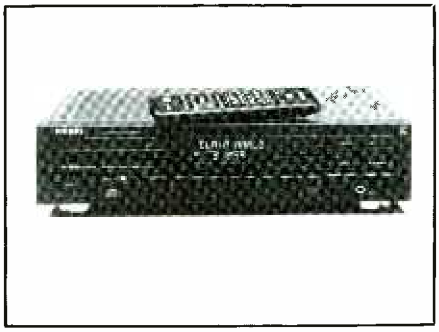
SIMCHECK identifies individual defective chips in a module and detects short/open wiring problems to provide intelligent repair information. The tester's two-line LCD window displays test results and instructions. All module sockets are ZIF type, and automatic current limiters provide short-circuit protection for the module under test. SIMCHECK measures just 7″ × 5″ × 1.5″ and weighs less than 2 pounds, including ac adapter. $995.

CIRCLE NO. 117 ON FREE INFORMATION CARD

Bitstream CD Player

Philips' Model CD840 is the first CD player to feature one-bit pulse density modulation dual D/A conversion with 256× oversampling. With this Bitstream approach, 16-bit digital samples read from a CD are transformed into a high-speed one-bit data stream that is converted into an analog signal by a high-accuracy one-bit converter. This arrangement is said to eliminate noise and distortion that frequently occur in multiple-bit converters.

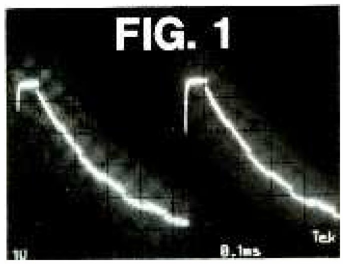
In addition to Bitstream technology, the player offers FTS Info and Direct Play/Program. FTS Info summarizes the status of the memories in Active Info messages in the display in five modes: number of discs programmed in FTS 1; number of discs programmed in FTS 2; FTS memory space available; in sequence, the number of each disc and number of times it has been played; and title display mode. With Direct Play/Program, selection or programming on any disc track is done in one step. In direct play, any track can be played by pressing the appropriate number key on the keypad. In direct program, tracks can be programmed into a play sequence of FTS program



! STOP !

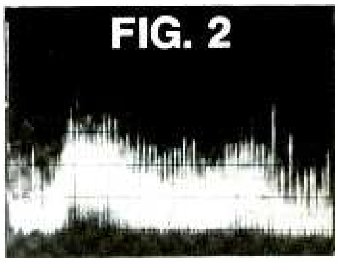
COMPUTER RADIATION

Have you ever observed the situation where an electric device is adversely affected by a nearby computer? We look at the waveform in the time domain and think we understand it.



time

10dB per DIV

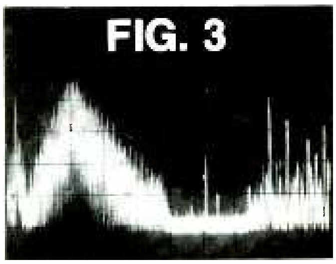


100 µv

frequency 100MHz

The scope photos show the wave form being conducted by ribbon between shielded circuit and keyboard within a computer, in both time (fig. 1) and frequency (fig. 2) domain. The Spectrum Probe is placed directly on the line and has no effect on the waveform because of the low capacity input. Clock and waveform harmonics are low—but unnecessary spurious is radiated by this lead up to about 70MHz.

10dB per DIV



100 µv

frequency 100 MHz

Fig. 3 shows the waveform being connected to the outside world (read "radiated") by a rear panel connenctor. There is no digital information present, yet there is extremely high and completely unnecessary spurious energy at about 20MHz. Most spectral lines above 50MHz are due to residual pickup of RF, even without connecting an exterior lead, indicating that a reasonably good radiating antenna is present!

107 SPECTRUM PROBE

converts any scope into a 100MHz spectrum analyzer

$199 direct

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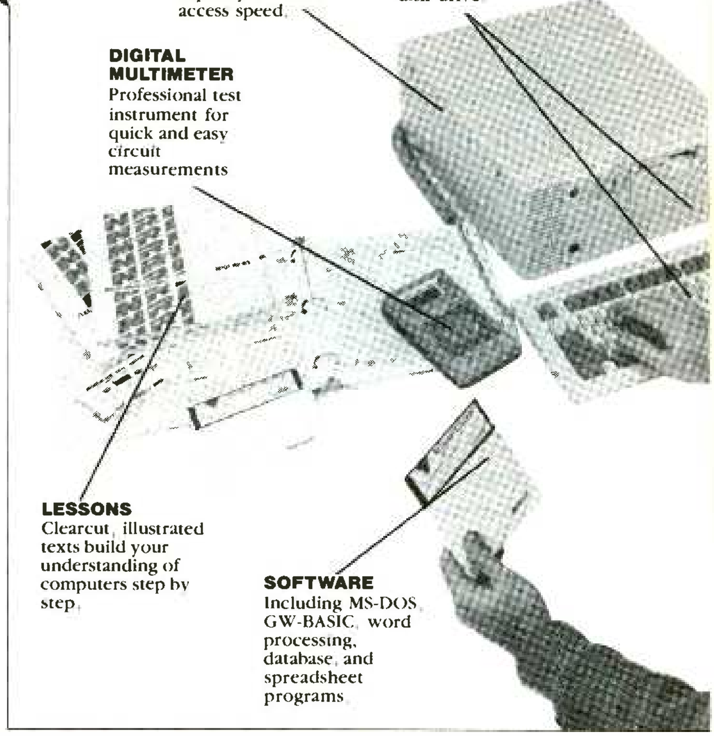
No other training—anywhere—shows you service computers

NEW! Now includes AT-compatible computer with 1 meg RAM and 20 meg hard drive!

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



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

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

You get in-demand computer skills as you train with your own AT-compatible computer system—now with 20 meg hard drive and 1 meg RAM

With NRI's exclusive hands-on training, you actually build and keep the powerful new AT-compatible West Coast 1010 ES computer, complete with 1 meg RAM and 20 meg hard disk drive.

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

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

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

Having fully assembled your West Coast 1010 ES, you take it through a complete series of diagnostic tests, mastering professional computer servicing techniques as you take command of the full power of your computer's high-speed 80286 microprocessor.

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

NEW

Voice synthesis training adds an exciting new dimension to your computer skills

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

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

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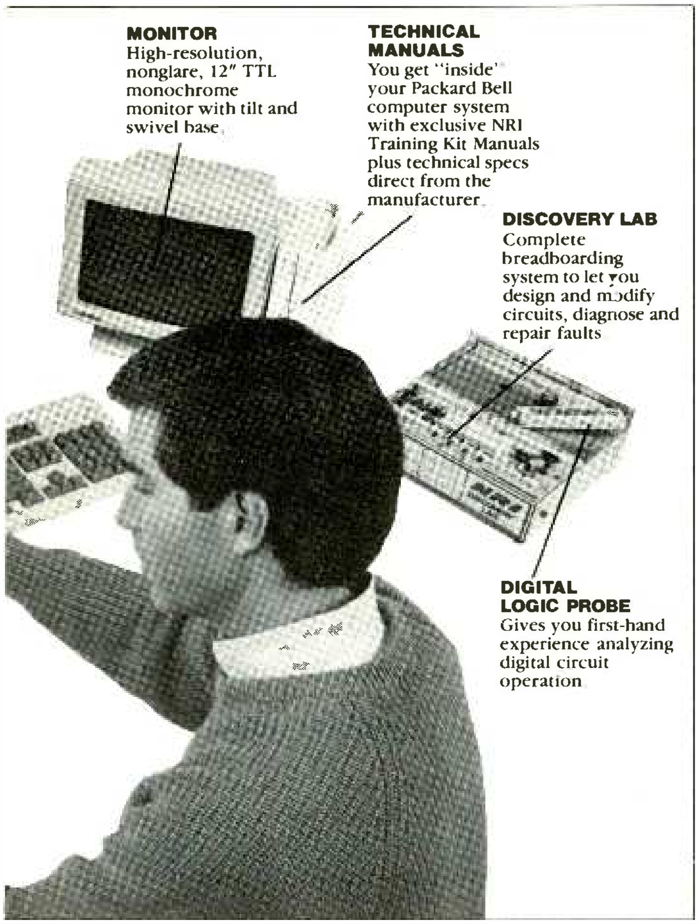
in school, on the job, how to troubleshoot and like NRI



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

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

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

No experience needed, NRI builds it in

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

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

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

Your FREE NRI catalog tells more

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

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

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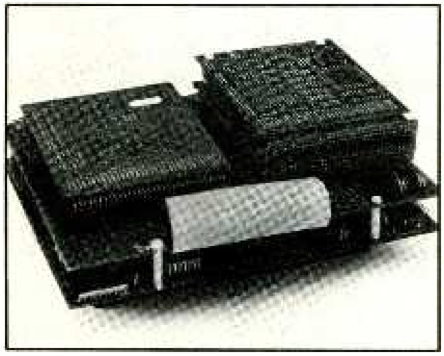
by pressing the appropriate key on the keypad.

Features include: double Favorite Track Selection with two memories; title display; digital CD record sync and edit; optical and coaxial digital outputs; full wireless remote control; random-order programming; random play of discs; selectable 10- or 20-second music scan with single-key programming; two-speed selectable forward and reverse music search; separate fast high-speed search with muted sound; and headphone output with separate volume control. $599.

CIRCLE NO. 119 ON FREE INFORMATION CARD

Mini Computer Modules

Ampro Computers announced a series of four new MiniModules for OEMs that measure only 3.5 × 3.8 inches. They mount directly on the company's Little Board and Slot Board single-board systems while remaining within the form factor enve-



lopes of those systems. The low-power-consumption MiniModules provide additional serial and parallel I/O, 2,400-baud Hayes-compatible modem, ARCNET LAN interface and an interface for hard-disk drives with embedded AT-but controllers.

The MiniModule/SSP ($131 each; all prices are in 100 quantity) provides two serial ports and one bidirectional parallel port. One serial port is RS-232C compatible, while the second can be configured for RS-232C, RS-422 or RS-485. The parallel port can be used for Centronics-compatible printing or general-purpose I/O. I/O addresses and interrupts for each port are jumper selectable. The MM/SSP supports an interrupt-sharing mechanism that permits virtually unlimited expansion of the serial and parallel ports inside a PC or AT architecture.

An industrial-quality, 2,400-baud modem, the MiniModule/Modem ($187 each) offers as options a speaker interface and cable assemblies with RJ-11 connectors.

The MiniModule/ATDisk ($79 each) provides an interface to hard-disk drives with embedded AT-bus controller. It has a 16-bit bus interface to the Little Board/286 for high-performance disk transfers. According to Ampro, this module allows standard operating systems like UNIX, XENIX and QNX to now run on the Little Board/286 without the need for special hard disks.

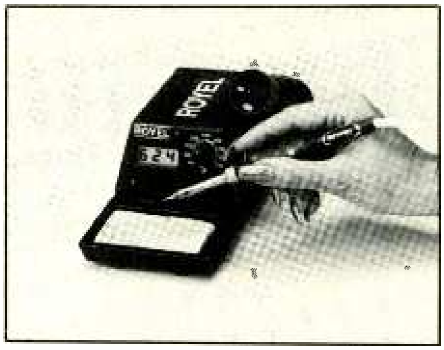
MiniModule/ARCNET ($187 each) provides single-board Ampro systems with an interface to the ARCNET LAN. It supports coax media in both star and bus topologies, fiber-optic media in star topology and twisted-pair wire in bus topology.

CIRCLE NO. 120 ON FREE INFORMATION CARD

Soldering Stations

A series of single-iron digital and analog soldering stations from Royel Soldering Systems, Inc. (Glendale, CA) exceeds Mil. Spec. DOD-STD-2000-1B. They provide a tip-to-ground resistance of 0.58 ohm, tip-to-ground leakage voltage of 0.70 mV and idling temperature maintained at ± 3°. These Thermatic Soldering Stations are said to provide ultimate soldering control, while minimizing thermal and electrostatic-discharge shock. Fast heat-up and recovery permits setting a lower temperature than with other systems to achieve the same production speeds.

These Soldering Stations feature a 24-volt dc power supply that protects the irons from transient voltage and switching spike damage. The case of the power unit and the handle of the



iron are made of static-dissipative material. Small-diameter tips facilitate penetration into high-density circuitry, while shortest possible tip length minimizes hand tremble in high-precision soldering. Both set-point and actual tip temperature are displayed simultaneously on the digital soldering stations.

The compact footprint of the power unit measures just 5.5"D × 4"W. The iron holder on the power unit can be left- or right-mounted. $259, Model T3000-115V with No. T300 40-watt, 3-mm tip ($269 with No. T500 60-watt, 5-mm tip); $359, Model T3050-115V with No. T300 iron tip; $369 Model T5050-115V with No. T500 iron tip.

CIRCLE NO. 121 ON FREE INFORMATION CARD

Digital/Analog Scope

The dual-trace Model 2522 portable digital/analog oscilloscope from B&K-Precision offers 10 megasample/second real-time sampling on each channel, 20 megasample/second repetitive sampling and display of one-shot events to 1 megasample/second equivalent sampling time. Also provided is full 20-MHz dual-trace analog operation at the touch of a button. Vertical sensitivity is rated at up to 1 mV/division, and V-mode is provided for viewing two signals with unrelated frequency.

In digital mode, a waveform can be frozen for close examination of transients, one-shot events, low-repetition-rate signals and events that occur before or after the trigger signal. Digital mode operation includes several × 100 time/division ranges to

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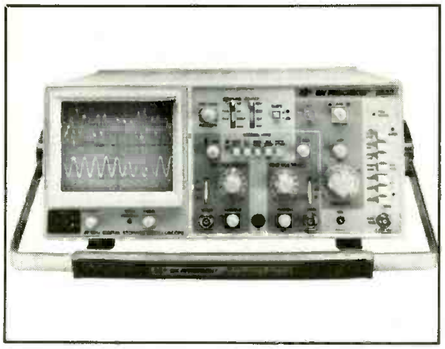

extend sampling time to as much as 20 seconds per division (200 seconds per screen) for viewing slow events. Stored waveforms can be expanded by ×10. "Dot joining" for linear interpolation between samples is also included. Specifications: 2,048 × 8-bit/channel storage word size (2K/channel with direct sampling, 1K/channel with equivalent time sampling), 20-MHz equivalent time sampling bandwidth and 256 vertical by 2,048 horizontal resolution.

In analog mode, selection is from among 20 calibrated sweep-time ranges with full variability between calibrated ranges. A ×10 magnifier permits close examination of analog waveforms while maintaining calibration. Additional features include X-Y operation, Z-axis input (TTL compatible), Channels 1 and 2 outputs on the rear panel for driving an analog plotter, and 8 × 10-cm CRT with internal graticule. $1,495.

CIRCLE NO. 118 ON FREE INFORMATION CARD

Universal Counters

Optoelectronics, Inc.'s new Model UTC3000 universal frequency counter/timer and Model 2600H basic frequency counter offer 1-Hz resolution in 1 second over a frequency range of 10 Hz to 150 MHz basic and to beyond 2.4 GHz with prescaling. Both counters have a 10-decade LCD display and high-speed ASIC and custom LCD technology. Both also feature multiple preamplifiers for maximum usable sensitivity to permit antenna pick-up measurements. A 16-segment bargraph displays input signal level to ensure reliable counting and aid in r-f security sweeps.

Front-panel operator controls include pushbutton switches for power on/off, gate select (four gate times available), function input, hold, prescale and direct-count selection. Calibration and bargraph adjustment controls are accessible through holes in the front panels. A gate LED rounds out the front-panel indicator line-up. In addition to the numeric frequency and analog bargraph displays, there are annunciators for function and gate time selected, number of cycles averaged, units and low-battery indication.

(Continued on page 81)

CIRCLE NO. 130 ON FREE INFORMATION CARD

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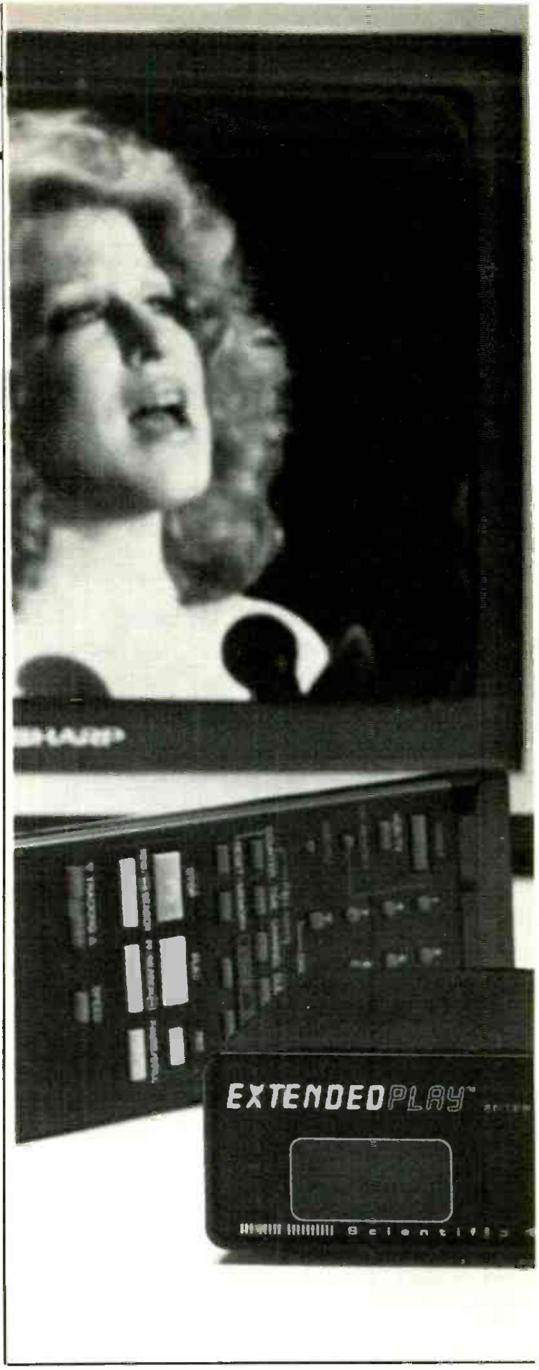
The Extended Play Remote-Control System (Part 1)



Extends functions of wireless remote controls to other rooms without extra wiring between entertainment systems

By Crady M. VonPawlak

As handy as they are, infrared remote-control devices for modern electronic home-entertainment systems are limited to line-of-sight operation. Consequently, you might string audio/video cable from, say, a VCR machine located in a den to a second TV set in your bedroom in order to view a video tape there. But you must work the controls directly from the VCR since the remote control cannot operate from the second room. Thus, you can't conveniently pause the tape to answer a phone call, stop and rewind the tape to view a scene that you missed because your mate asked you a question, etc.

There are indeed remote control extenders on the market to provide you with such control from another location. However, these control signals are sent from the remote location to the main location over wire or cable. This introduces drawbacks in addition to the need to route wire from one room to another: possible interface problems that cause picture degradation; and momentary noise in the picture or sound whenever the control transmission is made since it's added to incoming r-f modulated video/audio signals. Furthermore, such control signals may possibly even interfere with radio or cordless telephone reception.

The Extended Play Remote-Control system described here eliminates all the problems cited above. For example, it is wireless! Our Extender does not require stringing wires between rooms because it uses existing ac house wiring and a carrier-current technique to route control signals from any remote location to where the main equipment is located. Furthermore, novel circuit design eliminates the possibility of degrading video or audio reception or interfering with the operation of other electronic devices, as we will shortly discuss.

In its most basic form, the Extended Play system operates from any two 117-volt ac outlets in a given residence. If you wish, you can expand upon the system with additional transmitters and/or receivers, all interconnected by the same ac line. Installation is as easy as plugging the system into ac outlets, the receiver at the VCR or stereo system source, the transmitter(s) at the desired remote location(s).

In this first installment, our concentration is on the transmitter portion of the system. Next month, we will conclude with the theory of operation of the receiver and its construction, system checkout and installation and use.

Design Considerations

Although the Extended Play is similar in operation to the popular systems that control electrical appliances and other devices in home control in its use of carrier-current for transmission, significant differences exist between the two. The Extended Play uses only the frequencies and signal encoding it receives from an

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existing IR remote-control transmitter. No other signals are impressed onto the original control codes, nor is there any need for zero-crossing detection or switching.

IR energy generated by a hand-held remote-control transmitter is simply converted into an electrical signal that is then used to modulate the 117-volt ac power line for distribution throughout the home. At the receiving end, this signal is detected, filtered and restored to its original IR form. The resulting IR energy is then beamed to the device(s) to be controlled. This makes the system transparent to the IR control signal. Because these signals differ so markedly from those used by home control systems, inadvertent triggering one of those devices is an impossibility while using the Extended Play system.

This simple means of transmission translates into simple circuitry design. As you can see in the schematic diagram of the transmitter circuit in Fig. 1, component count is relatively low. For our purposes, the entire system need provide only the following functions: (1) Detect and accurately amplify the ultrasonic IR signal; (2) Convert the received data into a high-energy sinusoidal emf signal, free of r-f, and impress it onto the ac line wiring; and (3) Detect the transmitted emf at some remote location and reproduce it in its original IR energy form for re-transmission.

Although accomplishing these aims appears to be a straightforward proposition, special considerations must be kept in mind. For example, the IR detector/preamplifier must have a gain of 60 dB or so while maintaining a bandwidth of 30 kHz to 60 kHz without any significant rolloff. Also, because the levels of received IR energy vary greatly from room to room with distance and different models of remote controllers, automatic gain control (agc) at the front end of the amplifier is required.

To accomplish the above reliably with operational amplifiers requires complex and costly circuitry, but inexpensive devices designed specifically for use as IR preamplifiers are available. However, the bulk of these pass along only the data pulses while stripping off the ultrasonic carrier frequencies. (A carrier is needed if you intend to re-transmit the control signals.) Therefore, if you wish to transmit the IR control signal intact, you must exercise care in selecting an IR detector circuit.

The device used here is the TDA4060. This is an excellent choice for the Extended Play transmitter because it meets all of the criteria cited above and requires only a minimum of ancillary components.

Another component of the IR detector circuit worthy of consideration is the transducer. In the Extended Play, an SFH205 PIN-type photodiode was selected because it electrically matches the TDA4060 and is encapsulated in its own IR filter, which eliminates the need to add external light filtering. Unlike phototransistors, which are quite slow in opera-

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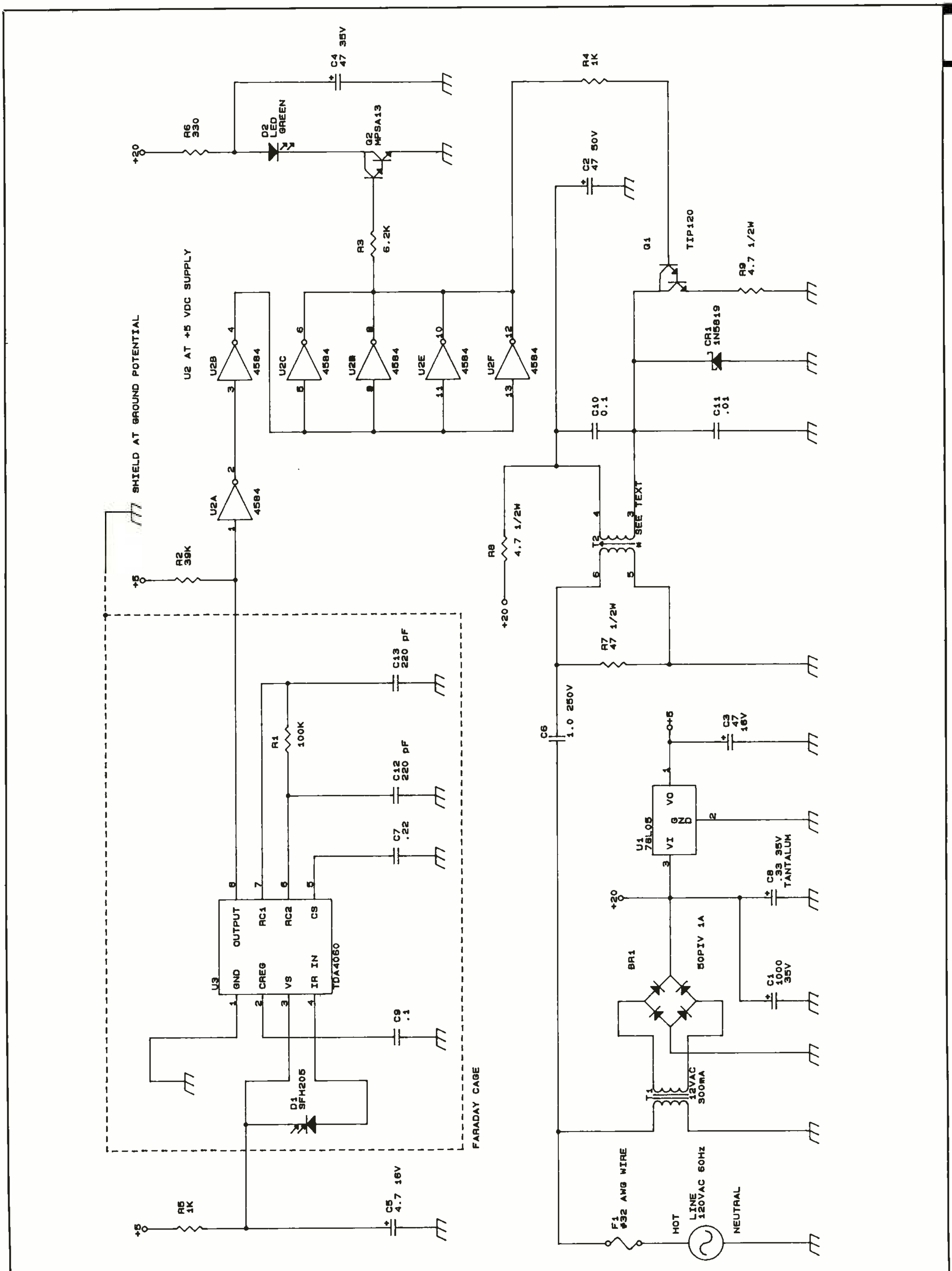

Fig. 1. Complete schematic diagram of Extended Play's transmitter module.

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TRANSMITTER PARTS LIST

Semiconductors
BR1—50-PIV bridge rectifier
CR1—1N5819 Schottky diode
D1—SFH205 photodiode
D2—T1¾ green light-emitting diode
Q1—TIP120 power Darlington transistor (TO-220 package)
Q2—MPSA13 Darlington transistor
U1—78L05 +5-volt regulator
U2—CD4584BC CMOS hex Schmitt-trigger inverter
U3—TDA4060 infrared amplifier

Capacitors
C1—1,000-μF, 35-volt electrolytic
C2—47-μF, 50-volt electrolytic
C3,C5—4.7-μF, 16-volt electrolytic
C4—47-μF, 35-volt electrolytic
C6—1-μF, 250-volt metalized polyester
C7—0.22-μF, 16-volt metalized polyester
C8—0.33-μF, 16-volt dipped tantalum
C9—0.1-μF, 16-volt metalized polyester
C10—0.1-μF, 100-volt metalized polyester
C11—0.01-μF, 100-volt metalized polyester
C12,C13—220-pF, 16-volt monolithic ceramic

Resistors (¼-watt, 5% tolerance)
R1—100,000 ohms
R2—39,000 ohms
R3—6,200 ohms
R4,R5—1,000 ohms
R6—330 ohms
R7—47 ohms, ½ watt
R8,R9—4.7 ohms, ½ watt

Miscellaneous
F1—¼-ampere fuse (see text)
T1—12.6-volt ac, 300-mA pc-mount power transformer
T2—Coupling transformer (TOKO No. 707VX-A043YUK)
Printed-circuit board; suitable enclosure (see text); ac line cord with plug; sockets for U2 and U3; fine copper mesh for Faraday shield (see text); hookup wire; solder; etc.

Note: The following items are available from Scientific Engines, P.O. Box 2295, Everett, WA 98203: Complete Extended Play transmitter and receiver kit (includes pc boards, enclosures, all electronic components, copper screen and self-adhering front-panel overlays), $160.50 plus $5.00 P&H; additional receiver and transmitter kits, $87.50 each plus $2.50 P&H; ready-to-wire transmitter and receiver pc boards, $32.50 per set of two plus $2.50 P&H. Mail orders, make payment via certified check or postal money order; Visa/MasterCard orders, call: (206) 348-7754. Washington residents, please add state sales tax to all orders.

tion, PIN photodiodes lend themselves well to high-speed data transfers. One explanation for this speed is the extremely low junction capacitance of the PIN photodiode (this device is not a true diode; rather, it is a very fast-acting photoresistor).

The PIN photodiode permits very fast turn-on/turn-off cycles. For a phototransistor to operate correctly at the frequencies used in this project would require extensive modification to the detector circuit. This would mean adding a constant-current device held at some negative voltage to the emitter circuit of the phototransistor. This is the only way to effectively draw off the characteristically high pn junction capacitance of the phototransistor, which decreases its rise and fall times.

Once the control signal has been detected and amplified to a usable level, it is impressed on the ac power-line wiring. This is handled by a power amplifier driving a 10:1 step-down coupling transformer (required because of only a few ohms of reactive load typically imposed by the ac line) with multiple impedance taps at its secondary winding. If you wish to maintain low-distortion output into such a heavy load, the design concern becomes one of current delivery into the line, rather than peak output voltage—hence the term "carrier-current" transmission.

For user safety and to protect the transformer, this current is capacitively coupled to the ac line. A similar transformer circuit is then duplicated at the receiver end to detect the control-signal transmission. The receiver filters, amplifies and uses the signal to drive an IR amplifier/driver output stage.

About the Circuit

Referring to the schematic of the transmitter shown in Fig. 1, photodiode transducer *D1* intercepts the signal generated by a hand-held or other IR remote-control transmitter. This transducer converts the received IR energy into an equivalent electrical signal, which is then passed by the anode of *D1* to the IR IN of wide-bandwidth preamplifier *U3* at pin 4. With the input threshold of *U3* in the microvolt range, this IC becomes sensitive to printed-circuit traces and component leads, which tend to act as antennas, passing their collective noise along with the received signal.

Due to extremely low energy received signal level and high signal gain of *U3*, a metallic emi/rfi (electromagnetic interference/radio frequency interference) shield must be used, as indicated by the dashed lines shown around this portion of the schematic. This Faraday shield is comprised of a metallic mesh "cage," extensive pc-board ground planes and the metallic enclosure itself, the last held at ground potential. The Faraday shield compensates for the electrically transmissive plastic end panels of the recommended enclosure and blocks any emi produced by the coupling transformer.

A low-pass RC filter, made up of *R5* and *C5*, is connected to the cathode of *D1* and pin 3 of *U3* to prevent noise on the dc power bus from being passed on to this IC via the pn-junction capacitance of *D1*. Components *C9*, *C7*, *C12*, *C11* and *R1* set the sensitivity and provide bandpass filtering for the amplifier.

Pin 8 of *U3* is the output for an open-collector stage. It is held in a normally high state by *R2*. This out-

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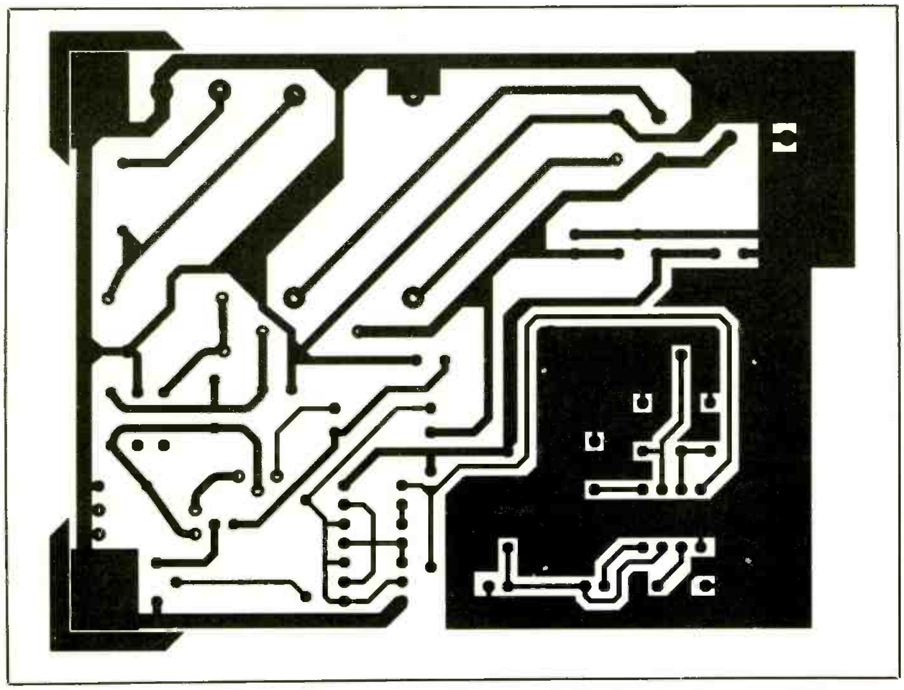

Fig. 2. Actual-size etching-and-drilling guide for transmitter module.

put exactly reproduces the input impressed on pin 4 of *U3* at an amplified, CMOS-compatible level.

Once amplified by *U3*, the signal at OUTPUT pin 8 is passed to Schmitt-trigger inverter *U2A* at pin 1. The remaining gates in *U2* are used to increase the fan-out of the IC while maintaining a normally-low output level when no input signal is present.

Hex Schmitt-trigger *U2* performs two functions. It cleans up the signal image produced at pin 8 of *U3* by eliminating any risetime errors. It also produces the required current to drive both visual indicator light-emitting diode *D2* and the carrier-current line driver circuits.

A high-brightness visual indication of the received signal is provided by light-emitting diode *D2*. This LED receives current through *R6*. Capacitor *C4*, which is connected to the anode of *D2* serves as a current buffer and maintains the high current levels supplied to *D2* to prevent significant supply dropouts and spikes that may occur during the fast LED turn-on and turn-off cycles. These cycles appear at the same rate and frequency as that of the received IR control signal.

A green LED must be used here because red and amber LEDs tend to emit small amounts of IR energy when pulsed at the levels used in the project. Though quite low in power, this energy can cause the receiver to self-oscillate.

Because *U2* cannot directly drive *D2* to the energy levels required for across-the-room viewing, switching transistor *Q2* makes up for this deficiency. This transistor is driven through current-limiting resistor *R3*. When the output potential of *U2* goes positive, a current flows between the emitter-collector junction of *Q2*, which forward-biases the LED.

The shared output of *U2* is passed to *R4*, which is connected to the base of *Q1*. Resistor *R9* sets the current limits of *Q1* at its emitter. Schottky diode *CR1* is a high-speed transient clamp. (Spikes in excess of one kilowatt instantaneous may be produced at the collector of *Q1*, caused by back-emf from the primary winding of *T2*.) Capacitor *C11* further softens these transients and insures overall signal integrity by shunting any r-f energy to ground. Resistor *R8* and diode *CR1* limit the currents produced by these transients.

The primary winding of coupling transformer *T2* and capacitor *C10*

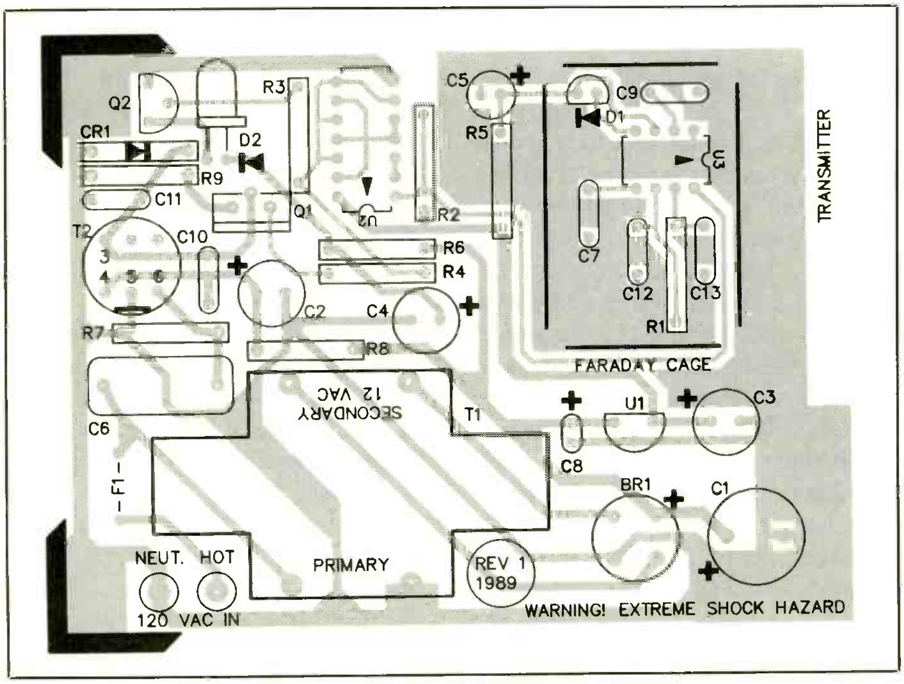

Fig. 3. Wiring guide for transmitter pc board.

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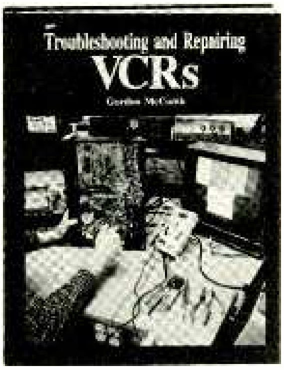

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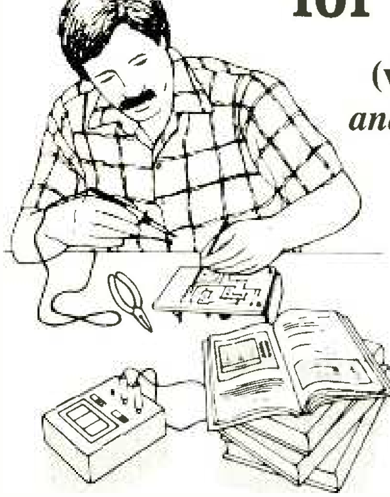

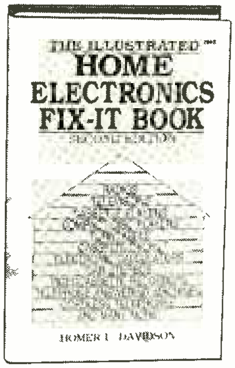

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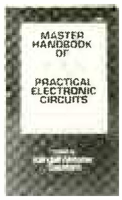

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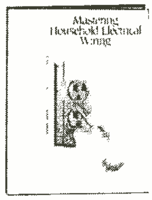
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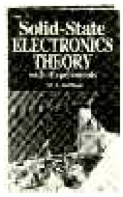

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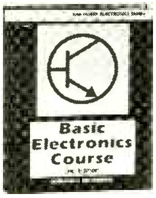

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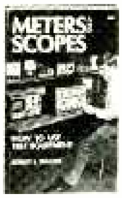

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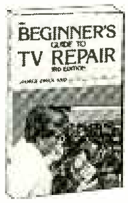

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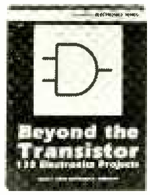

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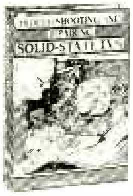

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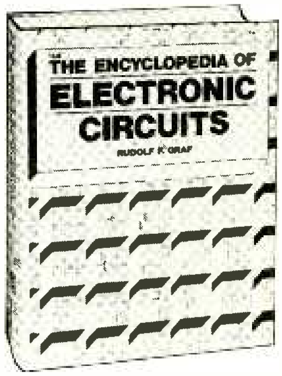

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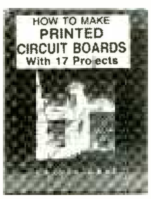

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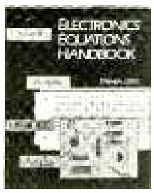

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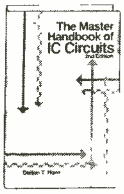

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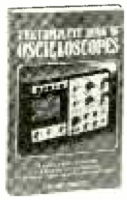
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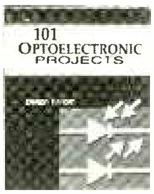

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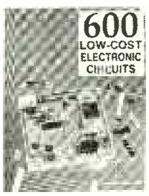

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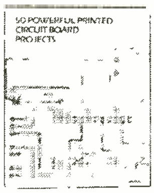
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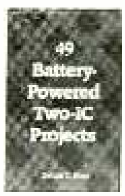

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make up a high-Q resonant LC tank circuit. This tank is designed for optimum operation in the frequency band of approximately 30 kHz to 60 kHz, which is the frequency range employed by the vast majority of modern hand-held IR remote control transmitters.

Buffer capacitor *C2* assists in maintaining the energy required by the transformer circuit to modulate the 117-volt ac power line. This prevents excessive dropouts and ripples from appearing on the transmitter circuit power-supply lines during carrier-current transmission.

When the output of *U2* makes a transition from low to high (positive-going), a current flows in the emitter-collector junction of *Q1*. When produced at or near the center frequency of the LC tank circuit, this current causes the tank to resonate and effectively doubles its excitation voltage. The excitation voltage is coupled to the secondary winding of the LC tank transformer and appears there as a sinusoidal waveform.

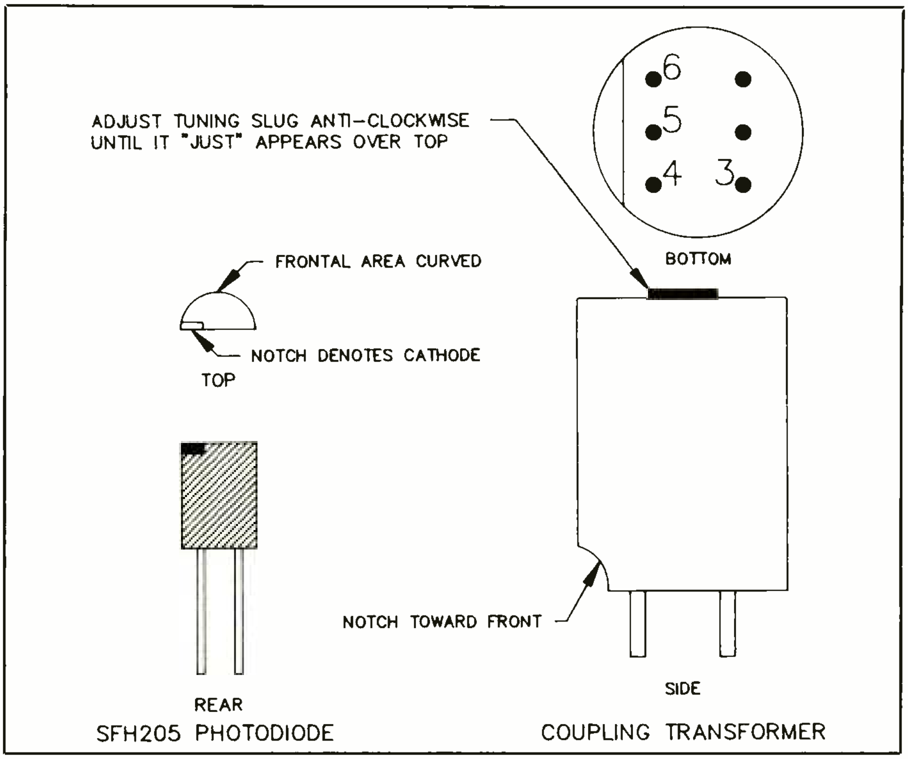

Fig. 4. Physical details for photodiode and coupling transformer. Refer to these drawings when installing these devices on the circuit-board assembly.

The secondary winding of *T2* is impedance-matched to the reactive load of the 117-volt ac wiring. Maximum signal voltage developed across this winding is an approximately 4.5-volt peak-to-peak sinusoidal waveform, as measured across a 4.7-ohm resistive dummy load (approximately 4.3 watts). This signal is coupled to the ac power line by high-voltage capacitor *C6* and resistor *R7*. These two components prevent current from the ac line from being directly coupled to *T2*, while allowing modulation of the ac line. Capacitive coupling greatly enhances overall safety of the circuit and, together with *R7*, snubs any significant power-line spikes before they can reach the transmitter circuitry.

The received control signal is transmitted over the ac power line in an unmodified state. Therefore, the method of transmission can be viewed as a form of pulse code modulation (PCM). No additional encoding or modulating frequencies are required or used in the transmission.

Shown at the lower-left in Fig. 1 is the power supply circuitry for the transmitter. Power transformer *T1*, bridge rectifier *BR1*, capacitors *C1*, *C3* and *C8* and regulator *U1* make up a regulated +5-volt dc power supply. Note here that there is also a pick-off for +20 volts.

Construction

Because of the susceptibility of the transmitter to picking up stray electrical noise, only printed-circuit construction is recommended. You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 2. Alternatively, you can obtain a ready-to-wire, silk-screened board from the source given in the Note at the end of the Parts list.

Wire the transmitter board exactly as shown in Fig. 3, referring also to Fig. 4 for physical details of some key components. Begin by installing and soldering into place the sockets for *U2* and *U3*. Do *not* plug the ICs into the sockets until after preliminary voltage checks have been performed and you are certain that the circuit board has been correctly wired.

Next, install and solder into place the resistors and then the capacitors, making certain that the electrolytic capacitors are properly polarized before soldering any leads to the copper pads on the bottom of the board. Continue wiring the circuit-board assembly by installing and soldering into place the diodes and transistors. Make sure the diodes are properly oriented and that the transistors are properly based. Note the case configurations of the transistors. During installation, the metal tab on *Q1* must be facing toward *C2* and *C10*, and the outline of the case of *Q2* must match that shown. Bend the center leads in both cases as needed to conform with the holes in the board.

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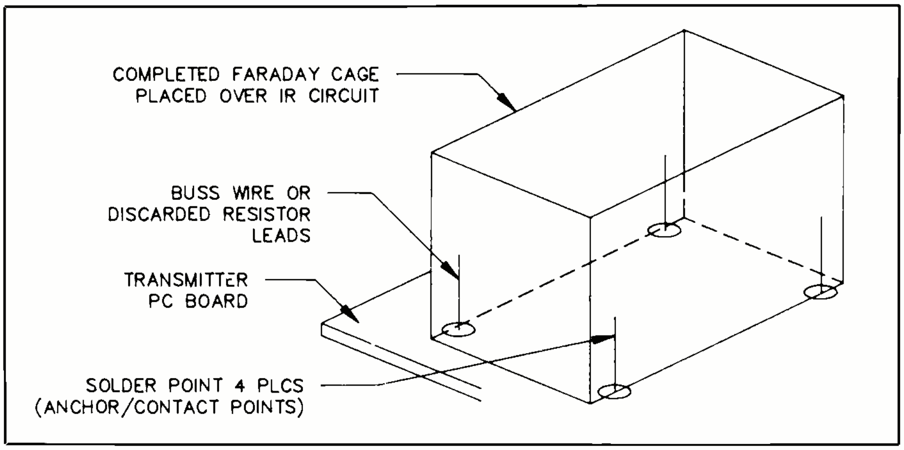

Fig. 5. Details for installing the Faraday shield on the circuit-board assembly. Cut-off resistor leads or bare solid hookup wire secures shield in place and connect electrically to circuit ground.

Identify the cathode lead of light-emitting diode *D2*, and locate it to your right while viewing the LED from the bottom of its case. Bend this lead downward at a 90-degree angle about ¼ to ⅜ inch from the bottom of the case. Then do the same for the anode lead. Plug the leads into the holes in the circuit board and push down until the case of the LED touches the top of the board. Ideally, the dome of the LED should either align with or overhang the front edge of the board by no more than $\frac{1}{16}$ inch (see Fig. 4). Adjust positioning as needed and then solder the leads into place and clip away excess lead length. Refer to Fig. 4 to identify the leads of *D1* and do the same for this photodiode and the D1 board location.

Install and solder into place power transformer *T1*. Then refer to Fig. 4 for pinout details of coupling transformer *T2*. Plug this transformer into the holes in the T2 location on the board and solder its pins into place. Still referring to Fig. 4, identify each lead of photodiode *D1*. Plug its leads into the D1 holes in the board to properly orient the photodiode. Mount the photodiode perpendicular to the top of the board with the bottom of its case $\frac{3}{16}$ to ¼ inch above the surface of the board.

Next, install fuse *F1* in place. You can use either a short length of No. 30 Wire Wrap wire for the fuse or a a solder-tail ¼-ampere fuse.

Now fabricate the Faraday shield. This simply consists of copper mesh cut to size and folded to form a 1.5 × 1-inch straight-sided rectangle that encloses *U3* and the nearby components, as shown in Fig. 3.

If you purchase the kit of parts from the source given in the Note at the end of the Parts List, the copper mesh for the Faraday shield comes as a 1 × 5-inch strip that simply needs to be folded to form the rectangle. Copper mesh purchased from any other source may require trimming to these dimensions. Whatever the source, if the mesh is discolored as a result of oxidation, clean it prior to use with a mild solution of powdered copper cleaner and warm water. Do *not* use a paste-type copper cleaner; it leaves a difficult to remove residue. After thorough cleaning and rinsing to remove all residue, bathe the strip in a cold tin-plating solution prior to soldering, removing and rinsing it when it has been completely plated with tin.

Use a ruler and a fiber-tipped marker with indelible ink to make marks 1, 2.5 and 3.5 inches from one end of the mesh strip to indicate where the folds are to be made. Carefully make a 90-degree bend at each marked point to form a straight-sided rectangular "cage." It helps if you use a rigid metal edge to assist you in making the bends.

When the cage has been formed, use a small amount of solder to tack together the open corner edge at two or three places. Select four cut-off resistor leads or 1-inch lengths of solid bare hookup wire. Place the circuit-board assembly in front of you facing up and oriented as shown in Fig. 3. Drop one wire into each of the four Faraday-shield holes and test fit the shield over the area in which it is to mount, with the wires on the *outside* of the cage, as shown in Fig. 5.

Carefully tack solder each wire at top and bottom to the mesh cage. Do *not* solder the wires to the copper pattern on the bottom of the board at this time. Remove the Faraday cage and more solidly solder each wire into place. Make sure that no wire moves as you do this. Then set aside the cage until it is called for later.

Prepare the face plates of the enclosure as follows. (Note: If you use any enclosure other than the one supplied with the kit, make suitable adjustments in the procedure to be described.) First, remove all screws that secure the front and rear panels in place from the enclosure and set them aside with the Faraday cage. Next, use a quality photocopier to make a same-size copy of Fig. 6. Carefully cut out the templates along the dotted lines.

Place the templates on the front of the front and rear panels of the enclosure. Use an X-acto knife fitted with a No. 11 blade or a small drill punch to carefully mark the center of the power-cord entry hole onto the rear panel. Repeat for the LED and IR window cutout hole centers on the front panel.

Remove and set aside the templates. Then drill the line cord entry hole through the rear panel. The panels of the enclosure provided with the kit are made from soft plastic that

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does not readily take to drilling large-diameter holes without becoming eccentric or/and ragged and shifting off-center. Therefore, begin drilling with a 1/16-inch bit and progress to a 1/8-inch bit. Follow up with a hand reamer tool (Radio Shack Cat. No. 64-815 or similar), working slowly and checking the diameter often until the given hole dimension is obtained.

When the hole is finished, insert an appropriate size vinyl grommet into it. Feed the free end of the power cord through the grommet and tie a strain-relieving knot in it about 4 inches from the unfinished end on the inside of the panel. Separate the two line-cord conductors to within ½ inch of the knot. Then tightly twist together the fine wires at the ends of both conductors and sparingly tin with solder.

Following the procedure detailed above, drill the hole for the LED through the front panel. When you are done, drill a 1/16-inch hole in each of the four corners of the IR window area as shown in Fig. 6. Follow up with a 1/8-inch bit and hand reamer until at least one hole is large enough to accommodate a nibbling tool (such as the Radio Shack Cat. No. 64-823), which should be used to finish up making the window.

Insert the cutting head of the nibbling tool from the-inward facing side of the end-panel. Do not be overly concerned if the edges of the window are slightly ragged; the self-adhering front-panel overlay will cover it and the rest of the panel.

If you are building the project using a different type of enclosure than that supplied with the kit, make the window as neat and squared off as possible and face or back it with a transparent red plastic filter. If you are using the enclosure supplied with the kit, do *not* install the overlay until the transmitter and next month's receiver have been fully tested and you are satisfied with their operation. If you do, the overlay will cover the panel mounting screw holes and will be destroyed if any attempt is made to remove it.

Place the circuit-board assembly in front of you, oriented as shown in Fig. 3. Plug the free ends of the ac line cord into the holes labeled NEUT. and HOT at the lower-left of the board. Solder both connections.

Preliminary Checkout

Use a battery-powered dc voltmeter or a multimeter set to the dc-volts function to perform preliminary voltage checks. Before you begin, though, keep foremost in mind that this project makes use of potentially lethal ac-line current. Therefore, you must exercise extreme caution when probing in the powered circuitry.

Place the circuit-board assembly on an insulated surface. Clip the common lead of the meter to power-supply ground, and plug the line cord of the project into a convenient ac outlet. Then use the "hot" probe of the meter to take readings at pin 14 of the *U2* socket and pins 3 and 8 of the *U3* socket. In all cases, you should obtain a reading of +5 volts. You should also obtain a reading of approximately +20 volts when you touch the "hot" probe to the + terminal of the bridge rectifier.

If you do not obtain the proper reading at any given point in the circuit, immediately power down by pulling the plug from the ac outlet. Check to make sure that all components have been installed in their correct locations and that all electrolytic capacitors, diodes, the bridge rectifier assembly, transistors and voltage regulator are properly oriented.

Also check all soldering. If you missed a connection, solder it now. Reflow the solder on any suspicious connection. Clear away any solder bridges with desoldering braid or a vacuum-type desoldering tool. Do

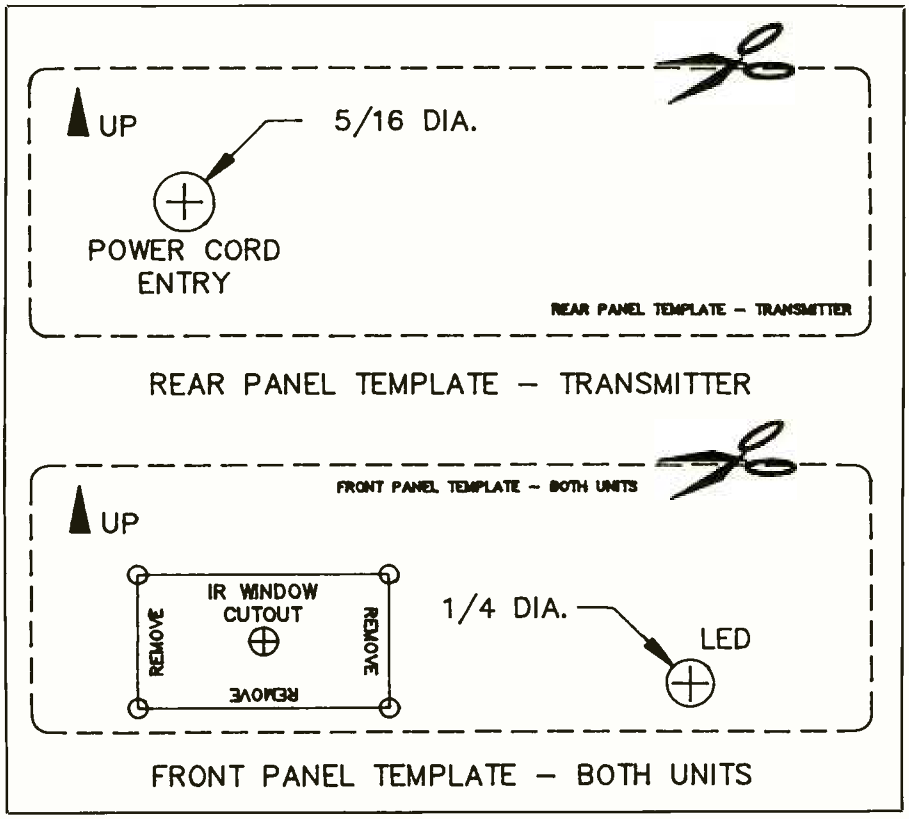

Fig. 6. Fabrication details for front and rear panels of the enclosure.

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not proceed with assembly until you have rectified the problem.

When you are satisfied that everything is functioning correctly, disconnect the power and allow time for the charges to bleed off the electrolytic capacitors in the power supply. Then install *U2* and *U3* in their respective sockets. Make certain that each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets. Also, exercise normal safety procedures when handling these CMOS devices.

Install the Faraday cage by plugging the ends of the wires you soldered to it earlier into the holes in the circuit-board assembly. Gently press the cage against the board until it is squarely seated in place and is flush all around. Then hold the cage in place as you solder the ends of the wires to the copper trace on the bottom of the board. Work quickly to prevent the wires from coming loose as a result of excessive heat.

Referring to Fig. 4, adjust the tuning slug of the coupling transformer until it is just visible along the top of the case of the transformer when viewed edge-on. Plug the line cord of the transmitter into the ac outlet.

Use a hand-held IR remote-control transmitter from a TV receiver or VCR to make an operational test of the Extended Play transmitter. Stand about 5 feet back from the receiver module and point the remote controller directly at the front of the circuit-board assembly. Each time you press any button on the remote controller, the green LED on the transmitter board should flash. Although the transmitter is sensitive to a range well beyond 20 feet, actual usable IR range is closer to 18 feet.

It is normal for the the LED to flash intermittently on its own. Outside of its enclosure the circuit is susceptible to stray emi. Bright fluorescent lighting in your work area may have to be shut off because it generates spurious IR energy that can interfere with normal operation.

Once you are satisfied with operation of the IR detector, disconnect the power cord from the wall outlet and install the circuit-board assembly in its enclosure, the edge with the detector and LED first. Carefully slide the assembly into the grooves located along the squared corners of the enclosure interior.

When fully inserted, view the space between the underside of the board and the floor of the enclosure to make certain no component legs come into contact with the enclosure interior. If there is adequate clearance, hold the assembly firmly in place and install only the rear panel via its four mounting screws. Do *not* install the front panel at this time.

The screws for the enclosure provided with the kit are stiff to install; so work slowly, exercising caution not to over-tighten or strip them. As the lower panel-retaining screws are threaded in place, they cut into the traces along the edges of the circuit-board assembly, making and maintaining electrical contact between circuit ground and the metal enclosure.

Together, the Faraday shield, ground planes on the circuit board and enclosure provide enough emi shielding to permit the transmitter to be conveniently placed on top of or alongside most TV receivers.

Coming Next Month

In this first installment, we have presented full theory of operation and construction details for the Extended Play transmitter module. Next month, in the conclusion, we will discuss operation and construction of the receiver module, system checkout and installation and use.

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Microcomputer on a Chip

Motorola's MC68701 microcomputer on a chip offers a wide variety of features that make it ideal for experimenter projects

By Brian B. Beard

Designed as a development tool for the 6801 masked ROM microcomputer, the Motorola MC68701 eight-bit single-chip microcomputer allows the user to make software changes before committing to final circuit version. Available from several sources for less than $15, it offers an abundance of resources and an affordable price make this chip almost ideal for electronic projects.

Like all Motorola processors, the 68701 uses linear addressing and memory-mapped I/O. As part of the 6800 family of microprocessors (including the 6801 and 6803), the 68701 has the same instruction set as its predecessors, which is an enhanced version of the 6800 instruction set. This instruction set is compatible with source and object code written for the 6800. Programming of these microprocessors is usually in assembly language. Therefore, in this article, we use Motorola syntax in which hexadecimal values are preceded by a dollar sign, as in $0F, $8A3E, etc.

This time out, we familiarize you with the 68701 in enough detail so that you can utilize this chip in your own projects. In an upcoming issue, we will detail how to program the internal EPROM and discuss construction details for a programmer you can build to accomplish this using a serial or parallel port of any personal computer.

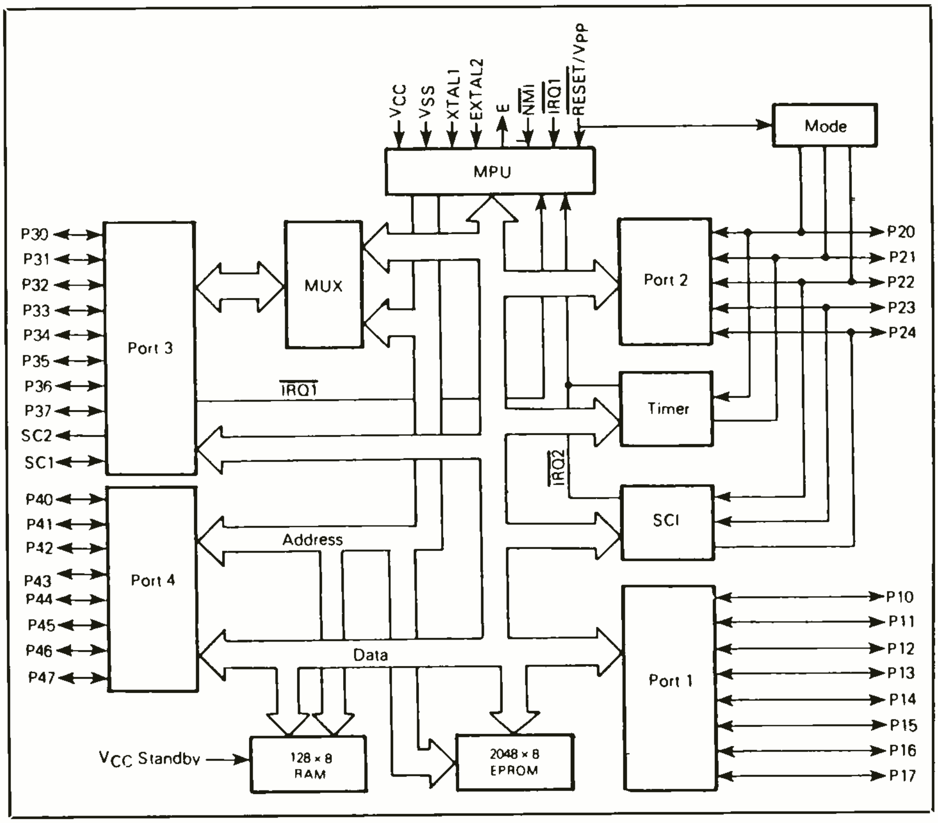

Fig. 1. Block diagram of internal architecture of Motorola's MC68701 microcomputer. (All figures courtesy of Motorola Inc.).

Chip Resources

Shown in Fig. 1 is a block diagram of all the resources contained on the 68701 microprocessor chip. These include: 2K bytes of EPROM, 128 bytes of RAM, serial communications interface (SCI), parallel I/O, clock oscillator and three-function programmable timer. The latest version of this chip, which bears the number 68701U4, has 4K bytes of EPROM, 192 bytes of RAM, more timer functions and a complete baud-rate generator. This enhanced U4 version does everything the standard version does and more. Because of the fact that two versions of the chip may be available where you buy and you may get only the original 68701, we will limit our discussion here to the standard version.

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Table 1. Summary of MC68701 Operating Modes

Common to all Modes:
Reserved Register Area
Port 1
Port 2
Programmable Timer
Serial Communication Interface (SCI)

Single Chip Mode 7:
128 bytes of RAM; 2048 bytes of EPROM
Port 3 is parallel I/O with two control lines
Port 4 is parallel I/O
SC1 is Input Strobe 3
SC2 is Output Strobe 3

Expanded Non-Multiplexed Mode 5:
128 bytes of RAM; 2,048 bytes of EPROM
256 bytes of external address space
Port 3 is an eight-bit data bus
Port 4 is an input port/address bus
SC1 is Input/Output Select
%MSC2 is Read/Write (R/W)

Expanded Multiplexed Modes 1, 2, 3, 6
Four memory map options, each with 64k address space
1. External RAM, EPROM, and interrupt vectors (Mode 3)
2. Internal RAM, external EPROM and vectors (Mode 2)
3. Internal RAM and EPROM, external vectors (Mode 1)
4. Internal RAM, EPROM, and interrupt vectors (Mode 6)
Port 3 is a multiplexed address/data bus
Port 4 is an address bus
SC1 is Address Strobe (AS)
SC2 is Read/Write (R/W)

Expanded Multiplexed Mode 0:
64k of address space
Internal RAM and EPROM
External interrupt vectors at $BFF0 through $BFFF
Used to program internal EPROM

Test Mode 4:
For factory testing

All versions of the 68701 are supplied in a 40-pin ceramic dual in-line package, the pinouts for which are shown in Fig. 2. Because Motorola recently changed package designations, you may find part numbers with either an L or S suffix.

Referring to both Fig. 1 and Fig. 2, let us now discuss the various elements that make up the 68701:

• *Clock Oscillator.* Available at pins 2 and 3, XTAL1 and EXTAL2, connect directly to most commercially available crystals whose operating frequencies are between 2 and 4 MHz. A divide-by-four circuit reduces the crystal frequency to establish the operating clock frequency of the chip, which is known as the E clock. The E clock is available at pin 40 of the 68701 and is used to synchronize data-bus transfers in the expanded operating modes. Maximum E clock frequency for the 68701 is 1 MHz, which is obtained with a 4-MHz crystal. A 20-picofarad capacitor should be tied from each crystal pin to ground to ensure reliable start-up.

• *Operating Modes.* The 68701 can operate in eight different modes, which are referred to as Mode 0 through Mode 7. The operating mode determines the memory map, use of Port 3, Port 4, SC1, SC2 and locations of interrupt vectors. Table 1 summarizes the characteristics of the operating modes. The operating mode is latched in from P20, P21 and P22 on the rising edge of RESET. The three-bit binary number on these pins at that instant is the mode number. Since these pins may also be used for general I/O, external circuitry may be required to force them to the correct mode number when RESET is low.

• *Memory.* At first glance, the amount of memory supplied in the 68701 may seem rather limited. Actually, there is plenty for the jobs the chip was designed to do. The 6801/68701 is usually used in embedded control applications that do not require large amounts of variable storage. If internal memory is not enough, of course, one of the expanded modes can be used. The lower 64 bytes of RAM, at locations $80 through $BF, are powered via pin 21. Whenever internal RAM is used, +5 volts must be applied to this pin. A

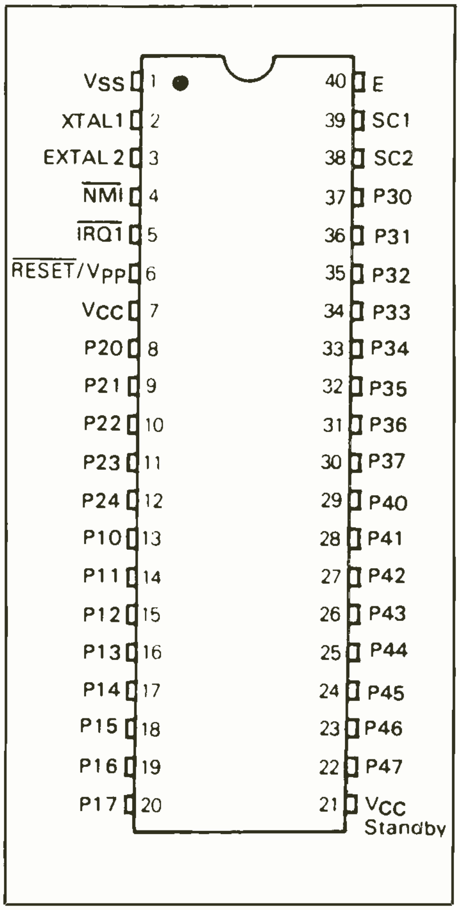

Fig. 2. Pin assignments for MC68701.

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Table 2. Internal Register Area of 68701

Register	Address*
Port 1 Data Direction Register	00
Port 2 Data Direction Register	01
Port 1 Data Register	02
Port 2 Data Register	03
Port 3 Data Direction Register	04
Port 4 Data Direction Register	05
Port 3 Data Register	06
Port 4 Data Register	07
Timer Control and Status Register	08
Counter (High byte)	09
Counter (Low byte)	0A
Output Compare Register (High byte)	0B
Output Compare Register (Low byte)	0C
Input Capture Register (High byte)	0D
Input Capture Register (Low byte)	0E
Port 3 Control and Status Register	0F
Rate and Mode Control Register	10
Transmit/Receive Control and Status Register	11
SCI Receive Data Register	12
SCI Transmit Data Register	13
RAM/EPROM Control Register	14
Reserved for future expansion	15-1F

*Addresses are in hexadecimal format.

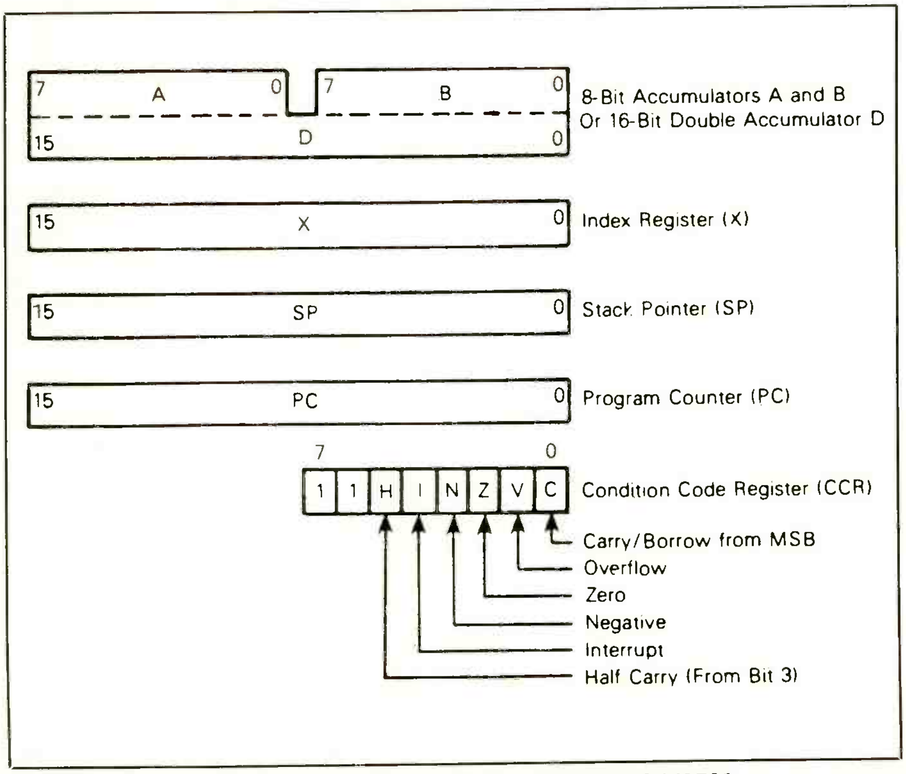

Fig. 3. Programming model for 6801/6803/68701.

back-up battery on his pin can keep critical data from being lost during power outages.

Memory from $0000 to $001F is the internal register area, as detailed in Table 2. This area is the same in all modes and consists of the registers used to control and monitor the on-chip peripherals.

• *I/O Ports.* There are 29 parallel I/O lines that are organized as four ports. Each port is controlled by two registers. The Data Direction Register determines which lines are input and which are output. A 0 in a bit location makes that line an input, while a 1 makes it an output. All Data Direction Registers are cleared when RESET goes low. The Data Register is used to both read input and write output data. Port lines are designated by the letter "P" followed by the port number and the bit number; thus P12 refers to Port 1, bit 2.

Port 1 (P10 through P17) is a mode-independent I/O port. Port 2 (P20 through P24) is a mode-independent multi-purpose I/O port. It is used to set the operating mode and provide access to the SCI and programmable timer functions. Port 3 (P30 through P37) can be an I/O port, a bidirectional data bus, or a multiplexed address/data bus depending on the operating mode.

Control lines SC1 and SC2 work with Port 3 in all modes. In single-chip mode, the control lines can latch Port 3 input data, strobe output or perform bidirectional handshaking. In multiplexed mode, SC2 becomes read/write (R/W), and SC1 functions as Address Strobe (AS). Port 4 (P40 through P47) functions as an I/O port in single-chip mode. In multiplexed modes Port 4 becomes address lines A8 through A15.

• *Programmable Timer.* The heart of the timer is a 16-bit free-running counter that is incremented by the E clock. The programmable timer does overflow detection, output comparison and input capture. Any or all of these features can be enabled and

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linked to interrupts by programming the Timer Control and Status Register.

Whenever the counter reaches a value of $FFFF, an overflow flag is set, which can be used to generate a periodic interrupt. When the 16-bit counter equals the Output Compare Register a preset level is clocked out to P21. Pulse-width modulation is easy to implement with this feature.

The Input Capture Register latches the current value of the 16-bit counter when a proper level transition is detected on P20. A proper level transition can be programmed as either a rising or a falling edge. By counting the number of E cycles between edges of a waveform, its period can be accurately measured.

• *Serial Communications Interface (SCI).* SCI mode and baud rate are determined by the Rate and Mode Control Register. Baud rate can be set to any of four frequencies derived from the E clock; E/16, E/128, E/1,024, and E/4,096. For many crystal frequencies, these choices do not yield standard baud rates, so one other option has been included on the chip. An external clock at eight-times the desired baud rate can be connected to P22.

SCI is full-duplex and asynchronous and provides one start bit, eight data bits and one stop bit. The Transmit/Receive Control and Status Register enables the transmit and receive sections and their interrupts and monitors the status of serial operations. Data written to the Transmit Data Register is shifted out, LSB first, to P24. Serial data to the receiver is connected to P23. As each complete byte is received, it is loaded into the Receive Data Register.

The Software

A programming model for the 6801/6803/68701 is shown in Figure 3. Eight-bit accumulators A and B operate identically in that any instruction that uses A can also be done using B. For 16-bit operations, A and B make up a 16-bit accumulator referred to as D (for Double accumulator), where A is the most-significant byte. Six addressing modes are supported, as follows:

• **Immediate Addressing.** In immediate addressing, the instruction contains the value to be acted upon—not as a pointer to the value. For example, "LDAA #3" loads Accumulator A with the value 3, not the data stored at address $03.

• **Direct Addressing.** Instructions using direct addressing contain a one-byte address for the data to be acted upon. Thus, only data stored between $00 and $FF can be accessed with direct addressing. The instruction "LDAA 3" loads Accumulator A with the data at address $03.

• **Extended Addressing.** Extended addressing is similar to direct but allows a two-byte address. Thus, data from $0000 to $FFFF, the entire 64k address space, can be accessed. The instruction "LDAA $81FF" loads the Accumulator with the data at absolute address $81FF.

• **Indexed Addressing.** Instructions using indexed addressing provide a one-byte unsigned offset (0 to 255) that is added to the value of the index register. The result of this addition is the address of the data. Consider the two lines of assembly code "LDX #$8000" and "LDAA 3,X." The first line loads Index Register X with the 16-bit absolute hex value 8000, while the second line loads Accumulator A with the data at address $8003 ($8000 + $03).

• **Inherent Addressing.** These are single-byte instructions. Op-codes specify everything that is needed. For example, the instruction "CLRA" means clear Accumulator A; nothing more is needed because the location to be accessed, Accumulator A, is inherent in the instruction.

• **Relative Addressing.** Only branch instructions use relative addressing. A branch instruction contains a one-byte signed offset (– 126 to 129) that is added to the program counter if the branch condition is true. If the condition is false, execution continues with the next instruction.

Further Information

This article is much too short to completely describe all the aspects of the versatile MC68701 microcomputer chip. If you want to learn more about the 68701, particularly if you plan on using it in a project, contact Motorola for complete data. A good way to do this is to call the Motorola Freeware Bulletin Board System at (512) 891-3733. Protocol is 300 or 1,200 baud, eight bits, no parity and one stop bit. This BBS is a treasure trove of valuable information. It offers free cross-assemblers and application notes, lists of local sales offices and distributors, user group libraries, and much more. ME

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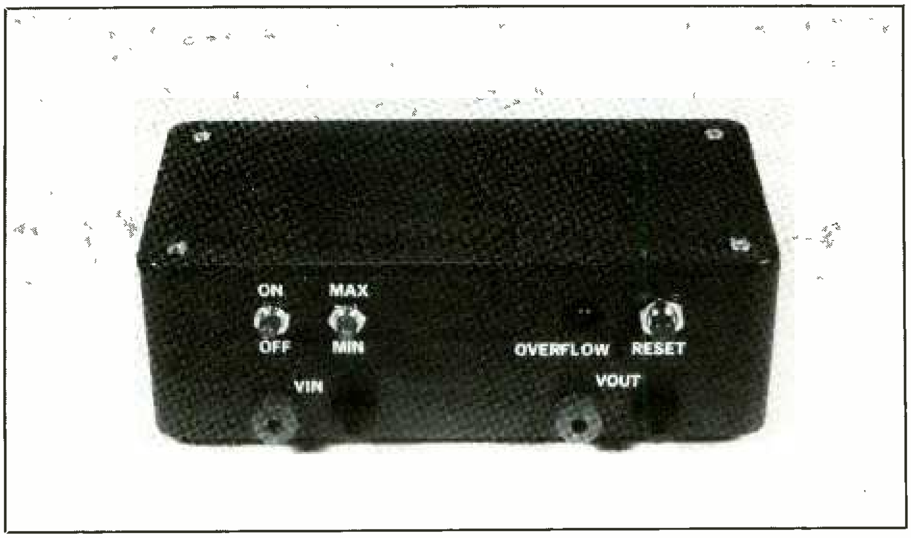
A Maximum/Minimum Voltage Detector

This voltmeter accessory tracks highest or lowest voltage, light or other physical parameter levels for testing, troubleshooting and other applications

By Jan Axelson



It is often useful to know the maximum or minimum measurement made over a period of time. For example, you might want to know the highest or lowest output voltage of a power supply, or the loudest noise, the dimmest light, the highest temperature or some other maximum or minimum value that occurs over a given period of time. The Maximum/Minimum Voltage Detector described here permits you to make this type of measurement by storing the highest or lowest voltage it detects. The stored voltage can then be measured with any dc voltmeter.

Sensors and additional circuitry can be used to translate light, sound, temperature and other physical phenomena into voltages that are measurable with this project.

Our Maximum/Minimum Voltage Detector continuously compares its input voltage to a previously stored value. If the input voltage is greater than the stored value (for maximum measurements) or less than the stored value (for minimum measurements), the input voltage becomes the new stored value. In this way, the stored voltage always equals the maximum (or minimum) voltage sensed.

About the Circuit

Designing and building a circuit that directly stores an analog voltage is difficult to do. A capacitor charged to a certain voltage might hold the charge for a given period of time. However, leakage current will eventually cause the voltage across the capacitor to droop. For this reason, a different approach is used in the Maximum/Minimum Detector, which stores its voltages in digital form. Two CMOS counters make up an analog-to-digital (A/D) converter that saves the maximum or minimum measured voltage as an eight-bit digital word. A digital-to-analog (D/A) converter transforms the digital word back into an analog voltage for comparison with the input voltage.

Shown in Fig. 1 is the complete schematic diagram for the circuitry of the Maximum/Minimum Voltage Detector. Batteries *B1* and *B2* provide +9 and −9 volts for the circuitry. Capacitors *C1*, *C2*, *C3* and *C5* provide filtering and bypassing for the dc battery supply. NAND Schmitt trigger *IC2A*, capacitor *C4* and resistor *R2* generate an approximate 700-kHz clock signal frequency at pin 3 of *IC2A*.

The input to the Detector (V_{in}) is the voltage across jacks *J1* and *J2*. Comparator *IC1* compares V_{in} to stored voltage V_{out} at pin 6 of *IC8*.

Comparator *IC1*'s output at pin 7 is high (+9 volts) if the potential at pin 2 is greater than that at pin 3, and low (0 volt) if the potential at pin 3 is greater than that at pin 2. Pull-up action for the open-collector output of *IC1* is provided by *R1*.

Switch *S2* determines whether the Detector stores the maximum or minimum voltage measured. This switch serves three functions: selects either a true or inverted output at pin 12 of *IC3D*; configures counters *IC5* and *IC6* to count either up or down

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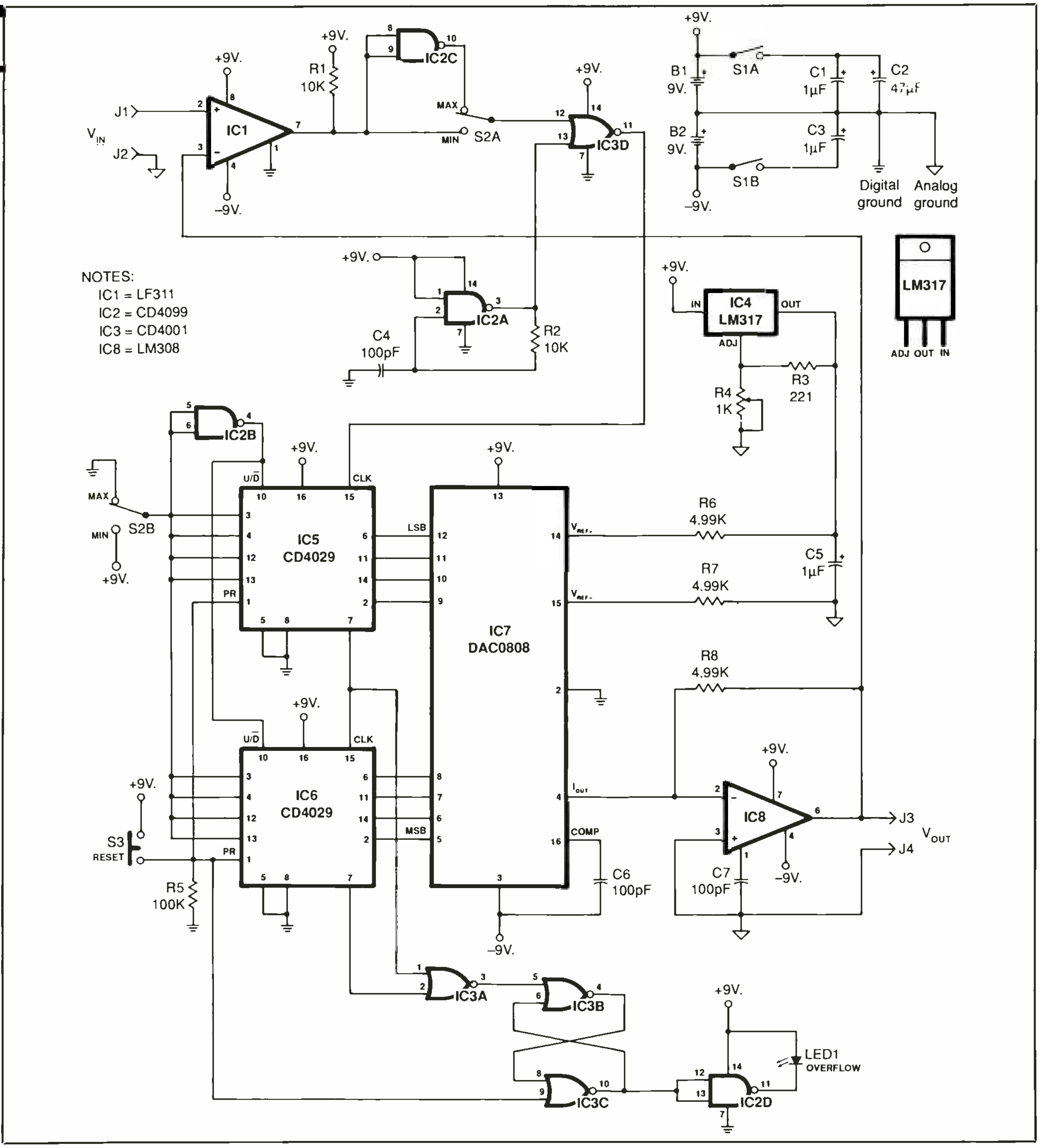

Fig. 1. Complete schematic diagram of circuitry used in Maximum/Minimum Voltage Detector.

(at pin 10); and determines whether the counters will reset to their maximum or minimum counts (at pins 3, 4, 12 and 13).

NOR gate *IC3D* serves as a switch that transmits or inhibits clock pulses to counter *IC5*. When pin 12 of *IC3D* is high, pin 15 of *IC5* is held low, and when pin 12 of *IC3D* is low, pin 15 of *IC5* is clocked by *IC2A* through *IC3D* (*IC3D* inverts the clock pulses).

Counters *IC5* and *IC6* are cascaded by connecting CARRY OUT pin 7 of *IC5* to CLOCK pin 15 of *IC6*. The outputs at pins 6, 11, 14 and 2 of the counters are in binary from 00000000 to 11111111 (decimal 255).

When switch *S3* is pressed, the outputs of *IC5* and *IC6* are preset to the count at their "jam" inputs at pins 3, 4, 12 and 13. If *S2* is set to MAX, pressing *S3* sets low the counter outputs and, if *S2* is set to MIN, *S3* sets high the outputs.

The outputs of the counters are the inputs at pins 5 through 12 of *IC7*, a DAC0808 digital-to-analog convert-

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PARTS LIST

Semiconductors
IC1—LF311 comparator
IC2—4093B CMOS quad NAND gate Schmitt trigger
IC3—4001B CMOS quad NOR gate
IC4—LM317 adjustable positive voltage regulator
IC5,IC6—4029B CMOS up/down counter
IC7—DAC0808 digital-to-analog converter
IC8—LM308 operational amplifier

Capacitors (25 WV minimum)
C1,C3,C5—1.0-μF tantalum
C2—47-μF electrolytic
C4,C6,C7—100-pF ceramic disc

Resistors (¼-watt)
R1,R2—10,000 ohms, 5% tolerance
R3—21 ohms, 1% tolerance
R5—100,000 ohms, 5% tolerance
R6,R7,R8—4,990 ohms, 1% tolerance
R4—1,000-ohm pc-mount 15-turn potentiometer

Miscellaneous
B1,B2—9-volt battery
J1 thru J4—Banana jack
S1—Dpst toggle or slide switch
S2—Dpdt toggle or slide switch
S3—Spst momentary-action normally-open pushbutton switch
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware (see text); sockets for all DIP ICs (two 14-pin, three 16-pin); snap connectors and holders for B1 and B2; panel-mount LED holder (optional); suitable enclosure; labeling kit and clear acrylic spray (see text); machine hardware; hookup wire; solder; etc.

er, or DAC. The DAC generates a current at pin 4 that is proportional to the binary count at its inputs.

The range of the DAC is set by references at pins 14 and 15. The lower reference is tied to ground through *R7* at pin 15. Voltage regulator *IC4* and resistors *R3* and *R4* provide an adjustable positive reference (V_{ref}) that ranges from 1.25 to 6 volts. V_{ref} connects to pin 14 of *IC7* through *R6*.

Operational amplifier *IC8* generates a voltage across resistor *R8* in proportion to the output current at pin 4 of *IC7*. This is the output voltage (V_{out}) of the Detector and is also the input at pin 3 of comparator *IC1*.

If *R4* is adjusted so that V_{out} is +5 volts, pin 6 of *IC8* increases from 0 to 5 volts as pins 5 through 12 of *IC7* count from 00000000 to 11111111. Capacitors *C6* and *C7* provide compensation and are recommended by the data sheets for *IC7* and *IC8*. Additional data and applications information about the DAC0808 can be found in Linear Databook 2 (1988 Edition) from National Semiconductor Corp.

If the counting circuitry overflows, a set of logic gates causes *LED1* to latch on. Pin 7 of *IC5* and *IC6* is a CARRY OUT output that goes low if a clock pulse occurs when pins 6, 11, 14 and 2 are all high (if counting up) or all low (if counting down). If pin 7 of both ICs are low at the same time, the counters are beyond maximum (or minimum) count.

NOR gates *IC3B* and *IC3C* make up a set/reset flip-flop. When pin 7 of *IC5* and *IC6* are both low, pin 3 of *IC3A* is high and pin 4 of *IC3B* is low. Unless *S3* is pressed, pin 9 of *IC3C* is held low through *R5*. Pin 10 of *IC3C* is high, pin 11 of *IC2D* is low and *LED1* is on. Once *LED1* turns on, it remains on until *S3* is pressed, bringing pin 10 of *IC3C* low and pin 11 of *IC2D* high.

As an example of circuit operation, observe what happens if V_{in} is 1 volt and *S2* is set to MAX. When *S3* is pressed to reset the circuit, *IC5* and *IC6* reset to 00000000 and V_{out} equals 0 volt. Since V_{out} is less than V_{in}, pin 7 of *IC1* goes high, pin 10 of *IC2C* goes low, and *IC3D* clocks *IC5*. With the rising edge of each clock pulse, the count at pins 5 through 12 of *IC7* advances one count. As a result V_{out} rises slightly.

The counters continue counting until V_{out} is slightly higher than the 1-volt V_{in}. At this point, pin 7 of *IC1* goes low, pin 10 of *IC2C* goes high and the counters stop counting.

If V_{in} now drops below 1 volt, V_{out} remains at 1 volt because the counters are holding the DAC inputs at their previous high count. If V_{in} goes higher than 1 volt, pin 7 of *IC1* will go high again, causing the counters to resume counting and V_{out} to increase. As soon as V_{out} is greater than V_{in}, the counters cease counting and the new maximum voltage is saved.

To measure minimum voltages, both halves of *S2* are set to MIN. Circuit operation is much the same as for measuring maximums, with these differences: *IC5* and *IC6* now count down instead of up; the counters reset to 11111111 instead of to 00000000; and the output of *IC1* is not inverted by *IC2C*, so the counters count when V_{in} is less than (not greater than) V_{out}. Also, *LED1* turns on when the count goes lower than 00000000, instead of higher than 11111111.

Construction

The circuitry for the Maximum/Minimum Voltage Detector is suitable for construction using Wire Wrap or soldering hardware and techniques and perforated board with holes on 0.1-inch centers. If you prefer, you can use a printed-circuit board of your own design. Whichever method you choose, sockets are recommended for all DIP ICs.

Any suitable-sized plastic or metal enclosure can be used. Be sure to reserve room in the enclosure for the two 9-volt batteries and the switches and jacks that will mount on its walls. Figure 2 shows a completed Wire Wrapped project in its enclosure.

The project's components are commonly available from local stores and mail-order houses. For best accuracy and stability, use 1-percent precision resistors for *R3*, *R6*, *R7* and *R8* and a precision 15-turn potentiometer for *R4*.

The circuit easily fits on a 3 ×

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4-inch circuit board. If you go the Wire Wrap or point-to-point soldering route, take some time to plan your component layout—including the locations for where the connections to +9 volts, −9 volts and ground will come onto the board—to obtain a minimum-size assembly.

Except for *S1*, *S3*, *LED1*, *B1* and *B2*, and *J1* through *J4*, all components mount on the circuit board. These exceptions mount on the front or top panel of the enclosure. When you are ready to lay out the components on the circuit board, mount the IC sockets but *not* DIP ICs themselves in their respective locations. Save installation of the ICs until after assembly is completed and you have run preliminary voltage checks. When you are finished wiring the circuit-board assembly, the only IC that should be on the board is regulator *IC4*.

Begin wiring the circuit by installing the DIP IC sockets and voltage regulator. Then proceed to wiring from the sockets and *IC4* to +9 volts, −9 volts and ground. Minimize noise in the analog portions of the circuit by using a separate ground return for the analog circuitry. Note that in Fig. 1 analog grounds are shown as a triangular symbol, whereas normal power ground is depicted by the traditional three lines in triangle form. Wire these connections to a common point, keeping them electrically separate from the other ground connections. Then wire this point directly to the ground connection for the battery connectors.

Continue wiring the on-board circuitry with the resistors and capacitors. Be sure to observe proper polarity for the electrolytic capacitors. Connections to the batteries, switches, LED and jacks require two 9-volt battery clips and 16 short lengths of hookup wire with ¼ inch of bare wire at each end.

To prepare your enclosure, drill appropriate-size mounting holes for the jacks, switches, LED, battery clips and the circuit-board assembly. After drilling is complete, deburr any holes drilled through metal to remove sharp edges. Then use a dry-transfer lettering kit to label the controls and the LED. Follow up with two or more light coats of clear acrylic spray to protect the legends.

When the spray acrylic has completely dried, mount the jacks, switches, LED and battery clips via their respective holes. If the LED does not remain in place, secure it with a daub of clear fast-setting epoxy cement. Then mount the circuit-board assembly in place using ½-inch spacers and 4-40 × ¾-inch machine screws, nuts and lockwashers. This done, wire the panel-mounted components to the circuit-board assembly. Before placing the fresh batteries in the enclosure, wrap them in a piece of nonconductive foam to keep them from shorting against other circuit components.

Checkout & Use

Begin checkout of the project with the power-supply circuitry by making voltage measurements at strategic locations in the circuitry. Set POWER switch *S1* to ON and measure the potentials between ground and all +9- and −9-volt connections to the IC sockets. Use a dc voltmeter or a multimeter set to the dc-volts function to take all measurements. Connect the common lead of the meter to analog/circuit ground, leaving it there throughout the procedure.

Touch the meter's "hot" probe to pin 8 of the *IC1*, pin 14 of the *IC2* and *IC3*, pin 16 of the *IC5* and *IC6*, pin 13 of the *IC7* and pin 8 of the *IC8* sockets. In all cases, the reading obtained should be approximately +9 volts. Touching the meter's "hot" probe to pin 4 of the *IC1* and *IC8* and pin 3 of the *IC7* sockets should yield a reading of approximately −9 volts.

If you fail to obtain the proper reading at any point in the circuit, power down and recheck all your wiring and component orientations and the polarities of the connections to the batteries. Also measure V_{ref} at the OUT pin of regulator *IC4*. Adjusting *R4* should cause V_{ref} to vary from +1.25 to at least +6 volts. For initial check-out of the circuit, set V_{ref} to +5.0 volts.

When you are certain that the project is properly wired, power down

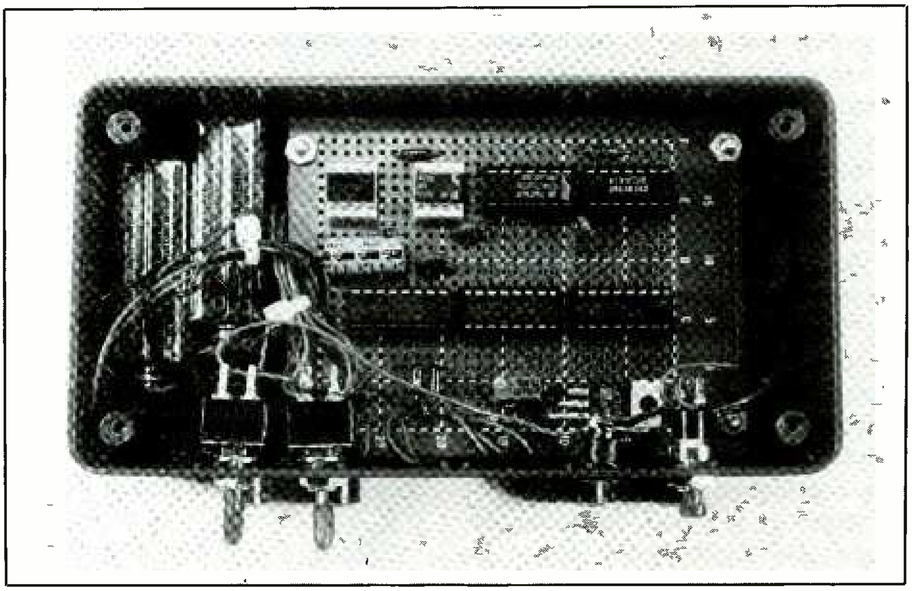

Fig. 2. Project be built using pc board or Wire Wrap techniques and materials as shown.

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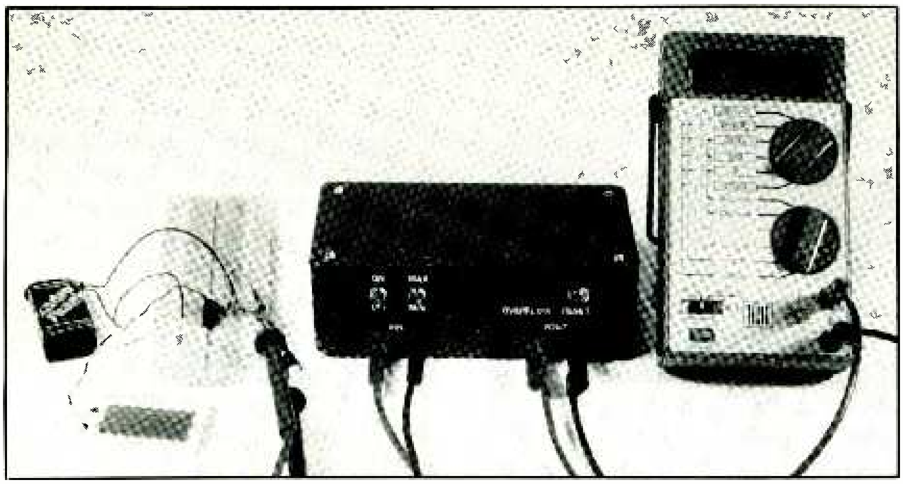

Fig. 3. To use Maximum/Minimum Voltage Detector, connect the voltage to be measured to V_{in} and voltmeter to V_{out}; voltmeter displays maximum (or minimum) voltage measured.

and plug the DIP ICs into their respective sockets. Make certain that each IC is properly oriented and in its appropriate socket. Make certain, too, that no pins overhang the sockets or fold under between any IC and its socket.

Wire together a simple test circuit for the detector using a potentiometer and an additional 9-volt battery. The value of the potentiometer is not critical. Use test leads to connect one end leg of the test potentiometer to the + terminal of the 9-volt battery and the other end leg to the − battery terminal and to *J2* in the project. Then connect the wiper lug of the potentiometer to *J1*. Adjust the potentiometer for 0 volt between *J1* to *J2*. Then connect test leads from your voltmeter to *J3* and *J4*, with the more positive lead to *J3*.

Set *S2* to MAX, set *S1* to ON and press *S3*. The meter reading should be 20 millivolts or less. Slowly increasing V_{in} by adjusting the test potentiometer should cause V_{out} to increase accordingly. If you increase and then decrease V_{in}, V_{out} should remain at highest voltage for V_{in}.

When V_{in} is 5 volts, *LED1* should light. The LED should remain lit even if you adjust V_{in} to a level below 5 volts. To reset and begin a new measurement, press *S3*.

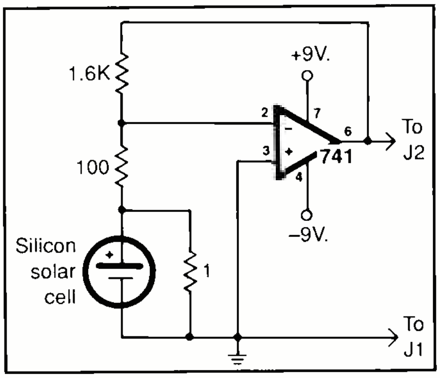

Fig. 4. The 741 op amp translates output current of silicon solar to a voltage measurable by the Maximum/Minimum Voltage Detector.

To measure minimum voltages, set *S2* to MIN and press *S3*. Now V_{out} should be equal to the lowest voltage measured, and the LED should light when V_{in} drops to a level of 0 volt.

To measure other potentials with the Maximum/Minimum Voltage Detector, connect test leads between the voltage to be measured and *J1* and *J2*, with the more positive lead to *J1*. Connect the voltmeter between *J3* and *J4* as above. Figure 3 shows the project in use.

Shown in Fig. 4 is the schematic diagram of a light-sensing circuit you can use with the project. The sensor here is a silicon solar cell that generates a current of 300 milliamperes in full sunlight. Most of the output current from the cell feeds through the 1-ohm resistor, with about one percent feeding through the 100-ohm resistor.

A 741 op amp in the Fig. 4 circuit generates a voltage that is proportional to the output current of the solar cell. As the output of the cell varies from 0 to 300 milliamperes, the voltage across the 1,600-ohm resistor varies from 0 to about − 5 volts.

To measure the relative maximum or minimum light level detected by the solar cell, connect the output of the Fig. 4 circuit to *J1* and *J2* on the project. Since the output of the op amp is the more negative voltage, it connects to *J2*. Now set *S1* to ON and *S2* to MAX or MIN, as desired, and press *S3* to reset the project.

The Maximum/Minimum Detector will now store a voltage in proportion to the maximum or minimum light level detected. A reading of 5 volts means that the output of the solar cell is 300 milliamperes, 2.5 volts means 150 milliamperes, and so on in direct proportion.

When using the Detector, there is no need to plug the voltmeter into *J3* and *J4* until your measurements are complete. Of course, you must leave the Detector powered until you read the measurement.

You can vary the range of the Detector by adjusting V_{ref} from 1.25 to 6 volts with *R4*. For highest possible resolution, adjust *R4* so that V_{ref} is slightly greater than the maximum voltage you expect to measure. The reason for this is that with the maximum 6-volt range, each of the 255 counts at the eight-bit input of the DAC represents about a 23-millivolt change at V_{out}. V_{out} does not change perfectly smoothly; it rises or falls in steps of about 23 millivolts from 0 to 6 volts. As you reduce the range, the size of the steps decreases. If the range is just 1.25 volts, each step is 5 millivolts, so you get greater precision, though at the expense of reduced range. **ME**

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Super-Sensitive Gas Detector

Using a newly refined semiconductor device, this professional-quality detector "sniffs out" combustible gases and noxious fumes and sounds an alert or lights a LED when it detects them

By Anthony J. Caristi

When properly maintained, home smoke detectors can save lives. Smoke/fire detectors are good insurance, of course, but the protection they provide does not go quite far enough. To be truly effective, a detection system in the home should also detect gas and other dangerous fumes. The Super-Sensitive Gas Detector described here provides the added protection needed. This project is not intended to be a substitute for a smoke detector, but a supplement to it.

Our Gas Detector is a sensitive, professional quality, accurately calibrated instrument. It monitors the air for an indication of an abnormal amount of combustible gases, such as natural methane gas or LPG propane and provides a visible or audible warning if even a small amount of gas is detected.

Although this project is useful for detection of natural gas and propane it is sensitive to such other types of reducing (deoxidizing) gases as carbon monoxide, ethanol, hydrogen and others. The gas sensitivity of the detector used in the project is also useful in detection of vehicle exhaust fumes and gases resulting from heater or furnace combustion. These often contain deadly amounts of carbon monoxide, of which even very small amounts (less than 0.1 percent), inhaled over a period of time, can prove fatal.

Project Operation

At the heart of our Gas Detector is an improved version of a semiconductor gas sensor manufactured by Figaro Engineering, (Osaka, Japan). This sensor is supplied as a factory calibrated gas detector that permits an accurate instrument to be built and to respond to a known concentration of gas. In our project, the alarm is designed to be triggered when the level of gas reaching the sensor is at a concentration of 500 ppm (parts per million) of methane. When operated in "sniffer" mode, the sensitivity of the instrument is significantly greater than this.

The gas detector/sniffer may be operated in either of two ways. The conventional method, lights a LED or sounds an alarm when the gas concentration reaches the predetermined 500-ppm level. The second method of detection employs a novel circuit that allows the user to "sniff" out the source of gas contamination.

When the project is operated in the

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sniffer mode, the detector is exposed to gas and an audio signal is generated when gas is detected. As the concentration of gas increases, the frequency of oscillation also increases. This allows the full sensitivity of the detector to be exploited for locating relatively low concentrations of gas, much less than the 500-ppm sensitivity when the project is operated in the normal mode. The variable frequency characteristic of the oscillator helps in locating the source of the gas contamination. This makes the project useful in checking gas pipe connections for suspected leaks.

The project is powered by a set of six Ni-Cd or alkaline cells in series to provide complete portability. If you wish, you can use an ac-operated power supply to make the project independent of battery power. Another option is to assemble the project with its own built-in charging circuit to eliminate the hassle of having to periodically replace the battery.

Detector Fundamentals

Gas concentration can be expressed either as a volume percentage or in parts per million. The relationship between these two quantities is 1 percent gas by volume equals 10,000 ppm. The relationship is linear; that is, 1,000 ppm is equal to a gas concentration of 0.1 percent by volume.

When flammable gas is to be monitored or detected, it is important to be familiar with Lower Explosive Level (LEL). This is the minimum concentration of flammable gas that will result in explosion or combustion in the event of ignition by means of a spark or other ignition source.

It is obvious that any gas detector must be designed so that it signals an alarm at much lower than LEL gas concentrations. A practical value for alarm level is 10 percent of LEL.

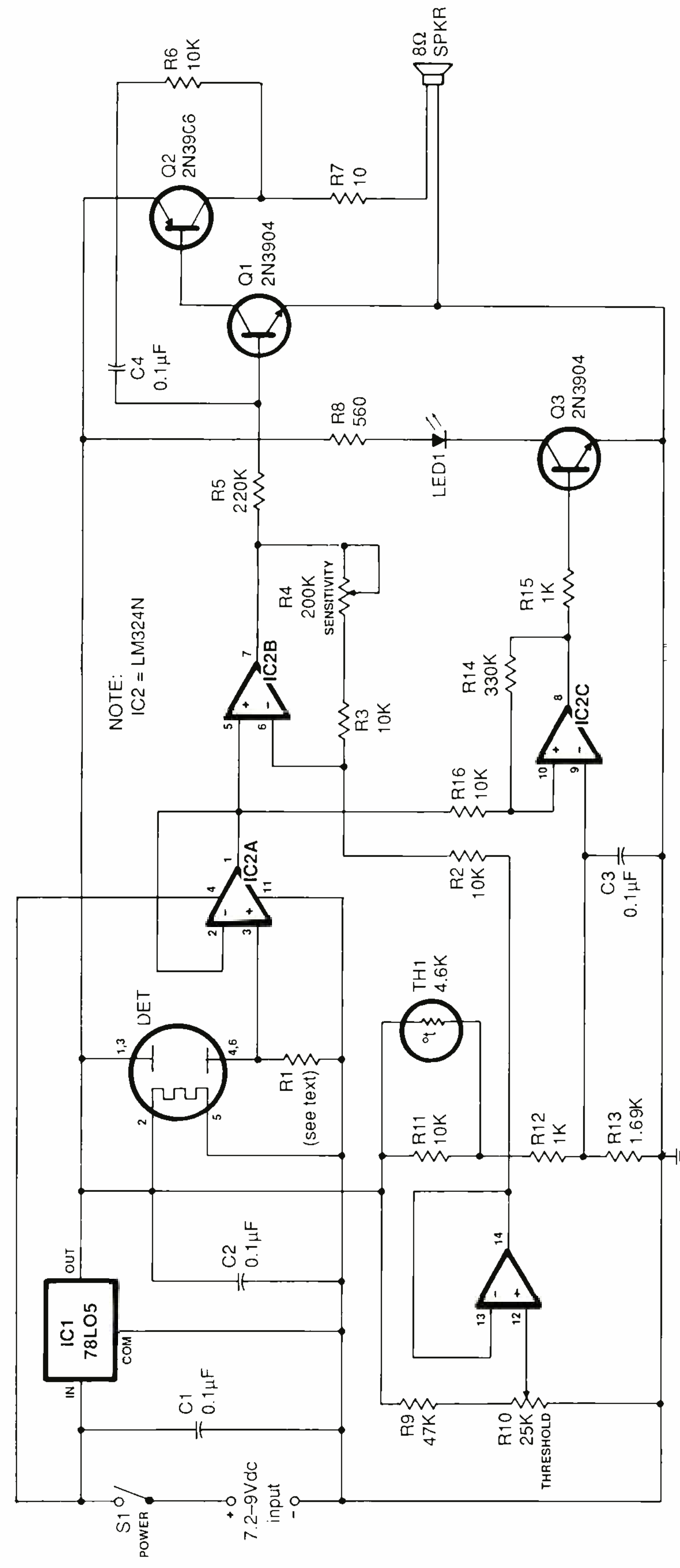

Fig. 1. Schematic diagram of basic Gas Detector circuitry.

However, setting the trigger at too low a point can result in false alarms, since the detector will respond to the mixture of "noise" gases that are always present in the atmosphere.

A methane gas detector should be able to respond to a concentration of not more than a 5,000-ppm concentration, since the LEL of methane is 50,000 PPM. Because the detector used in this project can easily respond to lower concentrations of gas, 500 ppm is the level selected as the point at which the alerting LED lights or audible alarm sounds.

Natural gas is mostly methane, which accounts for 80 to more than 95 percent of the mixture, depending upon the source. Although methane is not a toxic gas, breathing an atmosphere containing large quantities of it can cause physical discomfort or even death if it prevents sufficient oxygen from reaching the body. For this reason, as well as the possibility of explosion, suppliers add a chemical odor to the gas so that a leak can be readily detected. The danger here is that it takes a concentration of about 1 percent (10,000 PPM) for many people to detect the odor. Our Gas Detector provides a warning long before anyone smells the gas.

PARTS LIST

Semiconductors
D1 thru D4—1N4001 or similar silicon rectifier diode
DET—Figaro No. TGS813C gas sensor
IC1—AN78L05 fixed +5-volt regulator
IC2—LM324N quad operational amplifier
LED1—Red 2-volt, 20-mA light-emitting diode (or 5-volt dc piezoelectric buzzer—see text)
Q1,Q3—2N3904 or equivalent npn silicon transistor
Q2—2N3906 or equivalent pnp silicon transistor

Capacitors
C1,C2,C3—0.1-μF ceramic disc
C4—0.01-μF ceramic disc
C5—1,000-μF, 25-volt electrolytic

Resistors (¼-watt)
(5% Tolerance Carbon-Composition)
R1—Sensor load (see text)
R2,R3,R6,R16—10,000 ohms
R5—220-000 ohms
R7—10 ohms
R8—560 ohms
R9—47,000 ohms
R14—330,000 ohms
R15—1,000 ohms
R17—Current limiter (see text)
(1% Tolerance Metal-Film; do not substitute)
R11—10,000 ohms
R12—1,000 ohms
R13—1,690 ohms
R4—200,000-ohm pc-mount trimmer potentiometer
R10—25,000-ohm linear taper, panel-mount potentiometer

Miscellaneous
B1—Six C-size alkaline or sub-C Ni-Cd cells (see text)
F1—½-ampere slow-blow fuse
S1—Spst toggle or slide switch
SPKR—8-ohm miniature speaker (Radio Shack Cat. N. 40-245 or similar)
T1—12.6-volt C.T. power transformer (Radio shack Cat. No. 273-1365 or similar)
TH1—4,600-ohm thermistor (Panaonic No. ERT-D2FHL462S)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (Radio Shack Cat. No. 270-223 or similar); miniature 7-pin tube socket; socket for IC2; small-diameter heat-shrinkable tubing; in-line fuse holder; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Etched and drilled pc board, $9.95; TGS813C gas sensor, $25.50; 7-pin miniature tube socket; $2; AN78L05, $2; LM324N, $1.75; thermistor, $3; set of three metal-film resistors, $1.50. Add $2.75 P&H per order. New Jersey residents, please add state sales tax.

About the Circuit

As shown in Fig. 1, the heart of the project is *DET1*, a Figaro No. TGS813C detector element. This device consists of a pair of sintered tin-oxide (SnO_2) electrodes mounted on a ceramic tube. A heater coil inside the sensor raises the temperature of the electrodes so that they become sensitive to combustible gases. This sensitivity manifests itself in the value of resistance between the electrodes, which varies inversely with the concentration of the ambient gas level. Solid-state circuitry is then employed to monitor the change in resistance and provide both an audible and visible warning that the concentration of gas has exceeded the normal ambient level.

It is mandatory that the heating coil within the sensor be operated from a regulated 5-volt dc source so that sensor operation is stable and predictable. Fixed 5-volt regulator *IC1* provides the power needed to operate both the heater and sensor circuit.

The sensor is factory calibrated at a gas concentration of 3,000 ppm of methane. (Figaro also makes a version of the sensor calibrated for propane gas.) The resistance between the sensor electrodes is measured during calibration, and a fixed resistor of equal value is shipped with the unit. This is the resistor shown as *R1* in Fig. 1. The value of *R1* is in the range from 3,000 to 9,000 ohms. Since the value of *R1* is equal to the resistance of the sensor between pins 1 and 4 at 3,000 ppm of methane, it can be seen that at this gas concentration the voltage across *R1* will be half the supply potential, or 2.5 volts.

Additionally, the resistance of the sensor at gas concentrations other than 3,000 ppm is a known function of the value of *R1*. Figure 2 is a normalized graph supplied by the manufacturer that illustrates the variation in sensor resistance with different types of gases at a variety of different concentrations.

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Figure 2 has been normalized for 1,000 PPM of methane, indicating unity as the relative value of sensor resistance at this level of gas concentration. Since the sensor resistance (3,000 to 9,000 ohms) is determined by the manufacturer during calibration of the sensor at 3,000 ppm of methane, it is a simple matter to calculate the sensor resistance for any concentration of any of the gases shown in the graph.

Using the information provided by Fig. 2, sensor resistance at 500 ppm of methane is approximately equal to the value of *R1* multiplied by 2.4. Using Ohm's law, the potential across *R1* for 500 PPM of methane is 1.47 volts. This is the trigger point for the voltage comparator alarm circuit that follows.

The voltage developed across *R1* is fed to *IC2A*, connected here as a voltage follower. Amplifier *IC2C* is used as a voltage comparator, with the reference voltage at pin 9 determined by the resistances of resistors *R11*, *R12*, *R13* and thermistor *TH1*. The output of *IC2A* goes to the noninverting (+) input of the comparator so that the output at pin 8 goes high when the voltage output of the sensor exceeds the reference input. Resistor *R14* provides hysteresis to the circuit by means of positive feedback between output pin 8 and noninverting input pin 10.

A thermistor is used in the reference voltage-divider string to provide temperature compensation of the alarm circuit. This is required because the output voltage of the detector is temperature dependent.

Under normal operating conditions, when there is essentially no contamination of gas present in the atmosphere, the voltage across *R1* is much less than the reference 1.47 volts, and the output of *IC2C* is zero. Transistor *Q3* is cut off and light-emitting diode *LED1* is extinguished.

When the detector is exposed to a gas concentration of greater than 500 ppm the potential across *R1* exceeds

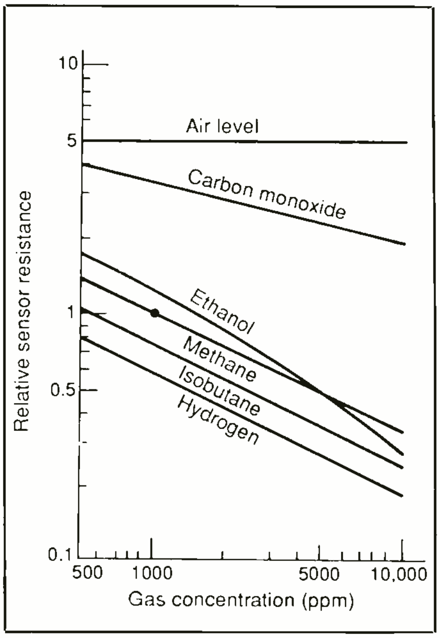

Fig. 2. Gas sensor resistance relative to standard condition at 1,000 ppm of methane.

the reference input of 1.47 volts. As a result, the output of *IC2C* goes high, driving *Q3* into conduction and illuminating *LED1*. This provides visual indication that the gas level has exceeded the trigger level of 500 ppm. (If you wish, you can substitute a piezoelectric buzzer for *LED1* to provide an audible alert.)

For greater operating sensitivity, the sniffer portion of the circuit can be used. Here, the output of *IC2A* is fed to the noninverting input of differential amplifier *IC2B* at pin 5. This stage has a voltage gain that can be adjusted over a range of about 2 to 22 by means of potentiometer *R4*. Simultaneously, a positive voltage, generated by a voltage-divider network composed of resistor *R9* and THRESHOLD control *R10* is fed to the inverting (–) input of the amplifier.

Adjustment of *R10* allows you to null out the residual voltage that appears across *R1* when the sensor is exposed to contamination in free air. Thus, the output of the amplifier at pin 7 can be set to a low voltage (near zero) that will not forward-bias *Q1*. When this is done, the circuit is extremely sensitive and will respond to a very small increase in voltage across *R1* should a minute quantity of gas enter the chamber of the detector.

When the voltage across *R1* increases by just a few millivolts as gas enters the detector, the amplified output at pin 7 of *IC2B* rises from zero and causes base current to flow into transistor *Q1*.

The circuit composed of *Q1* and *Q2* is a variable-frequency audio oscillator with positive feedback taking place through *R6* and *C3*. The frequency of oscillation is largely determined by the output voltage of *IC2B* so that as the gas concentration detected by the sensor increases, the frequency rises. Collector current from *Q2* flows into the speaker, creating an audio signal. By taking note of the change in frequency, you can determine the relative strength of gas as the instrument's location is changed. Potentiometer *R10* can be set to one end of its travel to silence the speaker when the sniffer feature is not required.

The circuit requires a power source that can deliver about 7.2 volts at 170 milliamperes. For intermittent use, a set of six alkaline C cells connected in series provides about 10 hours of operation. An alternate choice would be to use Ni-Cd cells as the power source and build into the project the recharging circuit shown in Fig. 3. An advantage of using Ni-Cd cells is that smaller cells than C size can be selected, since Ni-Cd cells can supply greater current than alkaline cells.

Since the circuit draws about 170 milliamperes from the power source when it is operating, sub-C cells rated at 1.2 ampere-hours made a good choice for the rechargeable-battery supply. Ni-Cd cells require a constant charging current equal to $\frac{1}{10}$ the ampere-hour rating of the cells being used for a period of 14 to 16 hours. In the case of sub-C cells rated at 1.2 ampere-hours, proper charg-

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ing current is 120 milliamperes.

With the above in mind, the value of *R17* must be chosen so that charging current is limited to ⅒ the capacity of the battery cells selected. This value will be in the range of 25 ohms for sub-C cells and have a minimum power rating of 1 watt. Select the resistance and wattage rating for the particular cells you choose for your project.

A final powering option is ac-only. If you wish to go this route, use the circuit shown in Fig. 4.

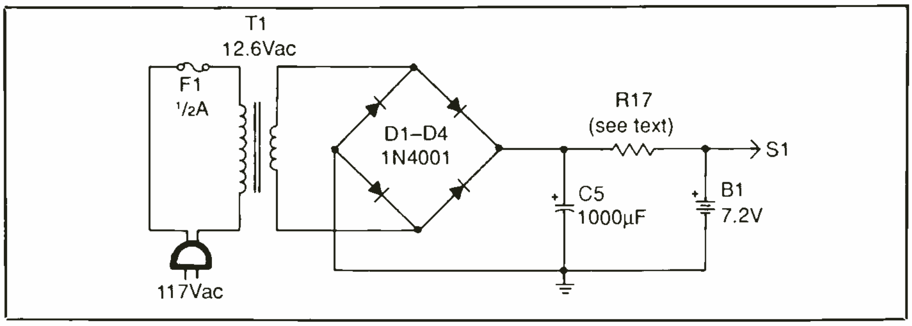

Fig. 3. Constant-current charging circuit details for Ni-Cd battery. Value of R17 *must be selected to deliver one-tenth ampere-hour rating of cells used.*

Construction

The bulk of the Gas Detector circuitry mounts on a single-sided printed circuit board, the actual-size etching-and-drilling guide for which is shown in Fig. 5. The circuit is not critical. Therefore, if you prefer not to fabricate a pc board or purchase a ready-to-wire one from the source given in the Note at the end of the Parts List, you can use point-to-point wiring. If you go this route, use perforated board with holes on 0.1-inch center and suitable Wire Wrap or soldering hardware. Whichever method you choose, however, it is a good idea to use a socket for *IC2*.

From here on, we will assume you are wiring the circuit on a pc board. Refer to the component installation guide shown in Fig. 6. Begin wiring the board by installing and soldering into place the IC socket. Do *not* install the IC in the socket until after you have conducted voltage checks.

Except for *LED1*, battery *B1*, POWER switch *S1*, speaker *SPKR*, THRESHOLD control *R10*, sensor *DET* and optional ac-operated power supply or charger, all components mount directly on the circuit board. Therefore, continue populating the board by installing and soldering into place the resistors, trimmer potentiometer *R4*, thermistor *TH1*. The resistor supplied with the gas sensor *must* be installed in the R1 location.

Note that the resistors that make up the voltage-divider string at pin 9 of *IC2* are specified as metal-film types. The reason for this is to ensure that the trigger voltage that defines alarm condition is precisely controlled. Ordinary carbon resistors do not have the necessary temperature stability for this application and should not be used here. Continue populating the board by installing voltage regulator *IC1* and transistors *Q1*, *Q2* and *Q3*. Make certain that the regulator and transistors are properly based before soldering any leads or pins into place.

The gas sensor is designed to fit a miniature seven-pin tube socket, which should be mounted on the outside of the enclosure so that the sensor can be exposed to the gas it is to detect. Four 5-inch-long hookup wires are needed to connect the socket to the circuit-board assembly. Prepare these wires by stripping ¼ inch of insulation from both ends of each. If you are using stranded wire, tightly twist together the fine conductors at all ends and sparingly tin with solder.

Following Fig. 7, plug one end of these wires into the pins 2, 4, 5 and 6 holes in the circuit-board assembly for the sensor. Solder all four wires into place. (Pins 1 and 3 and pins 4 and 6 are connected together inside the sensor.) When the project is finally assembled and the sensor plugged into its socket, sensor pins 4, 5 and 6 plug into socket pins 5, 6 and 7, with socket pin 4 unoccupied.

Next, prepare seven more 5-inch lengths of hookup wire as above. Plug one end of these wires into the holes for *LED1*, *R10* and *SPKR1* and solder each into place. The other ends of the wires will be connected later. Meanwhile, if you did not use color-coded wire, tie a loose knot in the *LED1* cathode (K) and *SPKR1* + wires to readily identify them.

If you are building into the project the Fig. 3 battery-charging circuit, you can wire rectifier diodes *D1* through *D4*, filter capacitor *C4* and resistor *R17* on a five-lug terminal strip. Use the lug that connects to the mounting tab as the ground point, wiring the anodes of *D1* and *D4*, and negative (−) lead of *C5* to it.

Use the second lug of the terminal strip for the cathode lead of *D1* and anode lead of *D4* and the third lug for the cathode lead of *D3* and anode lead of *D4*. Do *not* solder either connection; simply make them mechanically secure. The fourth lug of the terminal strip is for the cathodes of *D2* and *D4*, + lead of *C5* and one lead of *R17*. Solder this connection. Finally, crimp and solder the free lead of the resistor and a 5-inch-long hookup wire to the fifth lug.

If you are incorporating the ac-only option shown in Fig. 4, wire *D3*, *D4* and *C4* on a four-lug terminal strip. Crimp and anodes of the diodes to two separate lugs and their cathodes positive (+) lead of the capacitor to a third lug. The fourth lug (common with the terminal strip

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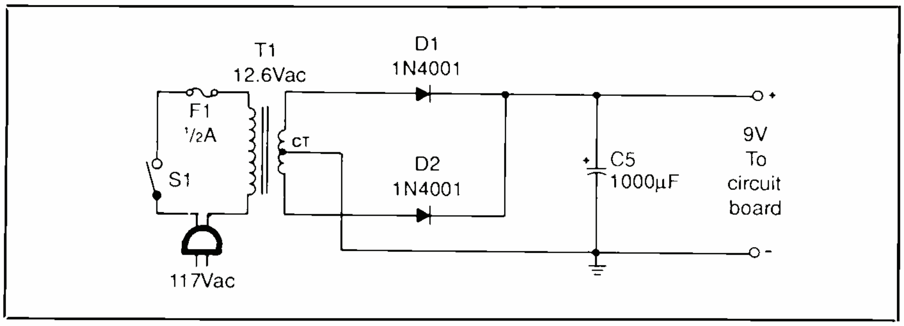

Fig. 4. Ac-only power-supply option circuit details can be substituted for straight battery powering of project.

mounting tab) is circuit ground to which the negative (−) lead of the capacitor connects. Solder only the connections made to the third lug of the terminal strip.

Select a suitable enclosure for the project. This can be all-metal, all-plastic or a plastic enclosure with a metal "front" panel. The size of the enclosure you need depends on how you plan to configure the project. If you are planning on battery-only power, you can use a fairly small enclosure. On the other hand, if you wish to be able to operate the project from the ac line or be able to recharge an internal Ni-Cd battery supply, you need a substantially larger enclosure to accommodate the power transformer needed, as well as support components.

Machine the enclosure as needed. That is, drill mounting holes for the circuit-board assembly, tube socket for the sensor, THRESHOLD control, POWER switch and light-emitting diode. Also drill a series of small holes in the area of the front panel behind which the speaker will mount. Additionally, if you are incorporating the ac power supply or charger circuitry, drill mounting holes for the power transformer and terminal-strip assembly. Also drill an entry hole for the ac line cord. You also have the option of replacing *LED1* with a piezoelectric buzzer rated at 5 volts. If you do this, you will need additional panel space and a hole or holes drilled in the panel through which the buzzer's leads can be routed.

After machining is done, deburr all holes drilled through metal to remove sharp edges. If you drilled the entry hole for the ac line cord through a metal panel, line the hole with a rubber grommet.

Carefully inspect the circuit-board assembly. Check to make sure that all components are mounted in their correct locations and in correct orientation. Then turn over the assembly and inspect your soldering. Solder any connection missed and reflow the solder on any connection that appears suspicious. Check for solder bridges, especially between closely spaced IC pads. If you locate any, remove them with desoldering braid or a desoldering tool.

Mount the circuit-board assembly inside the enclosure, using ½-inch spacers and suitable machine hardware. Mount the switch, potentiometer and tube socket in their respective holes in the front panel. Then mount the speaker in place with silicone adhesive.

If you are using the ac power supply or echarger, mount the power transformer and terminal-strip assembly in their respective locations. If you are using the piezoelectric buzzer, mount it in place by whatever means is appropriate and pass its leads through the hole(s) drilled for them.

Now connect and solder the four wires coming from the DET location on the circuit-board assembly to the lugs of the tube socket, referring to Fig. 7. Wire 2 from the board goes to lugs 1, 2 and 3 of the socket, wire 4 to lug 5 of the socket, wire 5 to lug 6 of the socket and wire 6 to lug 7 of the socket. This done, connect and solder the free ends of the wires coming from the R10 location on the circuit board to the lugs of the panel-mounted potentiometer.

If you are using the ac power supply or charger, feed the unprepared end of the ac line cord through its entry hole into the enclosure and tie a strain-relieving knot in it about 5 inches from the unprepared end inside the enclosure. Tightly twist together the fine wires of each conductor and sparingly tin with solder.

Slip over each line cord conductor a 1-inch length of small-diameter heat-shrinkable tubing. Twist together one conductor and one lead of an in-line fuse holder. Solder the connection. Twist together the other conductor and one primary lead of the power transformer and solder this connection.

If you are using the ac-only supply option, crimp and solder one transformer primary lead to one lug of the POWER switch. Crimp and solder one lead of an in-line fuse holder to the other switch lug. Then connect and solder the other fuse holder lead to one lead of the ac line cord. Now connect and solder the remaining primary lead to the other line-cord conductor. Slide the tubing over the connections and shrink into place.

Crimp and solder the secondary center tap lead to the grounded lug of the terminal strip. Then crimp and solder the other two secondary leads to the lugs to which the diode anodes are connected. Crimp and solder the free end of the wire labeled TO S1 on the board to the lug to which the cathodes of the diodes and + lead of the capacitor are connected. Similarly, terminate the wire labeled TO B1 − at the lug to which the − lead of the capacitor is connected.

If you opted for the Fig. 3 power-

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ing circuit, crimp and solder one lead of the ac line cord to one lead of the in-line fuse holder. Slip a 1-inch length of small-diameter heat-shrinkable tubing over both leads of the transformer primary. Connect together this lead and the other lead of the fuse holder and solder the connection. Similarly, connect and solder together the remaining line-cord conductor and primary lead. When the connections cool, slide the tubing over them to completely insulate the connections and shrink into place.

Crimp and solder one transformer secondary lead to the terminal strip lug to which the cathode of *D1* and anode of *D2* are connected. In like manner, crimp and solder the other secondary lead to the lug to which the cathode of *D3* and anode lead of *D4* are connected. Then crimp and solder the free ends of the wires coming from the TO S1 hole on the circuit-board assembly to the lug to which the + lead of *C4* is connected and the TO B1 – hole to the lug to which the anodes of *D1* and *D3* are connected.

Plug a ½-ampere slow-blow fuse into the holder.

Crimp and solder one secondary lead of the transformer to terminal-strip lug to which the cathode of *D3* and anode lead of *D4* are connected. Similarly, crimp and solder the other secondary lead to the terminal strip lug to which the cathode of *D5* and anode lead of *D6* are connected.

If you opted for battery-only power, simply plug the free end of the wire coming from the TO B1 – hole on the circuit-board assembly to the negative end of the battery. Use a length of hookup wire to connect from the positive end of the battery to one lug of the POWER switch and terminate the free end of the wire coming from the TO S1 hole at the other lug of the switch.

Assuming you opted for the Fig. 3 battery-charger option, use suitable lengths of hookup wire to bridge from the negative end of the battery to the ground lug of the terminal strip and from the positive end of the battery to the lug to which *R17* terminates and is specified to go to it. Then Wire from this lug of the terminal strip to one lug of the POWER switch, and crimp and solder the free end of the wire coming from the TO S1 hole on the circuit-board assembly to the other lug of the switch.

Caution: Even when partially charged, nickel-cadmium (Ni-Cd) cells can deliver many amperes of current into a short circuit. For this reason, you must be very careful to avoid shorting out the cells through a wiring error. Should you mis-wire the circuit, printed-circuit (and other) wiring can be instantly vaporized, and you can receive a nasty burn. Therefore, double-check your wiring of the battery circuit as you proceed with wiring it.

Identify the cathode lead of the LED and trim it to a length of ½ inch. Locate the TO LED1 wires coming from the circuit-board assembly. Slide a 1-inch length of small-diameter heat-shrinkable tubing over the ends of each wire. Crimp and solder the free end of the wire labeled K to the cathode lead of the LED.

Next, trim the anode lead of the LED to ½ inch in length and crimp and solder the free end of the *LED1* anode wire coming from the circuit-board assembly to it. When both connections cool, slide the two lengths of tubing up over them until they are flush with the bottom of the LED's case and shrink into place. Plug the LED into the hole you drilled for it in the front panel. If the fit is too loose to retain the LED, use a spot of fast-setting epoxy cement or silicone adhesive to secure it into place.

If you are substituting a piezoelectric buzzer for the LED, simply connect and solder its + and common leads to the anode and cathode wires, respectively, coming from the *LED1* holes on the circuit-board assembly. Another alternative is to wire a small 5-volt dc relay into the collector circuit of instead of the LED or buzzer

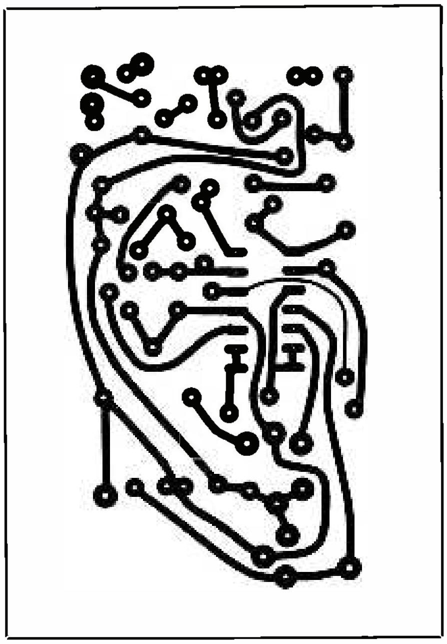

Fig. 5. Actual-size etching-and-drilling guide for making printed-circuit board for project.

so that the relay contacts can control power to an external remote alarm. Then, observing polarity, wire the speaker into the circuit.

Now plug the sensor into the tube socket on the front panel. The sensor is a bilateral device that can be plugged into the socket in either of two positions. Make sure that pin 1 of the sensor goes into pin 1 of the tube socket.

Checkout & Use

Fully charge the battery (assuming you are using this means of power) to prepare the project for voltage checks. When you are ready, set the POWER switch to "on" (plug the line cord of the ac-only option into an ac outlet before doing this). Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to circuit ground.

Touch the "hot" probe of the meter to the OUT pin of *IC1* and note the meter reading. It should be about +5 volts. Assuming you obtain the appropriate reading at this point, touch the "hot" probe of the meter

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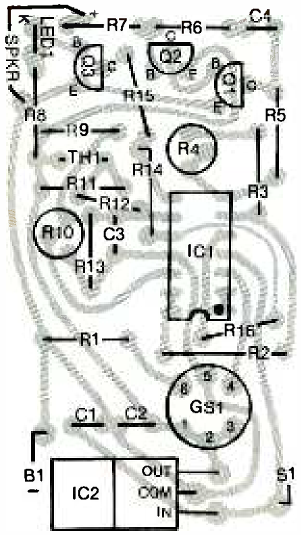

Fig. 6. Wiring guide for pc board. Use this as a general component layout guide for point-to-point wiring.

to pin 4 of the *IC2* socket and once again note the meter reading. This time around, it should be between 7.2 and 9 volts, depending on the powering option you chose.

If you do not obtain the proper reading at either or both points, immediately power down the circuit and rectify the problem. Do not proceed until you are sure the project is properly wired.

With no power applied to the project, plug an LM324N into the *IC2* socket. Make sure this IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

Now perform an operational check of the Gas Detector. To do this, you need a source of gas fumes. This can be obtained by placing about a teaspoon of ordinary rubbing alcohol in a shallow dish.

Set SENSITIVITY control *R4* and THRESHOLD control *R10* to the middle of their ranges. Apply power to the circuit. Now measure the voltage between the 5-volt regulated bus and ground; you should obtain a reading between 4.8 and 5.2 volts. If you do not obtain the correct voltage reading, power down the circuit and rectify the problem before proceeding.

Make sure that the power source is delivering at least 7.2 volts to the circuit. Check the ICs to ascertain that they are placed into the board as illustrated in the parts layout. Measure the resistance between the +5-volt bus and ground to be sure that you do not have a short circuit. Normal resistance reading will be about 30 ohms—the resistance of the sensor heater coil. If you suspect a short on the +5-volt line, remove the sensor from its socket and check the circuit with an ohmmeter.

When power is first applied to the project, you may notice that the speaker howls and the LED lights (or buzzer sounds) after a few seconds. This is normal, as the sensor requires a few minutes to stabilize. After about 2 minutes of warm-up, adjust the THRESHOLD control over its entire range. At one end of travel, the speaker should be silent, and as the control is rotated the audio oscillator should start at a low frequency and increase. Set the THRESHOLD control so that the oscillation just ceases.

Place the sensor close to the dish of alcohol (be careful not to allow the sensor to touch the liquid). The audio oscillator should sound off immediately and the LED should light (or buzzer sound) after a few seconds. When you distance the sensor source from the alcohol fumes, the LED should extinguish (buzzer cease sounding) as the audio tone diminishes in frequency.

If you do not obtain the responses as indicated above, use the following procedure to troubleshoot the circuit:

(1) Check the power source and output voltage of the regulator to be sure that +4.8 to +5.2 volts is being delivered to the circuit. The regulator requires at least 7 volts at its IN lead to properly provide a +5 volt regulated source. Normal load current seen by the regulator is about 170 milliamperes. Should this current be excessive due to a wiring error or defective component, the regulator protects itself by shutting down.

(2) Check the sensor to be sure that the heater is operating. Do this by measuring the potential between pins 2 and 5 of the sensor, which should be 5 volts. Make sure the sensor is wired to the board in accordance with Fig. 7. You can tell if the heater of the sensor is operating by feel; if you note that the body of the sensor is warm to the touch when it has been on for a few minutes, it is working properly.

(3) Check the voltage across *R1*. When the project is first turned on after being off for some time, the reading across *R1* will increase from zero to over 1 or 2 volts, and then slowly decrease to a relatively stable

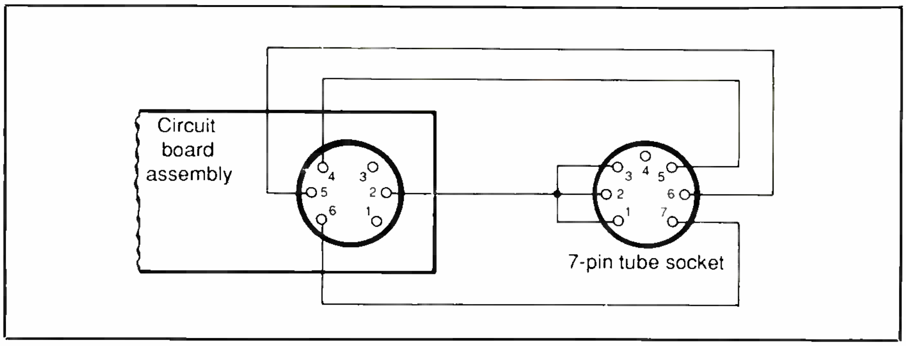

Fig. 7. Wiring details for connecting from circuit-board assembly to sensor's front-panel-mounted seven-pin tube socket.

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level of less than 1 volt. If no voltage is obtained across *R1*, check that both pins 4 and 6 of the sensor (5 and 7 of the socket) are connected to the circuit in accordance with Fig. 7.

(4) Measure the voltage at pin 14 of *IC2* as the THRESHOLD control is rotated over its full range. You should obtain a reading of zero and about +1.7 volts. Check the voltage at pin 7 of *IC2* as the THRESHOLD control is rotated over its range. You should obtain a reading of about zero to +4 or more volts. If you do not obtain the correct readings, check the wiring associated with *IC2* sections A, B and D. Also, try a new IC.

If the voltage at pin 7 of *IC2* is correct but there is no sound from the speaker, check the wiring associated with *Q1* and *Q2*. Ascertain that these two transistors are not interchanged and each is wired into the circuit correctly. Check the wiring to the speaker and be sure that the voice coil is not open. A good speaker will have a coil resistance of about 8 ohms.

If the LED does not illuminate when the potential across *R1* exceeds +1.5 volts, due to gas striking the detector, check the potential at pin 9 of *IC2* to be sure it is close to the design level of +1.47 volts. The thermistor causes this voltage to vary by a few tenths of a volt at low or high ambient temperature levels. Measure the output voltage at pin 8 of *IC2* to be sure it goes high when an alarm condition exists. Check *LED1* and *Q3* to be sure that these parts are good and not placed incorrectly into the circuit.

THRESHOLD control *R4* is functional only in sniffer mode. Setting this trimmer potentiometer to mid-position should be satisfactory; but if you desire to make your project more or less sensitive, you can adjust *R4* accordingly. Maximum sensitivity is obtained when the control is set to maximum circuit resistance. Bear in mind that greater sensitivity settings cause the setting of the THRESHOLD control to be more critical; so try to use as little gain as possible in the amplifier.

Before attempting to use the instrument, be sure that the batteries are good. Alkaline cells that have no-load terminal potential of less than 1.4 volts are probably exhausted and should be replaced. Ni-Cd cells left idle for several months will probably need recharging, since it is normal for them to self-discharge over a period of time.

When the project is operated after being idle for a week or more, the gas sensor may require a few extra minutes to stabilize. And when the unit is first turned on the audio oscillator will sound and the LED will turn on (or the buzzer sound). This self-test feature tells you that the battery is good and the circuit is operating. After a couple of minutes, the circuit will stabilize and the instrument will be ready for use.

To use the sniffer function, adjust the THRESHOLD control so that the audio oscillator is set to as low a frequency as possible, or to the point where it is just turned off. Then, any gas sensed by the detector will start the oscillator and alert you to its presence. Frequency will increase as you move the detector closer to the source of fumes as the concentration of gas becomes greater. When you move the sensor away from the source, the frequency will decrease.

When the sniffer function is not in use, adjust the THRESHOLD control to silence the speaker. The project can then be used as a go/no-go device that indicates the presence of gas contamination by turning on the LED or sounding the buzzer. When searching out the source of gas, allow a couple of seconds for the sensor to respond; it needs some time for the gas to enter the sensing chamber and trigger the alarm.

Be sure to turn the unit off when you are finished using it. Otherwise, you may find exhausted batteries when you turn it on again.

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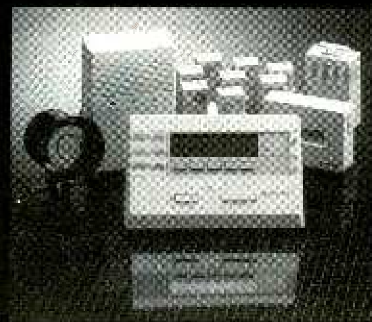

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Telephone Answering Machines

(Conclusion)

Installing an answering machine, making the connection and maintenance

By Steven J. Bigelow

Last month in Part I we discussed how telephone answering machines work and some tips on buying the right model for a given application. This month, our focus is on selecting a suitable location for your answering machine, making the connection, maintaining the answering machine for top-flight performance and troubleshooting it should a problem arise.

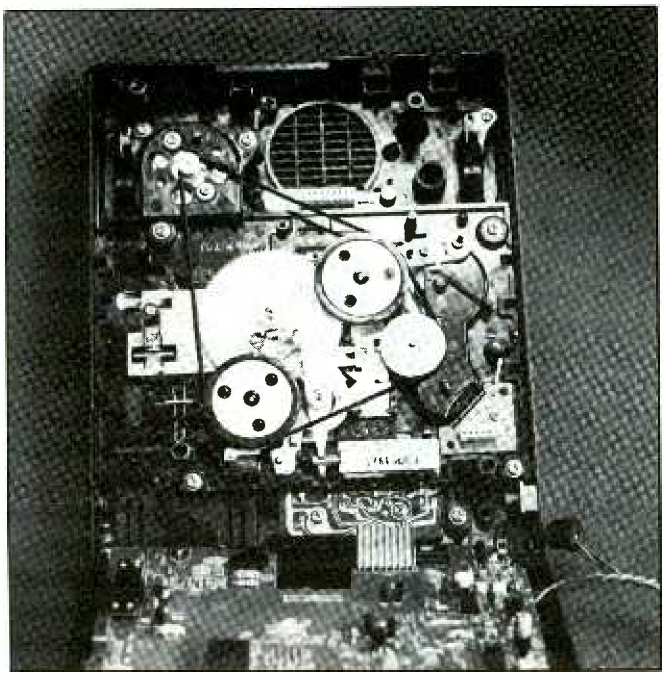
Selecting a Location

Once you have decided to add an answering machine to your existing telephone system and have made your selection of the desired make and model, installation is a relatively simple procedure. For your new system to operate flawlessly and unobtrusively, however, there are a few simple guidelines you should keep in mind, both in selecting a location for the machine and wiring it into your telephone system. We will discuss each of these in turn here.

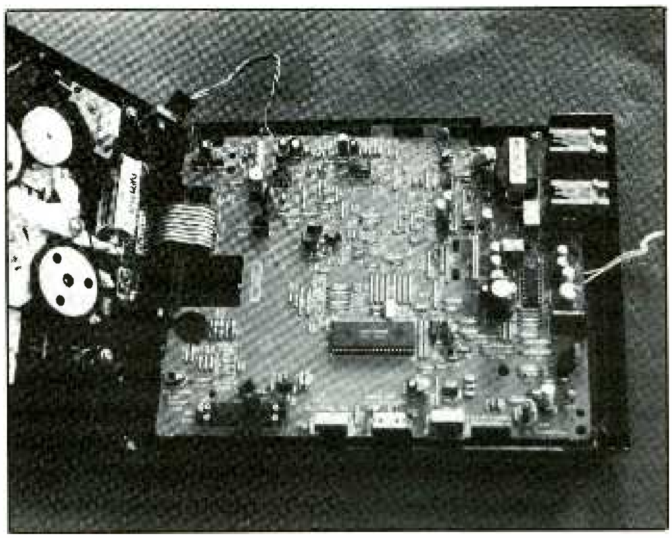
Some important things to keep in mind when selecting a location for your answering machine include:

(1) Never place the machine in a location where it will be subjected to strong magnetic fields, such as on top of a TV receiver or a high-power speaker. Magnetic fields of force can easily garble the information recorded on a cassette tape. To be on the safe side, locate the machine no closer than 2 feet from any appliance or device that generates electromagnetic fields of force.

(2) Keep the machine away from any device that generates electrical noise, including fluorescent lamps and electric motors. Electronic circuits in the machine, especially in microprocessor-driven units, can pick up electric noise and interpret it as false control signals. This would re-



Two interior views of a Panasonic telephone answering machine: (A) showing drive motor and mechanisms and (B) showing main printed-circuit board assembly that contains machine's electronics.



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sult in sporadic or spontaneous operation.

(3) Even though microprocessor-controlled answering machines are regarded by the FCC as Class B computing devices, they may still generate enough r-f energy to interfere with radio and TV reception. Therefore, test out the machine in the selected location before making a final installation. If you note any interference, moving the machine to a new location should eliminate the problem. However, if the interference persists, noise may be coupled into the radio or TV receiver through the ac-line wiring. The solution is to try an outlet on a different branch of the ac wiring.

(4) Never install an answering machine in a location where dust, moisture, condensation, direct sunlight or high heat, extreme cold, or unusual vibration exist.

Dust will accumulate on the magnetic recording and playback heads, and concentrations of it will clog mechanical elements in the tape transport mechanism, which will result in distorted sound in both play and record.

Moisture is particularly destructive to electronic components. Even if it is not concentrated enough to cause a direct short circuit, acids, chemicals and minerals contained in rain and other forms of moisture can oxidize and corrode component leads and printed-circuit traces.

Excessive heat and cold are hostile to electronic circuits. A typical commercial integrated circuit has a rated operating range of 40 to 100 degrees Fahrenheit. Direct sunlight can raise the temperature inside the machine's enclosure to in excess of 150 degrees after just a few hours. Excessive cold is normally not a consideration with telephone answering machines, but if you plan on having your machine located in an unheated trailer, cabin or other location during the winter, it must be taken into consideration. The bottom line is: Avoid any extremes of temperature.

When moving an answering machine from one place to another, keep in mind that violent jarring or/and vibration will cause misalignment of mechanical elements and can loosen electrical connectors within the machine, which will result in intermittent operation. Gentle handling of an answering machine will obviate any such problems.

Never use any type of solvent—such as acetone or benzene—to clean the enclosure in which the answering machine is housed. Plastics and finishes used in fabricating the enclosure normally will not bear up to such harsh chemicals. The only safe way to clean an enclosure is to wipe it with a soft cloth that is only slightly dampened with water.

Do *not* overload a telephone line by connecting an excessive number of devices to it. A standard telephone line has a REN (Ringer Equivalence Number) of 5.0, which is the total additive load of the devices connected to the line. It should not exceed 5.0. For example, if a typical phone line has a telephone with an REN of 1.0 connected to it, an answering machine with a REN of 0.4 may be connected without problems (1.0 + 0.4 = 1.4, which is less than 5.0).

According to the above, if five telephone instruments are connected to the line in the above example and each has a REN of 1.0, the line is at its limit. Therefore, at least one instrument must be disconnected from the line before an answering machine can be installed. Bear in mind that all devices connected to the telephone line *must* be registered with the FCC to ensure compliance with standards of construction and safety. After registration, devices are issued an FCC registration number that, along with the REN, is printed on the outside of the housing of the device.

Making the Connection

All answering machines require a power source to operate. This is usually the 117-volt ac line. Machines that require a low dc voltage are supplied with a power pack that plugs into the ac line.

A common telephone circuit consists of only two conductors, identified as a green-insulated "tip" conductor, and a red-insulated "ring" conductor. (Some modern circuits also have a black-insulated "control" conductor and a yellow-insulated "ground" conductor. The control and ground conductors are not normally used in residential wiring.) The tip and ring conductors, to which the telephone answering machine connects, carry the ring, dialing, control-pulse, busy, hang-up, and ringback-tone signals, as well as the two-way voice conversation signals between parties.

An answering machine can be connected to a telephone line all by itself, which is the hook-up arrangement used by businesses that have "call-in" information lines. With this arrangement, a long outgoing message gives the caller information—such as event dates, times, and locations—and then asks him to leave his name and address for addition to a mailing list. Machines are used in this way when the phone line does not need, or is not intended, to be answered.

When a machine is to be used in conjunction with a telephone instrument, two general configurations exist. One is the parallel approach in which a duplex jack is plugged into the phone line's wall jack and into which the answering machine and telephone instrument are plugged. This arrangement connects the machine and instrument in parallel across the telephone line so that the two share the same resource without adding complexity and cost to the existing wiring.

Older and very compact newer answering machines may not have a jack into which a telephone instrument plugs, which necessitates the use of the external duplex jack. New-

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Telephone Answering Machines Buyer's Guide

Manufacturer	Model	Price	Message Indicator	Blinking LED	Numeric LED	Voice Announce	OGM Cassette	OGM Microcassette	OGM Digitized Voice	OGM Speech Synthesizer	ICM Cassette	ICM Microcassette	ICM/OGM Single Cassette	ICM/OGM Microcassette	ICM VOX	ICM Fixed Time Only	Toll Saver	Ring Selector	Announce Only	Beeperless Remote	Remote Turn-On	Remote Room Monitor	Call Screening	Memo	Private Codes Message	Extension Pick-Up	Power-Fail Protection	Two-Line Capability	Built-In Telephone	Time/Date Stamp
AT&T	3110	$100	•										•		•		•	•	•	•			•	•		•				
Cobra	AN-8511	$60	•										•		•		•	•		•	•		•	•						•
	AN-8531	90	•										•		•		•	•	•	•	•		•	•			•			•
	AN-8533	80		•									•		•		•	•		•	•		•	•			•			
Code-A-Phone	1350	$100	•											•			•	•		•	•		•	•		•	•		•	
	1650	80	•											•	•		•	•		•	•		•	•			•		•	
DuoFone	TAD 241	$60	•							•	•					•		•												
	TAD 245	130	•					•				•			•			•	•	•	•		•	•						
	TAD 252	280	•					•				•			•		•	•	•	•	•	•	•	•		•			•	
	TAD 325	120	•				•				•				•		•	•	•	•	•	•	•							
	TAD 330	140	•				•				•				•		•	•	•	•	•	•	•	•				•		
	TAD 440	140				•	•				•				•		•	•	•	•	•	•	•	•		•				
Emerson	TAD 8100	$70	•											•	•		•	•		•			•	•						
GE	2-9860DB	84	•				•				•					•	•	•	•	•	•		•	•	•					
	2-9882	130	•					•				•			•		•	•	•	•	•		•	•			•			•
	2-9891	90	•										•		•		•	•	•	•	•		•	•			•		•	
Panasonic	KX-T1418	$70	•				•				•				•		•	•			•		•	•						
	KX-T1450	90	•				•				•				•		•	•		•		•	•	•		•				
	KX-T2427	150	•				•				•				•		•	•	•	•			•	•					•	
Phone-Mate	5000	$60	•											•		•	•	•		•			•	•						
	5050	100	•											•	•		•	•		•	•		•	•					•	
	6900	90	•						•		•				•		•	•		•	•		•	•			•			
	7050	118		•			•				•				•		•	•		•	•		•	•		•			•	
	7300	150		•					•		•				•		•	•	•	•	•		•	•		•	•			•
	7400	170	•				•				•				•		•	•	•	•	•		•	•			•	•		•
Record a Call	2140	$130			•		•				•				•		•	•		•	•		•	•		•	•		•	
Sanyo	TAS 344	$85					•				•				•		•	•	•	•	•		•	•						

*Manufacturers and models listed represent only a sampling of answering machines available to show feature and price comparisons. Black dots indicate presence of feature; no dot indicates that feature is either not available or no information was supplied.

er machines that do have this jack eliminate the need for the external duplex jack because the instrument can be plugged directly into this instead. With this arrangement, the two on-board jacks are wired in parallel with each other and the incoming phone line.

Maintenance

Telephone answering machines require very little maintenance. However, performing some simple routine maintenance can reduce failures and extend the useful life of the machine. Two things that should be avoided when performing maintenance. Firstly, do *not* use any oil or grease on the mechanical elements of the machine. The motor pulley and drive mechanisms are very light and make up a precision assembly. Any substance used on the gears will add drag and result in audio distortion.

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Secondly, keep all magnetic items away from the play and record heads. If a head should become magnetized—for example from a screwdriver—it will cause severe distortion in the audio signal.

In average use, an answering machine will handle about ten calls per day. At this rate, the OGM and ICM tapes should be replaced about every six months. When more than ten calls are handled each day, tapes should be replaced more frequently, and vice-versa. For optimum overall performance, use normal-bias tapes. Unless otherwise specified, avoid using metal and chrome tapes.

To play from and record to a cassette tape, the head, a capstan, and a roller must come into contact with the tape surface. Dirt and residue from the tape slowly accumulate on these element over a period of time and eventually cause distortion and a loss of signal level in the OGM and ICM tapes. Therefore, it is a good practice to clean the contact parts each time the tapes are replaced.

Use a dry cotton swab to wipe away mild residue deposits. For stubborn deposits, lightly dip a cotton swab in 100 percent isopropyl alcohol, denatured alcohol, or a thin head-cleaner solution and carefully clean each head and around each capstan and roller. Make very sure that all of the cleaning solution completely evaporates before inserting the new tapes into the machine.

Troubleshooting

Should a problem occur with a telephone answering machine, the first step in any troubleshooting procedure should be to isolate the cause. When there is a problem with the phone line, remove the answering machine from the line and test the line with a known-good telephone instrument alone to see if it functions properly. If the problem disappears without the answering machine, the trouble is in the machine. If it persists, the trouble may be either the machine or the line. You can determine which is the case by trying the instrument on a known-good line. If the instrument functions properly on this line, the answering machine is confirmed bad.

To be doubly certain, however, you can test the answering machine on the known-good telephone line. If it is bad, it will still fail to function properly. Once you have isolated the problem to the answering machine, the only recourse is to seek out professional service for it.

Summing Up

In the business community, the answering machine has already become a necessity for conducting normal daily business. It has also rapidly become an integral part of many home telephone systems. The ever-increasing demand for flexibility and power has even begun to have an effect on home computers.

An entire answering machine using total speech synthesis is already available as a plug-in option for IBM and compatible computers. Connected directly to the telephone line, it runs under software control. With such a plug-in board, state-of-the-art speech synthesis technology permits both a custom recorded OGM to be digitized and storage of incoming messages as files on-disk. The result is a no-wear, tape-free, non-mechanical device not subject to wear.

Current prices for computer-type answering-machine boards are still pretty steep, ranging from $400 to $500. However, like the computers in which they are designed to run, prices are almost certain to drop dramatically in the not too distant future, to a point where their purchase will be economically acceptable for even those people who are operating on limited budgets.

There can be little doubt that the answering machine in its many guises is here to stay. With some insight and knowledge of its construction, operation, and care, an answering machine can greatly enhance any modern telephone communication system, whether in the business or the personal environment. Just as we have become heavily dependent on the telephone itself, this extension to that most popular of personal communication devices will add to its flexibility and utility and, in so doing, perhaps even add to that dependency as time passes. **ME**

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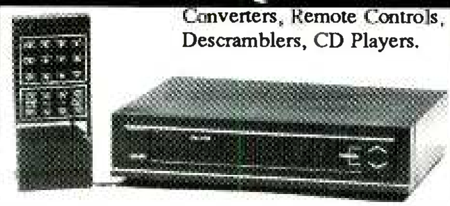
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Quick and Easy PC Boards

An innovative method for making printed-circuit boards using overhead projection film to bypass the traditional photographic process

By Bill Eubank

Even though most techniques for home-fabricating printed-circuit boards utilize the photographic process in one way or another, they can be cumbersome and messy. Light-sensitive copper-clad pc blanks require special handling and lighting, and negative or positive exposure masks must be made from original artwork. Needless to say, with the photographic technique, the potential for problems with light intensities, exposure times and handling of chemicals is great.

A practical solution to the above is to use sheets of ordinary overhead projection film to make pc boards directly from finished artwork. With the technique to be described here, you simply copy your artwork onto the projection film using a plain-paper photocopier and then transfer the image formed on the film directly to a clean pc blank using heat. Using heat, the "ink" that forms the image on the film directly transfers to the pc blank and eliminates the need for a separate resist. Once the image is transferred, you simply etch and drill the blank as you would normally do.

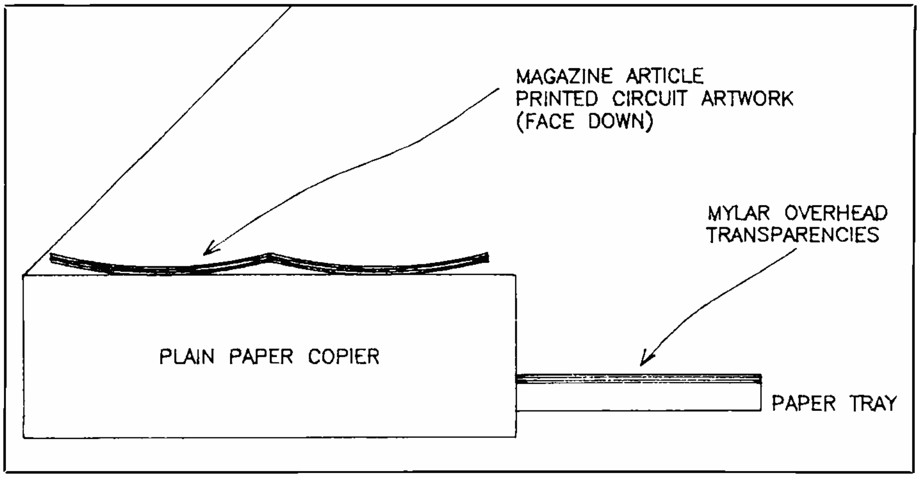

Fig. 1. Copying published actual-size printed-circuit artwork from a magazine or electronic book onto overhead projection film is done with a plain-paper photocopier as shown.

The Basics

In a typical dry-toner copier or laser printer, a sheet of paper is drawn between several rollers, one of which deposits the toner image on the paper. Other rollers, heated to about 180 degrees Fahrenheit, quickly fuse the toner to the paper.

Toner that adheres to the paper is like dense-black powdered hot-melt glue. If you reheat the toner to a high enough temperature, it becomes tacky enough to adhere to a blank copper-clad pc blank. Once transferred to the blank, this toner is impervious to the etchants normally used in printed-circuit board fabrication and, thus, takes the place of traditional resist.

The trick in transferring the toner from the paper (or, as in this application, overhead projection film) to the copper surface of the pc blank is to simulate the heat and pressure of the copier. A little muscle and an ordinary clothes iron or hotplate are all you need to accomplish this task.

Overhead transparency material is usually composed of a polyethylene (such as DuPont's Mylar material) base that is coated on both sides with acrylic to make the toner adhere to it. Mylar can withstand the heat and pressure involved in the xerographic copying process and makes an ideal medium for our printed-circuit board application.

It should not be difficult to locate overhead transparency film. It is commonly available from office-supply outlets. If the outlet near you does not normally stock it, chances are the proprietor will be willing to order it for you. Alternatively, you can contact the manufacturers di-

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rectly to request the name and address of a retailer in your vicinity that does stock what you need.

A box of 100 sheets of 8½ × 11-inch overhead projection transparency film usually costs about $50. This works out to about 50 cents per sheet, which is a bit steep but nowhere near as expensive as having made an actual-size film negative or positive of your original artwork or making your own exposure masks. I have had good results with transparency film made by both 3M and Labelon Corp.

3M's product is called "Scotch Brand PPC Transparency Film." The PPC stands for Plain Paper Copier. This film comes in various types that are specially adapted to specific copiers. The main difference between the different types of film available from 3M is in the acrylic coating used. This coating formulation determines the adhesion characteristic of the toner to the film. Image printing on the finished overhead film may be more or less durable, depending on which particular brand or type of film is used.

I have used Type 501 film from 3M with good results in my pc-board fabrication efforts. Labelon's XTR-650 general-purpose transparency film is an excellent alternative. (For addresses of manufacturers mentioned here, refer to the Names & Addresses box.)

According to one manufacturer, overhead transparencies for liquid-toner copiers have weak adhesion properties. Therefore, it would appear that using a liquid-toner transparency film in dry-toner copiers might be advantageous to the process that is detailed below. You want the toner to adhere weakly to the Mylar film so that when you transfer the image made up of it to the copper-clad pc blank, all the toner will transfer to the copper cladding. It is possible that using a liquid-toner transparency film is a good move, but I have not yet tried it to verify results.

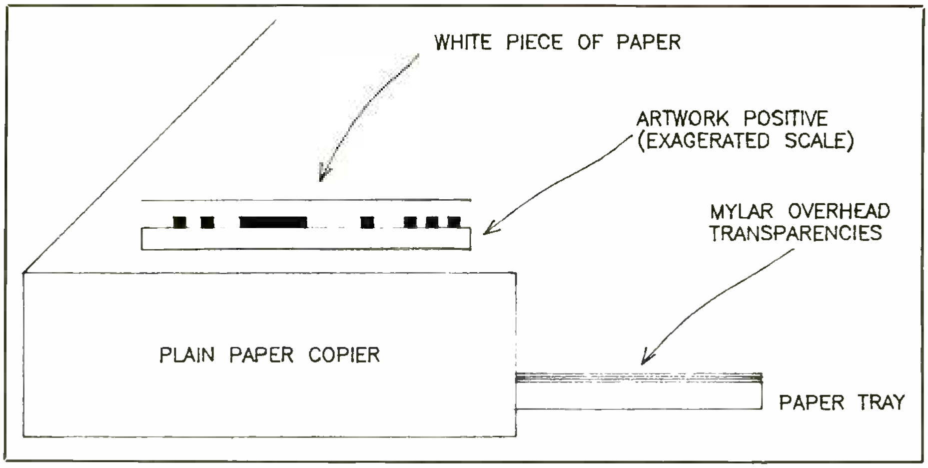

Fig. 2. When copying original artwork laid out on transparent film, place a sheet of clean white paper over the artwork before lowering the lid of the copier to prevent dirt and scratches on the lid from copying onto the film.

For illustrative purposes, let us assume that you plan on fabricating a printed-circuit board from the artwork published as part of one of the construction articles in *Modern Electronics*. For this operation, you must have on hand or have access to the following materials:

(1) Overhead transparency film
(2) A plain-paper photocopier
(3) A clothes iron or hotplate
(4) A small roller
(5) A copper-clad pc blank
(6) Etchant

The copier used for transferring the image from the printed page to the transparency film should have the minimum amount of distortion. Most copiers have a certain amount of distortion built in. Some have very little, others an excessive amount. Unless the distortion is really excessive and shrinks or enlarges the reproduced image enough to prevent integrated-circuit pins from reasonably aligning with the pad patterns in the image, a small amount of distortion will be tolerable. Distortion is usually negligible for small pc-board conductor patterns, but it can prove to be problematical for large, intricate patterns that require precise pad positioning, especially if you are working on artwork that must exactly align for double-sided boards.

The small roller you use should be the type meant for wallpaper work. Use the one that is designed for pressing the paper to the wall at the seam.

The copper cladding on the pc blank must be meticulously cleaned. Use scouring powder to bring out a uniform bright, shiny copper surface. Thoroughly rinse the board to remove all dirt and grit and either air-dry the clean blank or place it in a warm oven to force dry it. Once the blank is clean, handle it only by its edges to avoid getting fingerprints on the copper surface.

You can use either ferric-chloride or copper-persulfate to etch the pc blank once the resist pattern has been transferred to it. Either will work effectively.

With the foregoing in mind, let us detail the actual procedure from start to finish.

Seven-Step Process

Printed-circuit original artwork must be actual-size (1:1 ratio) to successfully apply the procedure about to be described. So, if you are preparing your own artwork from scratch, keep this in mind. Fortunately, most

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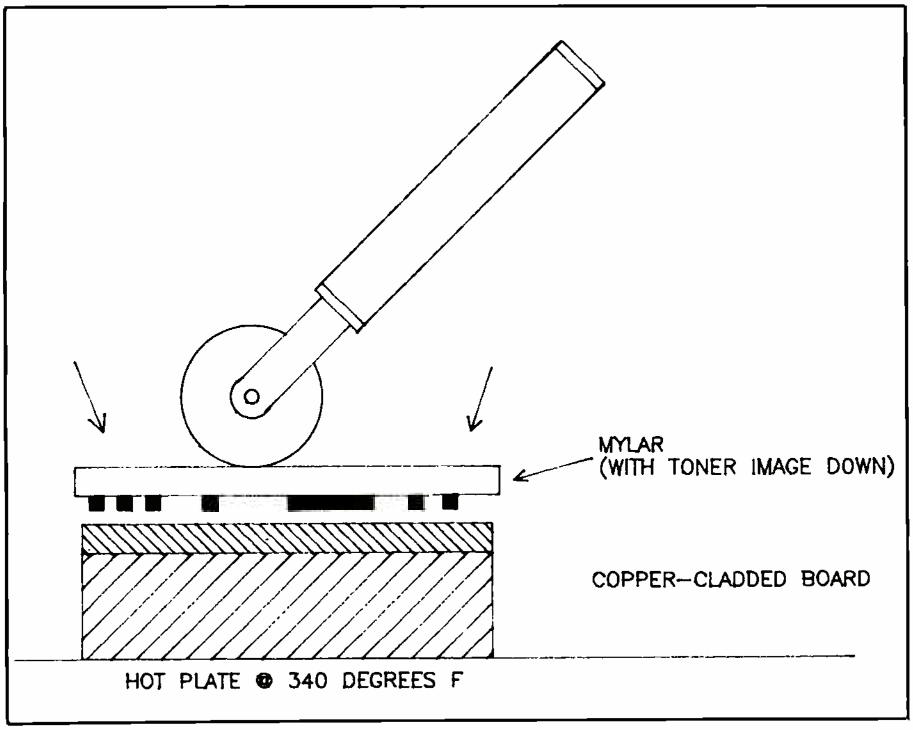

Fig. 3. Use of a hotplate and wallpaper seam roller, the latter to apply needed pressure during the transfer process, is simpler than using a clothes iron.

pc artwork that appears in print in magazines and many electronics books is actual-size; so it can be copied directly.

To apply our procedure, be aware that you must have a *conductor-side* view of the artwork to be copied. If the artwork you wish to copy is a so-called "x-ray" view through the top, or component side, of the board, you must mirror-image the copy that will be used to transfer the image onto the pc blank.

There are seven basic steps involved in fabricating a printed-circuit board with our procedure. They are as follows:

(1) Place several sheets of overhead projection film into the paper tray of the copier to be used. Copy the original artwork onto the film in the usual manner. If you are working with original artwork of your own design constructed on clear or translucent film, place the artwork in proper position and with the conductor side down, cover this with a sheet of clean white paper to prevent any dirt or scratches on the copier's cover from copying as well, and copy the artwork. If you are copying from a magazine or book, simply place this on the copier, as shown in Fig. 1, and make the copy.

When copying artwork you originated yourself using self-adhering donut pads, IC patterns and tapes, make certain that the artwork is in intimate contact with the glass plate of the copier to prevent any shadowing effect in the copy. To assure this intimate contact, place over the sheet of white paper a ⅛- to ¼-inch-thick sheet of soft foam plastic packing material, close the lid of the copier and apply gentle pressure as the copy is being made.

Your self-originated artwork will almost certainly be made with self-adhering tapes, donuts and IC patterns on transparent plastic film. Thus, you can copy it from either the conductor or component side. If you copy from the component side, as shown in Fig. 2, you will have to make two passes, one to make the intermediate component-side view and the other to make the conductor-side view that will be used in the transfer process.

If you are copying from a magazine or book, make certain that the artwork is perfectly flat. If not, you may have to cut the artwork out of the magazine or book to use it alone in the copier. Also, view the artwork head on to see if any of the printing on the other side of the page "bleeds" through. If it does, back the artwork with a sheet of matte-black construction paper.

When you have made a copy of the original artwork, place the transparency obtained over it to determine how much, if any, distortion has occurred. If the distortion is excessive and there is no way to make the pins of a DIP or other IC line up with the copied pattern, you must try another copier with less distortion.

(2) If you copied from x-ray-view artwork or your own originated artwork from the component-side view, you now have a positive of your artwork. You must now make a mirror-image copy of this. To do this, place the film on which the copy was made in the copier, toner side up, and make another copy on another sheet of overhead projection film. You will know which side of the film has the toner image on it by lightly sweeping the tip of a finger across the image and noting if you feel any rough spots where the image is. The side of the film that has a rough feel is the one with the toner on it.

When you copy the mirror image, treat it as you would an original artwork master. That is, place a sheet of clean white paper over the film to prevent any dirt or scratches on the copier's lid from copying as well. You do not have to worry about shadowing this time around, though.

Since the overhead film is transparent, you will obtain a copy that is a mirror image of the original be-

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cause the copier will be looking through the transparency as it scans to make the copy. You now have a reversed image of the original artwork, which can now be used directly to effect transfer of the copied pattern onto the copper cladding on the pc blank. Store the first copy away in a safe place for future use should you ever decide to duplicate the pc board for another identical project.

(3) Use scissors or a straight edge and sharp hobby knife to cut the Mylar film on which the copy has been made to about ¼ inch larger all around than the pc blank onto which you will be copying the toner pattern. This helps you to accurately position the artwork and lessens shrinkage of the film during the transfer process.

Place the clean pc blank copper-cladding side up on a sturdy, heat-proof surface. Then position the artwork, toner side against the copper cladding, on the pc blank.

(4) Polyethylene melts (fuses) at a temperature of 350 degrees Fahrenheit. Therefore, if the film begins to shrink and crinkle, you know that your heat source (clothes iron or hotplate) is too hot! Make a test run using some scrap film that you trimmed from the artwork sheet.

If you use a clothes iron as the heat source, set it to almost its hottest thermostat setting. This is usually the cotton/linen/wool temperature of about 340 degrees Fahrenheit. It is recommended that you cover the artwork film with a paper towel to prevent the film from sticking to the iron as you work.

Place the heated iron on the paper towel and apply steady downward pressure to use its heat to transfer the copied image onto the copper cladding of the pc blank. Press hard for 5 to 10 seconds, moving the iron in a circular motion to cover the entire surface of the board. If done properly, the heat of the iron will fuse the toner to the copper cladding. When you are done, remove the iron and allow the board with film and paper towel covering it to cool.

If you use a hotplate as the heat source, set it to a temperature of about 340 degrees Fahrenheit. Position the film with the transfer image on it on the pc blank as detailed above and gently place both on the hotplate. Allow several minutes for the pc blank to heat up. Then use the wallpaper seam roller to keep the film flat and in intimate contact with the copper cladding on the pc blank (see Fig. 3). Do not place a paper towel over the film this time. As the fusing temperature of the toner is reached, you will be able to see the toner melt and fuse to the copper cladding (see Fig. 4). When this occurs, carefully remove the pc blank with film on it from the hotplate.

(5) Allow the pc blank with film on it to thoroughly cool, which takes about 5 minutes. In Step 4, the hot toner fused to the copper cladding on the pc blank. To a lesser extent, it also fused the Mylar film to the blank. Once the blank has cooled, the toner preferentially adheres to the copper cladding on the pc blank as you slowly peel away the film.

When the film has been peeled away from the pc blank, you should have a positive black toner image fused to the copper cladding on the pc blank and a nearly clear piece of Mylar film. The toner on the blank now makes an excellent etch resist.

(6) Your pc blank is now ready to be turned into a printed-circuit board. Simply etch it in the solution of your choice. When this is done, thoroughly rinse it under cold running water to stop the etching action and remove all etchant. Then drill component lead and pin holes in all appropriate locations.

(7) The final step in the process is removal of the toner from the copper traces on the newly made printed-circuit board. You can use just about any organic solvent to do this. Rubbing alcohol works well here, as does water and a scouring pad.

The method of fabricating printed-circuit boards described above, while simple, does have a few drawbacks. One is that the pads and lines may appear to be somewhat "squashed" as a result of the pressure that must be applied during the process. I created a test pattern using my personal computer and the line

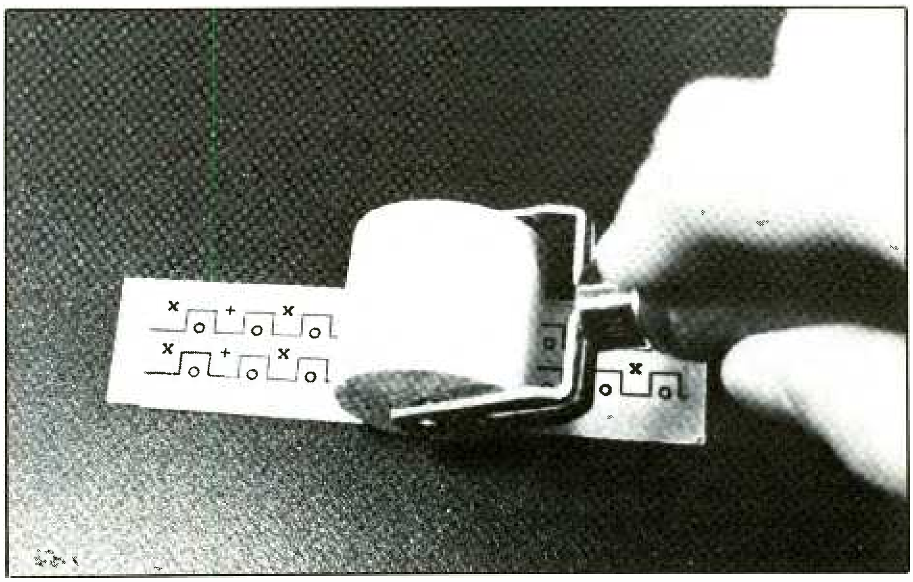

Fig. 4. Using the hotplate and wallpaper seam roller technique to transfer the image from the projection film to the copper cladding on the pc blank allows you to see when the toner on the film melts and adheres to the cladding.

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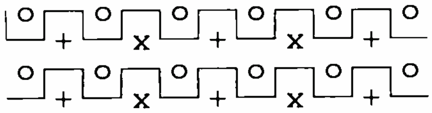
drawing mode of my word processor that appears as follows:



The small "x" in this pattern seems to contain the most structure for illustrative purposes.

Figure 5(A) shows this "x" as it appears freshly printed on overhead projection film. Notice here the fine detail, especially the individual particles of toner around the body of the character. Figure 5(B) shows how the "x" appears after a hotplate/roller treatment on copper-clad pc blank after it has cooled and the film has been peeled away. As you can readily see, the image is a bit flattened and spread out.

Figure 5(C) shows the result of the process after etching is complete and the toner that served as the resist has been removed. The flattening of the image is pretty evident, though it is not too bad for prototype printed-circuit boards.

With the foregoing in mind, if you are working on a board that has closely-spaced conductors and/or pads with the process described here, two or more may tend to run into each other when the process is complete. If you note this, you can attempt to clear the "bridges" by gently scraping between the pads and conductors with the point of a scribe to expose copper that can be removed during the etching step.

Some Observations

As is with all processes in which you must contend with many variables, the method of producing printed-circuit boards described above will require experimentation for you to determine the optimum conditions for your particular equipment and materials. You will have to experiment with copiers, temperatures, pressures and perhaps even type of etchant and etching time to use.

To determine the optimum conditions for your particular set of circumstances, it is best to make a bracketed exposure, as is commonly done in darkroom photography. For example, if you want to observe the effect of temperature on the process, you can cut several small strips of the Mylar overhead projection film and iron them individually onto the copper cladding on a pc blank, starting with a low temperature and steadily increasing the temperature for each strip used. This will help you to quickly discover the optimum heat-transfer temperature.

Though the clothes iron method of applying heat during the transfer process does work, I have had somewhat better results using a hotplate and wallpaper seam roller. With this combination, you can easily tell when the toner melts and fusion to the copper cladding on the pc blank occurs, thanks to the unobstructed view you have through the transparent Mylar film.

My best results have been obtained using DuPont's new Kapton film. This product melts at about 1,000 degrees Fahrenheit and does not shrink. The rub here is that this particular film costs about $3 per sheet in small quantities.

For those readers who wish to try the pc-board fabrication process described above but do not want to make a costly commitment in terms of materials until they are satisfied with the results obtained, I will supply two blank sheets of Kapton, three

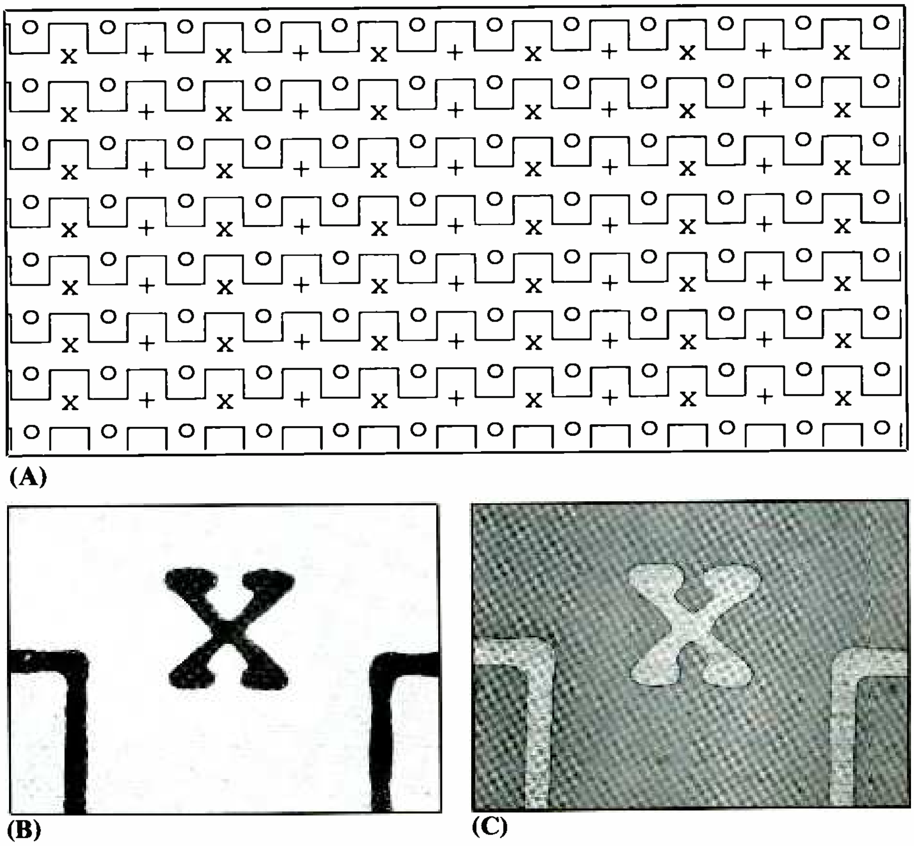


Fig. 5. Printed image on projection film has sharp outline and clearly defined structure; after being transferred to copper cladding on pc blank (B), image is slightly spread out and loses some of its structure; once board is etched and toner resist is removed (C), copper-trace image remains spread out but is adequate for prototype pc fabrication.

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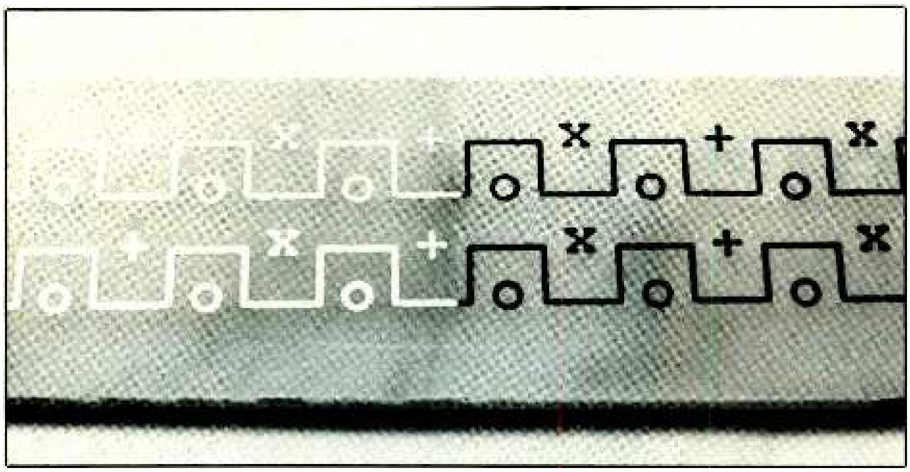

Detail of an etched board using a test pattern with some of the toner resist removed at the left.

blank sheets of Mylar and a small sheet of Kapton film on which is copied the artwork for a light-emitting diode flasher circuit built around a 555 timer chip. Except for the last, all sheets measure 8½ × 11 inches, and the cost for the package is $10 (see box for address to which to write). Incidentally, the Kapton sheets are durable enough for repeated use if you clean them carefully to remove all residual toner with a good solvent. **ME**

Names & Addresses

3M Company
Commercial Office Supply Div.
3M Center
St. Paul, MN 55144-1000
612-733-3300

DuPont Electronics
Dupont Co.
Barley Mill Plaza
Kirk Mill Bldg., Ste. 1103
Wilmington, DE 19880-0013
302-922-3714

Labelon Corp.
10 Chapin St.
Canandaigua, NY 14424-1589
1-800-482-5566
1-800-523-1009 in NY

For a sample packet of overhead projection film (see text) from the author, send $10 to: William R. Eubank, Jr., 276 N. Ilwaco Rd., River Falls, WI 54022

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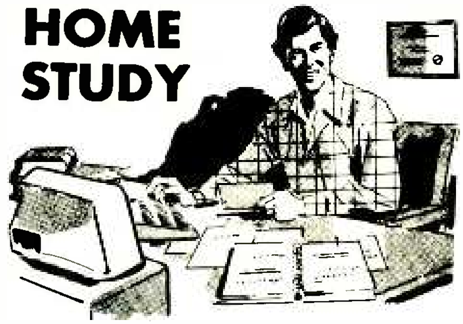

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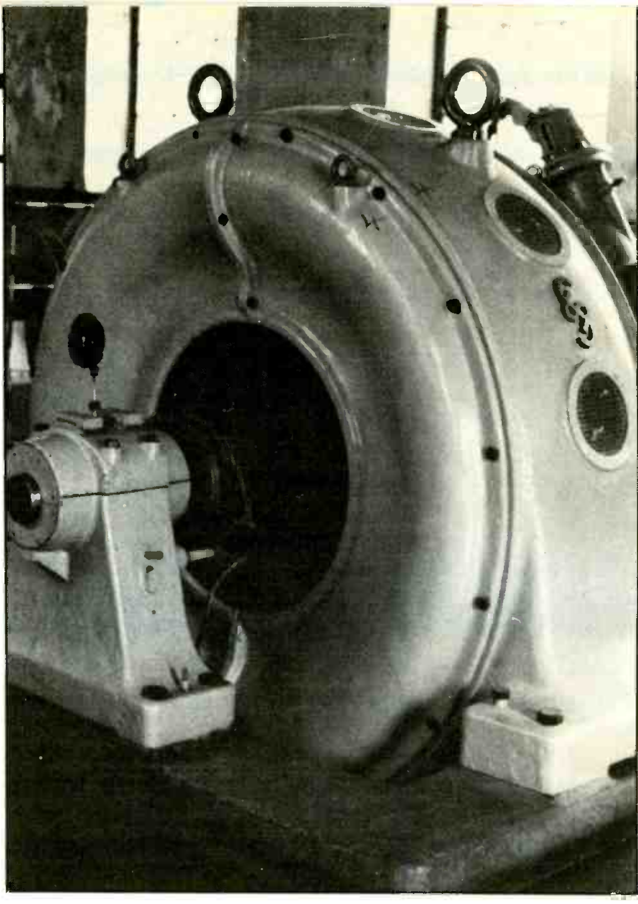

Three-Phase Motor Protector

Low-power semiconductor devices inexpensively prevent failure of multiple-horsepower ac motors

By Fernando Garcia Viesca

Because of its simplicity and ruggedness, the alternating-current electrical motor is commonly used to power appliances and other devices. Small ac motors—also known as fractional-horsepower (hp) motors—are always operated from a single phase of the ac line. However, motors rated at 1 hp or more, particularly greater than 3 hp, are generally three-phase devices. Typical of such motors is the one shown in the lead photo.

Multiple-horsepower ac motors suffer from a major drawback. If one phase fails, due to a fuse opening or some other cause, the motor will continue to run, but the remaining two phases will draw excessive current. If this is not corrected, the motor will burn out. Another cause of early failure is insufficient or too much line voltage. Either condition can cause the motor to draw excessive current and burn out.

The three-Phase Motor Protector described here was designed to automatically shut down the motor it is protecting to save it from costly destruction. Thus, one does not have to constantly monitor the motor to be ready to shut down power in the event of a potentially destructive condition. This relatively simple solid-state electronic circuit works along with existing fuse or circuit-breaker protection.

Some Basics

A number of reasons exist for three-phase operation of multiple-horsepower motors. In a single-phase circuit, pulsating power is delivered to the motor. This is analogous to a single-cylinder gas engine. On the other hand, three-phase motor circuits are like an engine with multiple cylinders that deliver power more smoothly. The rating of a given size motor or generator is 48 percent greater when operating three phase as compared to operation on one phase.

A single-phase motor has no starting torque. To get its rotor to begin rotating, an auxiliary starting winding and other devices are employed. Three-phase motors have inherent substantial starting torque and do not require such starting devices.

Finally, for a given amount of transmission power, all other parameters being equal, three-phase power requires only 75 percent of the weight in copper wiring of its windings as compared to the amount of wire used in single-phase motors. This results in substantial savings in both cost of materials and size/weight of the motor.

Motors are usually protected with fuses or thermal circuit breakers. Though effective in single-phase motor systems, this type of protection has two major shortcomings when it comes to three-phase ac motors:

(1) *Temperature Dependency.* Even though fuses and motors burn out for the same reason—excessive heat developed by excessive current drawn—this does not mean that both experience the same rise in temperature. The motor may be subjected to an external source of heat and experience a greater rise in temperature than is occurring at the location of the fuse or circuit breaker.

The time lag experienced by the fuse or breaker leading up to opening of the element or contacts may result in burn-out of the motor's windings before the protective device can react. Likewise, fuses subjected to too

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much heat will repeatedly burn open, causing annoying interruptions in motor service. Of course, thermo-magnetic circuit breakers have been designed to alleviate this effect.

(2) *Motor Size & Application Dependency.* Cost and complexity of protective devices spiral upward with increasing motor power. The protective circuit to be discussed here has no such dependency. It can be used with any three-phase motor, regardless of size or horsepower rating, without any changes in the circuitry. So cost of the protection it provides remains a constant.

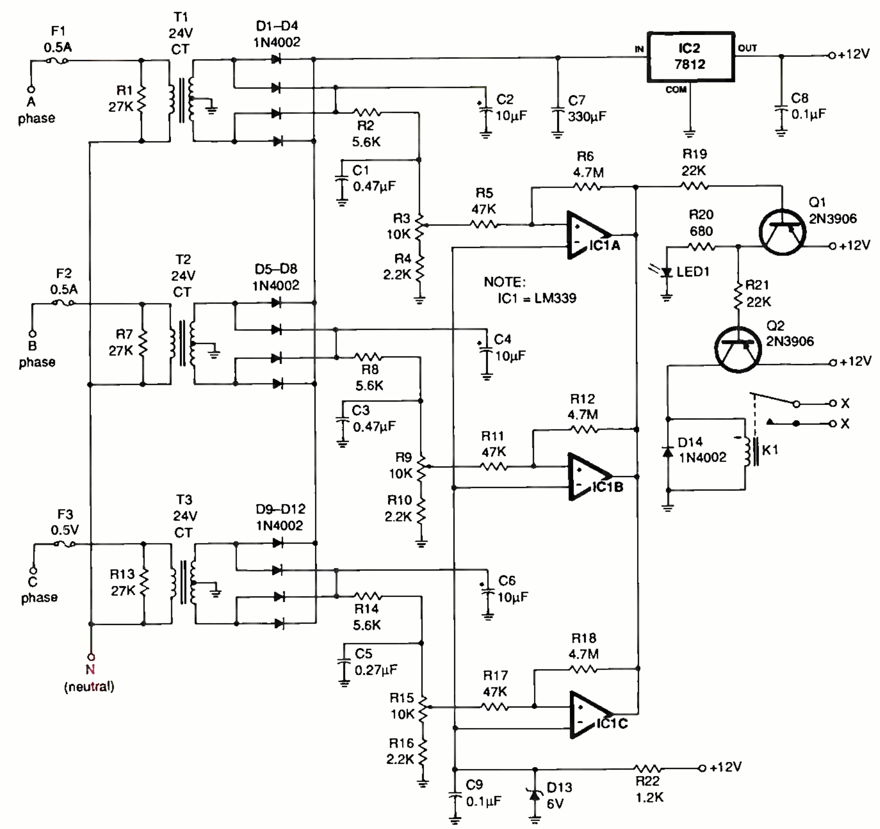
Our Motor Protector employs an electronic sensor that is used in conjunction with and complements existing fuses and/or circuit breakers.

About the Circuit

The complete schematic diagram of the circuitry required for the Three-Phase Motor Protector is shown in Fig. 1. As you can see, the circuitry is fairly simple and actually consists of three identical circuits, one for each phase to be protected. This being the case, we will detail operation of just one of the circuits.

Phase A of the ac power source, connected at the input end of fuse *F1* supplies power to transformer *T1*. In parallel with the primary winding of *T1* is balancing resistor *R1*, which provides a floating neutral point in the circuit. The primaries of all three transformers in this project are wye connected to enable 117-volt-rated transformers to be used across 208-volt ac lines or 127-volt transformers to be used across 220-volt ac lines.

The transformer in each leg of the circuit supplies power to two full-wave, center-tapped arrangements. In Phase A, the components involved in the first arrangement are *D1* and *D4*, along with filtering capacitor *C7*. The resulting dc is regulated to 12 volts dc by regulator *IC2*. The regulated dc output from *IC2* then powers the *IC1* and *Q1/Q2* circuitry.



PARTS LIST

Semiconductors
D1 thru D12,D14—1N4002 silicon rectifier diode
D13—6-volt, ½-watt zener diode
IC1—LM339 quad comparator
IC2—LM7812 + 12-volt regulator
LED1—Red light-emitting diode
Q1,Q2—2N3906 or similar silicon pnp transistor

Capacitors
C1,C3,C5—0.47-µF, 25-volt disc
C2,C4,C6—10-µF, 25-volt electrolytic
C7—330-µF, 25-volt electrolytic
C8,C9—0.1-µF, 50-volt ceramic disc

Resistors (¼-watt, 5% tolerance)
R2,R8,R14—5,600 ohms
R4,R10,R16—2,200 ohms
R5,R11,R17—47,000 ohms
R6,R12,R18—4.7 megohms
R19,R21—22,000 ohms
R20—680 ohms
R22—1,200 ohms
R1,R7,R13—27,000 ohms (1-watt)
R3,R9,R15—10,000-ohm pc-mount trimmer potentiometer

Miscellaneous
F1,F2,F3—0.5-ampere fuse
K1—12-volt dc relay (Digi-Key Cat. No. Z410-ND or similar)
T1,T2,T3—24-volt center-tapped, 120-mA power transformer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (optional—see text); socket for IC1; fuse holders; silicone or potting compound (see text); machine hardware; hookup wire; solder; etc.

Fig. 1. Complete schematic of Three-Phase Motor Controller circuitry.

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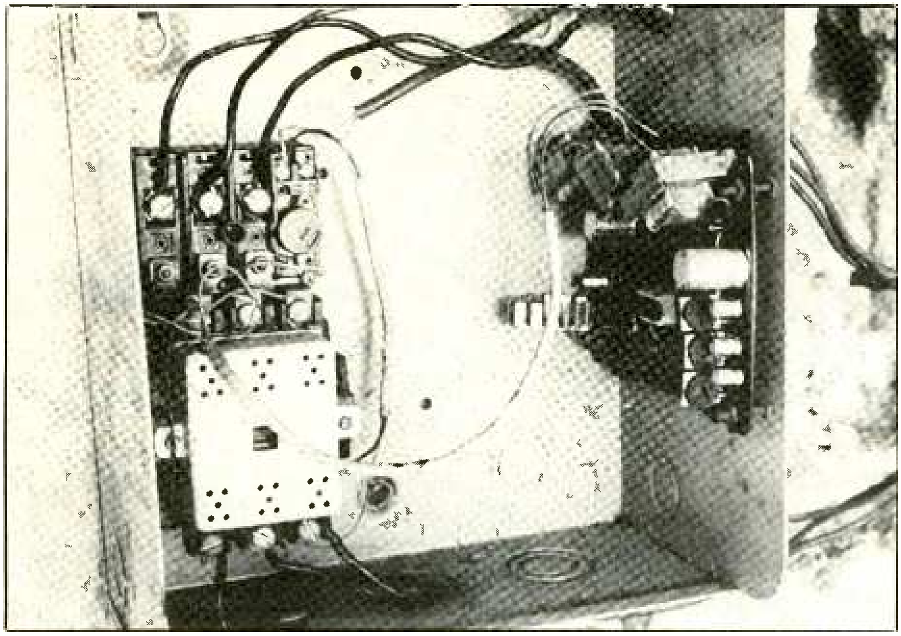

Fig. 2. Project shown installed inside electrical box that contains control circuitry for a three-phase motor. Large contactor is shown at lower left in photo.

Zener diode *D13* provides stable bias voltage for the inverting (−) inputs of *IC1*.

The other leg of the rectifier arrangement in Phase A consists of *D2*, *D3* and *C1*. This circuit provides a dc voltage that is proportional to the ac input voltage on the primary winding of *T1*. This dc voltage is fed to the voltage divider made up of fixed resistors *R4* and *R2* and potentiometer *R3*. The potentiometer permits adjustment of the sample voltage fed to the noninverting input of comparator *IC1A*.

Whenever the sampled voltage is less than the bias voltage, the output of the comparator swings low (to near 0 volt). Resistors *R5* and *R6* provide a small amount of positive feedback to include hysteresis in the trip point to obviate chattering of the relay in the collector circuit of transistor *Q2*.

Phase B and Phase C circuits follow identical conditions of operation. You can see that transformers *T2* and *T3* supply filter capacitor *C7* and voltage regulator *IC2* via the *D5/D8* and *D9/D12* arrangements. Thus, any phase that is active can supply power to the circuit.

The outputs of the comparator stages are open-collector in nature, allowing them to be wired in an AND configuration without having to use "glue" logic. Whenever any comparator output swings low, as a result of a fault in a phase circuit of the motor being monitored, pnp transistor *Q1* is driven into saturation and lights FAULT light-emitting diode *LED1*. This condition sends transistor *Q2* into cutoff and deenergizes relay *K1*. When this occurs, power to the motor being protected is disabled. Thus, the contacts of the relay will be closed only when suitable conditions exist on all three phases of the line feeding the project.

Construction

You can assemble the circuitry shown in Fig. 1 using any traditional wiring technique. If you wish, you can design and fabricate a printed-circuit board for the project. Alternatively, you can mount and wire together the components on perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware. In either case, it is a good idea to use a socket for quad comparator *IC1*.

The only caution that must be observed when laying out and wiring your circuit is to exercise care with the high-voltage sections of the circuitry. Make absolutely certain that the high- and low-voltage sections are adequately separated from each other and that adequate insulation is used throughout. After assembling and checking out the circuitry to make sure it is properly wired and operating as described, apply a thick coat of silicone caulking or potting compound to the high-voltage sections to assure good insulation.

Assemble the circuit, but do *not* plug the LM339 into the *IC1* socket until after you have performed preliminary voltage checks. Use the usual procedure in populating the circuit board. That is, begin by installing the IC socket; continue with installation of the resistors and capacitors; and finish up with installation of the diodes and transistors. Make certain that the diodes and electrolytic capacitors are properly polarized and that the transistors are properly based before soldering their leads into place.

You can mount fuse blocks for *F1*, *F2* and *F3* directly on the circuit-board assembly or off the board on one of the walls of the enclosure selected for the project. (An enclosure is not necessary if you plan on mounting the finished project inside an electrical panel box, as shown in Fig. 2.) Similarly, the transformers, light-emitting diode and relay can be mounted either on or off the board, depending on whether or not you are using an enclosure.

Checkout & Installation

With *IC1* still not installed in its socket, apply 117-volt ac line power between the Phase A and Neutral (N) input points. Being extremely careful

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not to touch the ac input, use a dc voltmeter or a multimeter set to the dc volts function to measure the voltage between circuit ground and pin 3 of the *IC1* socket. You should obtain a reading of + 12 volts. If you fail to obtain this reading, check the voltage at the OUT pin of regulator *IC2*. This should be about + 12 volts.

If you fail to obtain the appropriate reading at either point in the circuit, unplug the project from the ac line and rectify the problem before proceeding. Check to make sure all connections have been made and that all rectifier diodes are properly oriented. Also check to make sure that the electrolytic capacitors are properly polarized and that the regulator chip is properly based. Do not proceed until you are certain that the project is properly wired.

Once you are certain that the project is properly wired, disconnect it from the ac line and install the LM339 in the *IC1* socket. Make sure the IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

It is now time to power up the project once again and calibrate it. The first step in the calibration procedure is fairly safe to perform—if you follow directions to the letter.

Make sure that the fuses you use in the project are of the correct rating. Do *not* work on a metallic table! Work at a wood table or a standard electronics testbench or anywhere else that is fully insulated.

Use the test setup shown in Fig. 3, starting with the variac (variable transformer) set to its lowest output setting. If you include the shown isolation transformer in the test setup, the calibration procedure is virtually foolproof. Note at this point that Neutral terminal N in Fig. 1 and Fig. 3 is used only as the voltage reference during test and calibration. In actual three-phase service, the circuit does not make use of this terminal.

In a balanced wye-connected three-phase circuit there are three identical single-phase circuits that "see" an identical voltage, but each is displaced by 120 degrees in phase from the previous and following circuits. Since this ac voltage is being converted to a dc voltage, the phase shift is meaningless during the test and calibration operation. Therefore, you can "fool" the circuit and connect its three branches in parallel with each other to obtain calibration with a single voltage.

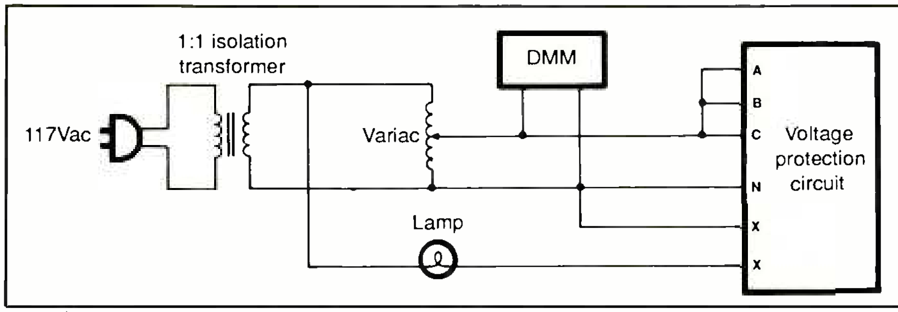

Fig. 3. Setup for calibrating project. Use of isolation transformer is strongly recommended.

To calibrate the project, slowly adjust the variac from zero (its lowest output setting) for a potential of: $V_v = V_{nom} \times 0.90/1.73$, where V_v is the voltage of the variac; V_{nom} is the nominal voltage imprinted on the specifications plate on the motor; 0.90 is used to make the trip point of the circuit at 90 percent of nominal line voltage; and 1.73 is the square-root of 3. (You can change the 0.90 value if you wish for a lower- or higher-percentage trip point.)

If any fuse in the project's circuit blows during the calibration procedure, immediately power down the project. Check for short circuits and rectify any located before proceeding. Under no circumstances should you omit the fuses from the project and wire the inputs directly to the transformers!

Set potentiometers *R3*, *R9* and *R15* so that their wipers are fully toward *R2*, *R8* and *R14*, respectively. Slowly adjust the setting of *R3* toward its other end of travel until the relay deenergizes and the LED turns on. Then back up slowly until the LED just lights again. Repeat this procedure with the other two potentiometers. This is all there is to calibration.

You can verify circuit action by disconnecting the input from any of the three phases and observing. When you do this, the relay should deenergize and the LED should light to indicate a fault condition. Repeat

(Continued on page 82)

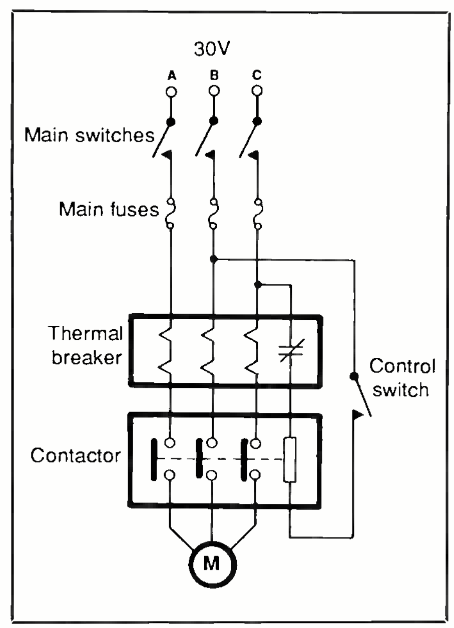

Fig. 4. Typical three-phase motor control schematic diagram. In electrical schematics, auxiliary normally-closed contacts are drawn as a modified capacitor symbol with a diagonal line through it.

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ELECTRONICS NOTEBOOK

More About Superconductors

By Forrest M. Mims, III

Experimenting with superconductors was the subject of the March 1988 installment of this column. Recently Ernest Laird, a local high school physics and chemistry teacher, asked me to advise one of his students who was preparing a science-fair project on experimenting with a superconductor. The experiments the student conducted were so interesting that I will describe them in this column. I'll also propose some new superconductor experiments you might wish to try. First, however, let's review a few superconductor basics.

Superconductor Basics

In 1911, Heike Kamerlingh Onnes discovered that mercury cooled to the temperature of liquid helium lost all resistance to the flow of an electrical current. He later discovered that both tin and lead also become superconductors at the temperature of liquid helium.

Because it is difficult to make and store, liquid helium is difficult to work with and expensive to buy. These drawbacks have greatly impeded research with superconductors and the development of practical applications.

The most important breakthrough since the original discovery of superconductivity by Onnes occurred in 1986 when K. Alex Muller and J. Georg Bednorz announced the discovery of a non-metallic ceramic superconducting material made from an yttrium-barium-copper oxide mixture. As remarkable as its unusual composition was the fact the new ceramic became a superconductor at a temperature of 90 degrees Kelvin, which is well above the 77-degree Kelvin temperature of liquid nitrogen.

Since liquid nitrogen is considerably cheaper and easier to work with that liquid helium, there was a rush by scientists around the world to develop ceramics that would become superconductors at even higher temperatures. Ceramics that become superconductors at temperatures as high as 120 degrees Kelvin have since been developed, and research on additional ceramic superconductors continues at an active pace.

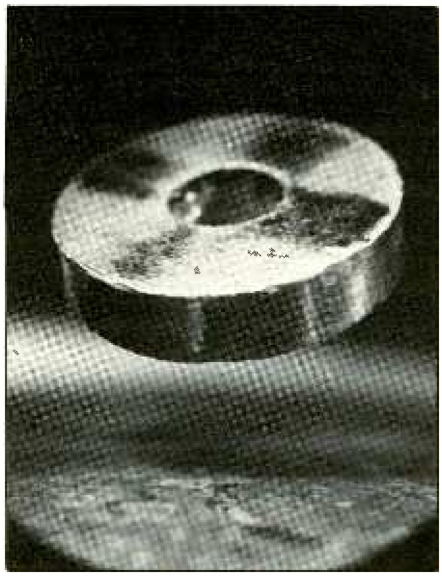

Fig. 1. A magnet floating above a superconductor chilled to the temperature of liquid nitrogen in the author's shop.

A pulse of electrical current induced from one coil of wire into a nearby coil of copper wire is a close replica of the pulse in the first coil. The current flowing in the second coil ends almost immediately after the level of the current pulse in the first coil falls to zero. The reason the current flowing in the second coil stops when it no longer receives an induced current is that the wire through which it flows exhibits a resistance to the flow of a current.

Now consider a superconducting wire, one that has no electrical resistance whatsoever. When a current is induced into a coil made from such a wire, current will continue to flow even after the inducing current is removed. This amazing ability permits electrical currents to be stored until needed. It also makes possible exceedingly powerful electromagnets.

In my previous column on superconductors, I described in detail the Meissner effect. An amazing phenomenon that results from this effect is the ability of a small but powerful magnet to float above a superconducting disk, as shown in Fig. 1. Though I have since seen this demonstration many times, sometimes in television commercials, it remains no less fascinating than the first time I saw it.

The Meissner effect was first observed in 1933 by Walther Meissner, who found that magnetic fields do not penetrate a superconductor. For this reason, a magnet placed near a superconductor is repelled. Of course, two magnets will repel each other when arranged with like poles facing. Unless the magnets are restrained, one will quickly spin around and slam against the other.

The difference with a magnet placed near a superconductor is dramatic. No matter which pole of the magnet is placed against a superconductor, the magnet will immediately be repelled upward where it will simply float in space. The magnet can even be rotated or moved to different positions.

How does the Meissner effect work? The most common explanation is that a magnet brought near a superconductor induces an equal but opposite magnetic field in the superconductor. The magnet is then repelled by the superconductor. The induction is not dependent on any motion of the magnet. As I reported in my previous column, the beam from a helium-neon laser reflected from a magnet floating above a superconductor revealed absolutely no motion.

While this explanation might be correct, it does not fully explain what happens. Why, for example, does the magnet float even above the edge of a superconductor? Why can the magnet be placed in various positions?

As you can see, a simple demonstration of the Meissner effect is alone worth the trouble of acquiring a superconducting disk and some liquid nitrogen. Be prepared, however, for lying awake at night reflecting on what you have seen and trying to understand it.

Experiments

While the floating magnet demonstration of the Meissner effect is fascinating, there are many more experiments that can be performed with a superconductor, as I recently learned when Ernest Laird asked

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me to advise one of his students, Jenny Lehmann, about her science fair project. Ernest supplied a superconducting disk and a liter of liquid nitrogen. I brought a second superconducting disk, several kinds of magnets, some string and a sheet of plastic film that indicates the presence of a magnetic field by a change in color.

After I reviewed with Jenny the basic precautions about working with liquid nitrogen, which are listed below, she conducted a series of simple but interesting experiments. For all these experiments, the superconducting disk was placed in an insulated receptacle cut from the bottom of a foam plastic cup. Liquid nitrogen was transferred from a small dewar flask to the superconductor by means of a second foam plastic cup.

The first experiment was to determine if a spinning magnet floating above a superconductor disk would remain stationary when the superconductor below it was rotated. If so, a new kind of gyroscope might be possible. A disk-shaped magnet floating above a superconductor will rapidly spin when given a gentle nudge by a pencil. The magnet I used, pictured in the pages of this magazine, had since broken in half when it was attracted with considerable force to a second magnet. Therefore, Jenny tried this experiment with a 3/16-inch-diameter neodymium-iron-boron magnet from Edmund Scientific (stock number J38,428). According to the Edmund catalog, magnets made from this formulation have an energy density of from 27 to 35 million gauss oersteds, making them among the strongest commercially available magnets.

The new magnet levitated nicely about 2.5 to 3 millimeters above both superconductor disks. However, it did not spin nearly as well as the larger samarium-cobalt magnet I used in my earlier experiments. Even though the magnet appeared circular, it slowed down fairly rapidly and then oscillated back and forth slightly for a few cycles, as if lopsided.

During the second or two when the magnet was spinning rather rapidly, Jenny rotated the superconductor disk to see if the magnet remained in place or moved with the superconductor. It moved with

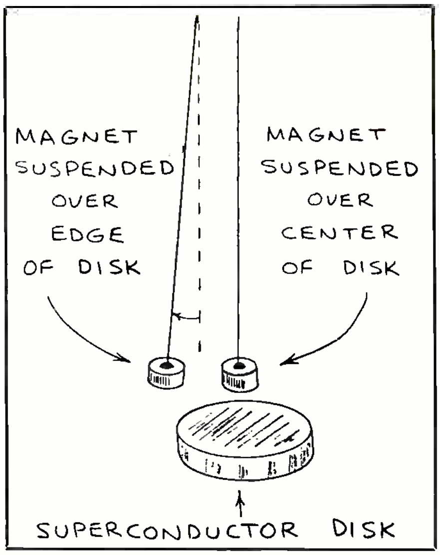

Fig. 2. Suspending a magnet above a superconductor

the superconductor. Indeed, when she lifted the superconductor with plastic tweezers, the magnet floated in place as if mounted atop an invisible pedestal.

Next, Jenny suspended a small cylindrical alnico magnet tied to a string held directly above the superconductor. While the superconductor does not possess a magnetic field, it apparently develops a magnetic field when a magnet is placed nearby. Since this field has the same polarity as the closest pole of the magnet, the superconductor, naturally, tends to repel the magnet.

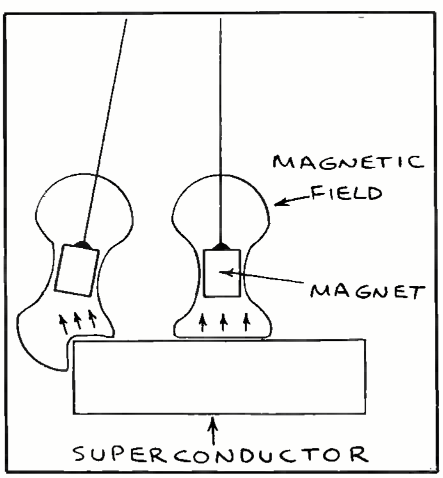

Fig. 3. How a the field of a suspended magnet is repelled by a superconductor.

When the magnet was suspended close to the center of the superconductor, it moved toward the center of the disk. When suspended near the edge of the disk, as shown in Fig. 2, the magnet swung slightly outward and away from the disk.

It's interesting to note that the magnet Jenny used was too weak and definitely too large to float above the superconductor. Nevertheless, it was definitely repelled by the superconductor.

The superconductor itself apparently reflects or repels the magnet's field, as shown in Fig. 3. The circular shape of the superconductor explains why the magnet was attracted toward (or repelled away from) the center of the disk.

That the superconductor appears to repel a magnetic field was confirmed with the help of a sheet of Magna View film purchased from Edmund Scientific (Cat. No. J33,447). This film is a sheet of plastic coated with encapsulated microbeads filled with ferrous oxide. A magnetic field realigns the particles in the microbeads and transforms the color of the sheet from green to blue.

While I held the Magna View film against the superconductor, Jenny grasped the neodymium-iron-boron magnet with plastic tweezers and pressed the magnet against the film over various points on the superconductor. She then pressed the magnet against several portions of the film some distance away from the superconductor. Hourglass-shaped patterns representative of the magnet's field were formed on the film where the magnet was touched to it away from the superconductor. No patterns were visible where the magnet was touched to the film over the superconductor.

While this experiment seemed to provide convincing proof that the magnet's field was repelled by the superconductor, we decided to see if the fact that the Magna View film was cooled to near the temperature of liquid nitrogen altered its sensitivity. Therefore, we dipped a corner of the film into liquid nitrogen and then

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placed a magnet against it. After the film warmed up enough to evaporate the thin layer of frost, we could clearly see the pattern left behind by the field of the magnet. The pattern, however, was not as bright or as distinct as those formed on the film at room temperature. Nevertheless, it did show a magnetic field pattern that was clearly absent when the same film was placed over a superconductor.

Ernest suggested that this experiment be repeated with the film held over the magnet as it floated over the superconductor. This time, the film clearly revealed the pattern of the magnetic film.

One of the most interesting superconductor developments of 1988 was the serendipitous discovery that a new kind of superconductor would suspend itself below a magnet. The discovery was made by Palmer Peters of the National Aeronautics and Space Administration while he was experimenting with a superconducting compound laced with silver oxide. When he lifted a magnet from a dish of liquid nitrogen, he noted that the piece of superconductor that was also in the dish had disappeared from the clear liquid.

Peters eventually spotted the superconductor hanging beneath the magnet, presumably by means of a stray piece of thread. Instead, Peters was startled to find that the superconducting material was actually floating below the magnet!

Later, Alan Hermann of the University of Arkansas found that some samples of another kind of superconductor would also float below a magnet. He also found that the material would remain in suspension, even when the magnet was rotated through 90 degrees. Figure 4 is a drawing that shows both of these remarkable effects. This drawing is adapted from a pair of photographs published in the October 1988 issue of *The Institute*, a publication of the Institute of Electrical and Electronics Engineers.

Jenny attempted to determine if the tiny neodymium-iron-boron magnet would hang in suspension below either of the two superconducting disks. It did not. She also tried stacking the two disks atop one another to see if the height of the floating magnet would be increased.

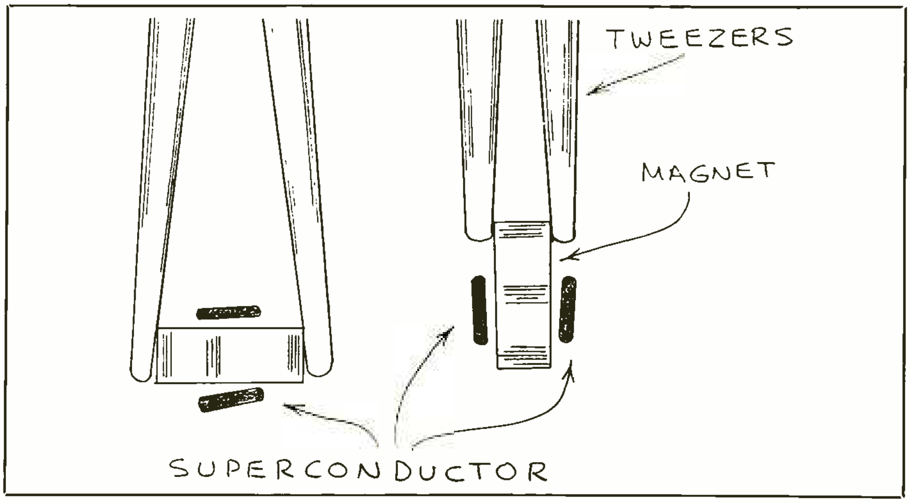

Fig. 4. A superconductor suspended below *and at the sides of a magnet.*

There was no apparent change.

Next, Jenny held a superconductor disk with plastic tweezers while a magnet was levitating above it. She then held a second magnet below the disk. In view of the superconductor's repulsion properties, we were all surprised when the floating magnet was immediately pulled down to the superconductor. Indeed, both magnets remained fixed to opposite sides of the disk, even though the disk was still cold enough to be a superconductor. When she repeated this experiment with a small steel magnet keeper, nothing happened. The floating magnet was not attracted to the steel below the superconductor. Instead, the magnet simply continued to float freely above the superconducting disk.

Finally, Jenny investigated the effect of a superconductor on a compass needle. When a superconducting disk was placed atop the compass, the needle continued to point north. However, the needle would move away from the disk when it was placed near the side of the compass. This phenomena is reminiscent of the behavior of the magnet suspended by a string above one edge of a superconducting disk.

As Jenny Lehmann's experiments nicely demonstrate, there is much more to superconductor experimenting than simply levitating a magnet. Another possibility would be to use a thermocouple to measure the temperature at which a superconductor disk crosses the superconducting threshold. Is the threshold sharp? That is, does a magnet floating above the superconductor gradually lose altitude or suddenly fall as the disk begins to warm?

The ability of a superconductor to repel a magnetic field provides several interesting areas to explore. One possibility is to examine the response of a superconductor to fluctuating magnetic fields produced by a small electromagnet.

You can make a small electromagnet by wrapping 100 or more turns of fine magnet wire around a steel pin. Alternatively, you can use the coil salvaged from a small magnetic earphone.

Figure 5 shows a 555 timer connected as a variable-rate pulse generator that applies brief pulses to a small electromagnet. The pulses can be speeded up by reducing the resistance of *R2* or the capacitance of *C1*.

Figure 5 also includes a suitable induction receiver that can be used to detect a fluctuating magnetic field by means of a similar small coil on the opposite side of a superconductor. Note that the 741 is powered by a dual-polarity supply. Be sure to keep the leads between the 741 and the batteries short. Also, keep the input portion separated from the output por-

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tion to avoid unwanted feedback. Use shielded cable to connect the coil to the amplifier unless the coil leads are only a few inches long.

If you prefer, the detection coil can be connected to a conventional audio amplifier through an impedance-matching transformer. Again, be sure to use a shielded cable.

Depending on the size and efficiency of your homemade electromagnet and pickup coil, you might be able to learn a great deal about the repulsion abilities of a superconductor.

An interesting variation of this experiment is to wrap the respective coils around opposite sides or ends of a superconductor bar or disk to see if the induction from one coil to another is altered when the superconductor becomes superconducting. If there is an effect, you should be able to measure a distinct change when the ceramic becomes superconductive. With the help of an oscilloscope or chart recorder, you should be able to determine the rate of the change.

Another experiment you might want to try is the effect of a superconductor on a small magnetic earphone driven by a tone generator or other audio source. Remove the phone's plastic cap and place the phone's metal diaphragm as close as possible to a superconducting disk cooled with liquid nitrogen. Does the repelling action of the superconductor reduce the movements of the diaphragm enough to reduce the volume of the sound generated by the phone? The magnet in the phone is much stronger than the phone's tiny electromagnet. Does its field swamp out any effects of the electromagnet?

I haven't yet tried any of these experiments, so I can't tell you what will happen. I'll leave that up to those of you who are curious enough to find out. If you do try any of these experiments or if you come up with other unusual superconductor experiments, please send me your findings. I'll describe the most interesting results in a future column.

Suppliers

You can purchase superconductors from several different suppliers. These materials typically become superconductors at around 95 degrees Kelvin, which is well above the temperature of liquid nitrogen.

Edmund Scientific (101 E. Gloucester Pike, Barrington, NJ 08007) sells a 1-inch-diameter superconductor disk for $17.50 (Cat. No. J37,446). Edmund also sells a demonstration kit that includes a superconductor disk, cobalt magnet and instructions for $36 (Cat. No. J38,169).

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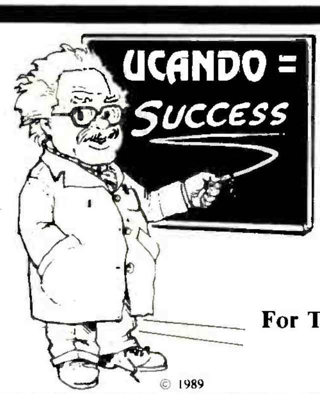

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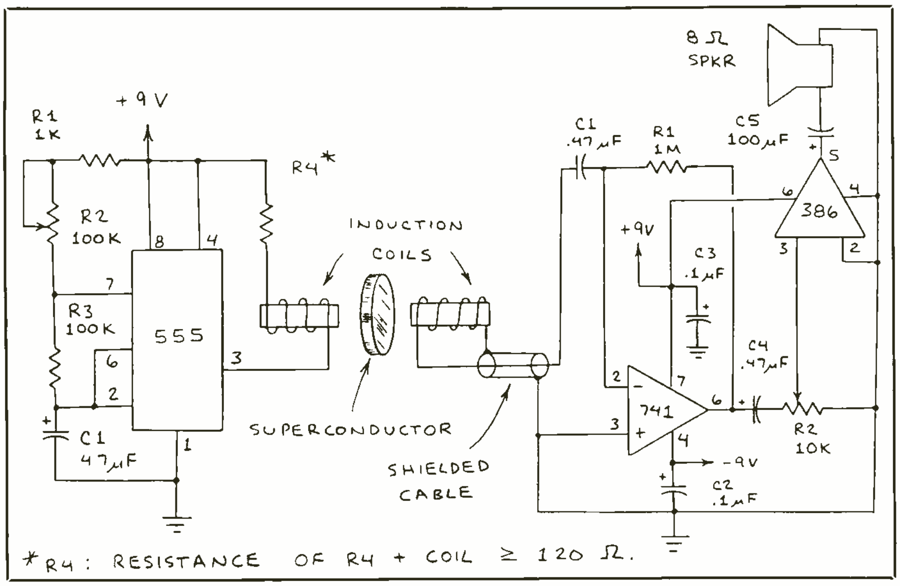

Fig. 5. Schematic diagram of a circuit you can use to investigate magnetic fields induced in a superconductor.

Van Ness Ave., Gardena, CA 90249; Tel. 213-323-3923) sells several different kinds of superconductor kits. A kit containing a coated, water-resistant superconductor disk and a cubical samarium-cobalt magnet sells for $29. A zero-resistance kit that comes with a thermocouple for measuring the zero-resistance point of a superconductive bar sells for $69. The company's most interesting kit is called a "Meissner Sandwich." It sells for $95 and includes nine miniature magnets and two superconductive disks. The sandwich is made by arranging the magnets into a rectangle, which is floated above one of the superconductor disks. The second superconductor disk is then lifted from liquid nitrogen and floated above the magnets! Orders for these kits should include $4.50 for shipping.

Incidentally, a representative from National Superconductor recently informed me the company plans to offer superconductors in various shapes and sizes. One experimental configuration is in the form of a ring. A current induced into the ring will flow even after the source of current is disconnected. Contact the company for additional information about these new products.

Large magnets will not float above a superconductor. Probably the best source for small, powerful magnets is Edmund Scientific. High quality samarium-cobalt magnets are used in better-quality magnetic earphones. You might be able to save $5 or more over the cost of an individual magnet by salvaging a pair of magnets from a pair of earphones. Be careful when salvaging them because samarium-cobalt magnets are brittle and may break in two.

Advertisements for additional suppliers of superconductors and magnets suitable for demonstrating the Meissner effect can sometimes be found in publications intended for secondary-school science teachers.

Safety Precautions

Certain ingredients of ceramic superconductors are toxic. Therefore, it is important to carefully observe any safety warnings that accompany a superconductor. This is especially important if you attempt to make your own superconductor or if you cut or break a superconducting pellet. Some manufacturers recommend that gloves be worn while handling superconductors. After handling a superconductor, under no circumstances should you touch your fingers to your face or eat without first washing your hands. Superconductors should be considered as toxic waste for disposal purposes.

Nitrogen, the principle component of air, is a colorless, non-toxic gas. The liquid form of nitrogen looks like ordinary water, but there the resemblance ends. At 77 degrees Kelvin (-196 degrees Celsius), liquid nitrogen can quickly cause frostbite on exposed skin. When it contacts anything warmer than itself, it vigorously boils, liberating large quantities of gaseous nitrogen. Therefore, *never* store liquid nitrogen in a sealed container.

Here are some safety precautions you should follow whenever you work with liquid nitrogen:

(1) Never place liquid nitrogen in a tightly closed container! If you do, the container will explode!

(2) Do not transport an open container of liquid nitrogen in a vehicle! Use a dewar specifically designed to hold cryogenic liquids.

(3) Wear eye protection when pouring liquid nitrogen.

(4) Liquid nitrogen boils violently when it is poured into a container at room temperature. Stand clear to avoid being splashed!

(5) If liquid nitrogen splashes onto your clothing, quickly grasp a dry section of fabric and pull the wet area away from your skin. The liquid will soon evaporate harmlessly from your clothing.

(6) Once again, *never* attempt to store liquid nitrogen in a tightly closed container!

Going Further

Many articles about ceramic superconductors have appeared in the popular press, trade magazines and in scientific journals. An excellent article on possible applications for ceramic superconductors appeared in the February 1989 issue of *Scientific American*. For additional information, visit a good library and check the periodicals section for publications beginning around March 1987. **ME**

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BOOKS

Treasure Hunters Buyers Guide. *Edited by Rosemary Anderson. (People's Publishing Co., Inc., 5440 Ericson Way, P.O. Box 1095, Arcata, CA 95521. Soft cover. 160 pages. $7.95.)*

This "buyers guide" to metal detector/locators and accessories includes many items just recently introduced. The majority of its pages give extensive listings of land and underwater metal-detectors. Two sets of listings are provided for each category. One is an alphabetical listing that uses text and photos to describe the products; the other a series of tables, arranged in ascending price order, that detail technical specifications and give instant comparisons for competing detectors in specific price ranges.

This book is a virtual one-step reference on currently available metal detectors ranging from a $20 beachcomber model to professional models selling for more than $1,000. Every major manufacturer and supplier is represented, and most have their entire lines included in the listings.

Several other chapters are included, one of which details how to choose the best metal detector, and another of which separates detectors by operating modes. Yet a third chapter, titled "Shop Talk," contains essays written by engineers who are designing the detectors of tomorrow. Following this is a list of manufacturers and almost 20 pages of ads from them.

A "Treasure Locators" chapter lists "big guns" in the field like ultra-sensitive and long-range devices that can cost as much as $4,000 and more. No buyers guide would be complete without a listing of accessory items, and this has an extensive one that lists probes, trowels, knives, water and sand scoops, wet and dry suits, a whole range of underwater electronic devices, and just about anything else a land or underwater treasure hunter might consider to be essential to his pursuit, including guides and booklets. The glossary at the end of the book makes an appropriate finale to a well-rounded treaure hunter's book/buyers guide.

NEW LITERATURE

Remote Controls Catalog. Thomson Consumer Electronics has a new 1990 edition of the RCA and GE Remote Controls Catalog, which lists all available direct-replacement remote-control hand units for RCA and GE TV receivers, VCRs, video-disc players, camcorders and audio components. Divided into three sections, the catalog devotes one part to photos (more than 220 in all) of each remote to aid in identifying the correct unit. The two remaining sections contain cross-references in model number and type number sequences. For a copy of the Stock No. 1F5790 catalog, write to: Service Dealer Merchandising, Thomson Consumer Electronics, Distributor & Special Products, 2000 Clements Bridge Rd., Deptford, NJ 08096-2088.

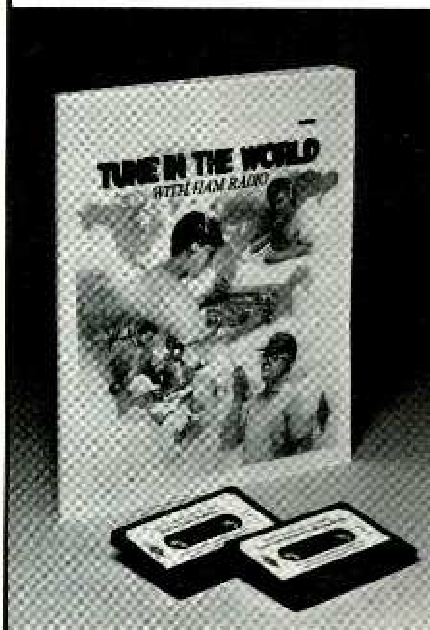
Privacy Devices Catalog. People who are interested in protecting their privacy will be interested in a new catalog from Capri Electronics Corp. This 20-page catalog describes a variety of transmitter "bug," video camera, carrier-current/subcarrier and wiretap detectors. A sophisticated countermeasures system designed to detect a variety of "bugging" devices ranging from r-f to infrared to audio is listed, as are a wiretap detector and an audio jammer. Write to: Capri Electronics Corp., 1238 Hwy. 160-B, P.O. Box 589, Dept. ME, Bayfield, CO 81122.

Full Product-Line Catalog. The 1990 JDR Microdevices catalog contains 100 pages packed with thousands of listings for computers and computer kits and accessories, software, discrete components, and test instruments and accessories. Highlighted are such items as a mini 386 motherboards, an 80386SX motherboard, high-density hard drives and controllers, laptop computers, and much more. Each item is fully described, including price, and many are accompanied by a color photo. For a free copy, write to: JDR Microdevices, 2233 Branham Lane., San Jose, CA 95124.

Electronics Courses Catalog. The Heath Company's new "HomeWorks by Heathkit" catalog lists and fully describes the company's full line of learn-at-home electronics courses. It features courses on robotics theory, digital processing, basic and advanced electronics, amateur radio operation and much more. A variety of Heathkit trainers and accessories, available in both kit and factory-wired versions, used in performing course experiments are highlighted throughout the full-color, 36-page catalog. For a free copy, write to: Heath Co., Dept. 350-048(ME), Benton Harbor, MI 49022.

HAM RADIO IS FUN!

It's even more fun for beginners now that they can operate voice and link computers just as soon as they obtain their Novice class license. You can talk to hams all over the world when conditions permit, then switch to a repeater for local coverage, perhaps using a transceiver in your car or handheld unit.



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JFET-Input Op Amps

By Joseph Desposito

JFET-input operational amplifiers provide an economical means of achieving high accuracy in applications that require wide bandwidths for large signals. They are ideal for pulse amplifiers, fast D/A converters, peak detectors, and logarithmic amplifiers.

These devices are an option for designers who require speeds greater than those provided by standard bipolar op amps. The high slew rates of JFET-input amplifiers make these devices attractive for pulse amplification and other applications that require wide bandwidths and handle large signals. Their low bias currents make them equally suitable for peak detectors and logarithmic amplifiers. Furthermore, their fast settling rates make them ideal for fast, high-precision digital-to-analog converters.

The offset voltage of many older JFET amplifiers displayed large thermal drifts. However, newer state-of-the-art precision JFET-input amplifiers exhibit relatively little drift with temperature, and the resulting output error is generally insignificant, unless you operate the amplifier at a high gain level. If your application requires minimum possible offset error, however, you can use a servo loop that automatically corrects offset-voltage and drift errors.

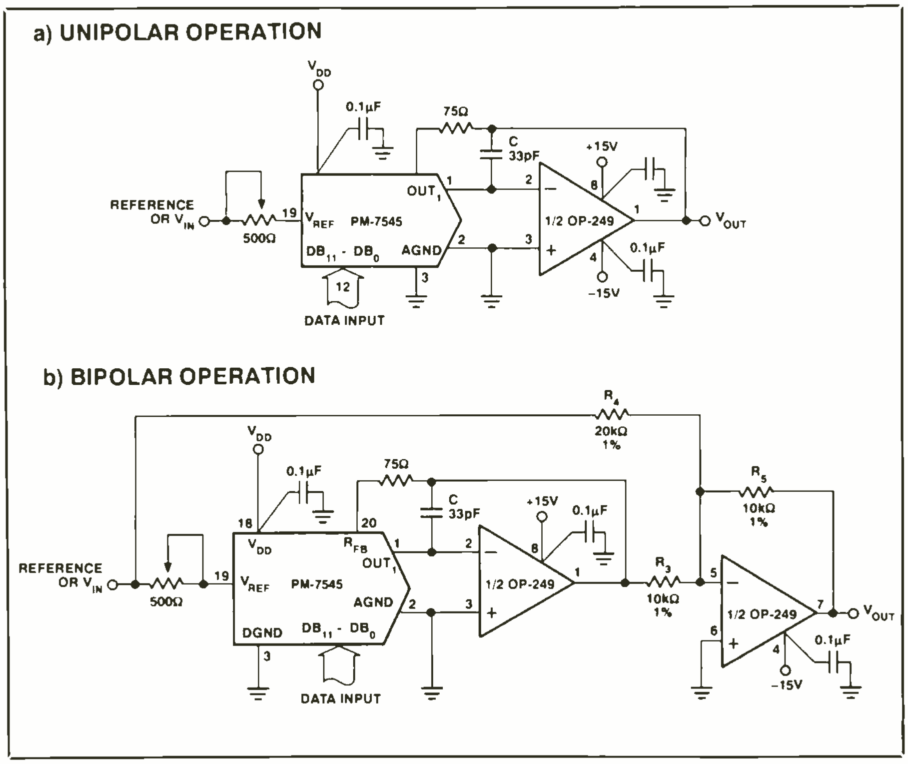

Fig. 1. Fast settling and low offset error of the PMI OP-249 JFET-input operational amplifier enhances CMOS DAC performance.

PMI OP-249

Precision Monolithics, Inc. (PMI) recently announced availability of its OP-249, a dual high-speed JFET precision op amp that features fast settling time, high slew rate and low distortion. Low offset voltage and extremely high open-loop gain make the OP-249 a true dc precision JFET op amp.

Featuring an offset of only 300 µV maximum, and low offset drift performance (0.5 µV/°C), the OP-249 can enhance the performance of CMOS D/A converters and dc precision circuits. Moreover, PMI guarantees a maximum offset voltage for the life of the device.

With a settling time of 1.2 µs maximum, a slew rate of 22 V/µs, and a gain-bandwidth product of 4.7 MHz typical, the OP-249 meets requirements for high-speed signal conditioning, servo controllers, fast D/A and A/D converters, active filters and sample/holds.

The device provides a large-signal response into a 600-ohm load. Combined with its high slew rate and a low distortion of only 0.002% typical, the OP-249 is a fine amplifier for audio applications such as preamplifiers, signal conditioning and output amplifiers for dual D/A compact disk players.

The OP-249 is available in eight-pin cerDIP, plastic DIP and TO-99 metal can. The 100-piece price for the plastic OP-249 covering the extended industrial temperature range (−40°C to +85°C) is $1.25. Prices for the cerDIP and TO-99 versions begin at $3.95 each, with the military grades (−55°C to +125°C) starting at $8.75 each.

OP-249 Application

Unity-gain stability, a low offset voltage of 300 µV typical, and a fast settling time of 870 ns to 0.01%, makes the OP-249 an ideal amplifier for fast digital-to-analog converters.

For CMOS DAC applications, the low offset voltage of the OP-249 results in excellent linearity performance. CMOS DACs will typically have a code-dependent output resistance variation between 11 kilohms and 33 kilohms. The change in output resistance, in conjunction with an 11-kilohm feedback resistor, will result in a noise gain change. This causes variations in the offset error, increasing linearity errors. The OP-249 features low offset voltage error, minimizing this ef-

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fect and maintaining 12-bit linearity performance over the full-scale range of the converter.

Since the DAC's output capacitance appears at the operational amplifier's inputs, it is essential that the amplifier is adequately compensated. Compensation increases the phase margin and ensures an optimal overall settling response. Required lead compensation is achieved with capacitor *C* in Fig. 1.

Circuit Layout Guidelines

To obtain the full performance that JFET-input amplifies are capable of, all the standard precautions in designing and laying out pc boards should be taken, along with a few extra precautions that are specific to JFET-input devices. The design principles that follow are critical for the performance of any high-speed amplifier.

- Always use separate supply traces and grounds for each amplifier.
- Bypass each supply, right at each amplifier with a 1- to 10-μF tantalum or electrolytic capacitor connected in parallel with a glass or ceramic capacitor that has a value of 0.01 to 1 μF.
- Provide separate supply lines and ground lines for the digital and analog sections of the system.
- Switching power supplies can inject spikes of several hundred millivolts into the supply lines, and they can radiate emi. Therefore, the analog sections should be shielded and all supply lines should be bypassed at the point where they enter the shielded enclosure.

Be careful not to exceed an amplifier's maximum input-voltage specification. If a signal could be applied before the amplifier's supplies reach their full values, provide clamping diodes—but remember that these devices add leakage and capacitance to the circuit.

Be careful not to exceed the maximum junction temperature or the maximum power dissipation ratings of an amplifier. If a capacitive load is connected to the output of an op amp, include the power dissipation caused by the rms ac currents delivered to the load in calculations. Internal power dissipation raises an IC junction temperature. The amount of increase can be found by multiplying power dissipation by the thermal resistance of the package. Junction temperature is the ambient temperature plus the increase in temperature.

Remember that the slew rate of an op amp varies according to the voltage difference between its two inputs. To achieve the maximum slew rate specified in the data sheet, ensure a difference of about 2 V between inputs of a JFET-input op amp so that one side of the op amp's differential-input circuit turns completely off. At unity gain, such voltages are normal, but in circuits that have a higher gain, the input-voltage levels—and, hence, the slew rate—decrease. A JFET-input op amp that yields a slew rate of 60 V/μs at unity gain might yield only 20 V/μs if operated at a gain of 100 with a ± 100 mV input signal.

Keep in mind, too, that an amplifier that has a high slew rate or a wide bandwidth doesn't necessarily settle fast. Many amplifiers with high slew rates obtain their speed at the cost of inducing excessive ringing in the output waveform. This ringing increases settling time. Also keep in mind that the ac characteristics of some amplifier types vary widely from part to part. Data sheets usually specify a typical settling time. Very few vendors guarantee a maximum value.

Most JFET-input op amps have input capacitances from 4 to 8 pF. A small capacitor placed across the feedback resistor compensates for the pole created by the input capacitance. The amount of compensation needed depends on the performance expected from the amplifier. Critical damping may give the fastest settling times to within very narrow error bands. In general, however, the settling time will improve, even to error bands as small as 0.01%, if compensation that yields slight under-damping is provided.

Optimum compensation is a function of the circuit and its layout, and its value is usually determined by experiment. Proper compensation becomes critical when an op amp is used to convert the current output of a DAC to a voltage output. The output capacitance of the DAC, in parallel with stray capacitance and the input capacitance of the op amp, exacerbates any ringing and instability problems and the compensation should be optimized for the desired combination of settling speed and accuracy.

A Monolithic Elliptic Notch Filter

National Semiconductor has announced a fourth-order elliptic-notch filter, designed for the rejection of power-line interference in electronic systems. It can also be used for communications systems and automotive test equipment.

The LMF90 is a switched-capacitor notch filter that requires no external components when used with an external clock. Notch depth, notch width, and clock-to-center frequency ratio are all pin-selectable.

The notch frequency range of the LMF90 is 0.1 Hz to 30 kHz. The device features a low offset voltage of 120 mV and high-center frequency accuracy of ± 1.5% over temperature.

The LMF90 includes a clock oscillator requiring an external crystal. With a low-cost color TV crystal and using the internal clock-frequency divider, the LMF90 can provide notch frequencies of 50, 60, 100, 120, 150 and 180 Hz for line-interference noise rejection. The ratio of clock frequency to notch frequency is pin-programmable to 100:1, 50:1 or 33.33:1. Notch depth is selectable at − 30 dB minimum or − 36.5 dB minimum.

The operating voltage range of an LMF90 ranges from + 4 to + 15 V, or from ± 2 to ± 7.5 V. Required supply current is only 5 mA (maximum) at ± 5 V.

The LMF90, offered in the commercial temperature range (0°C to 70°C), is available in a 14-pin plastic DIP as the LMF-90CCN. It is priced at $3.10 each in 100-unit quantities. **ME**

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ELECTRONICS OMNIBUS

Citizens Band Radio Update

By Curt Phillips

Several friends of mine were extremely surprised recently when they discovered that I was installing a Citizens Band radio in my car. The way they saw it, by doing this I was rejecting ham radio (the hobby I have for so long touted) for its "arch-rival," CB radio.

I don't feel that way at all. I don't have to reject ham radio to appreciate the areas where CB radio has an advantage. Anyway, the reputed "feud" between CB and ham radio is more fiction than fact, and most of the fact derives from the Citizen Band's previous allocation as the 11-meter ham band. This reallocation took place in the late 1950s, however, and most of the hams who were really upset about it have long since departed to the great ham shack in the sky.

For me, my introduction to amateur radio was a result of my introduction to Citizens Band radio. In 1964, during a mini-boom in the CB world that would be dwarfed about a decade later, my father purchased a couple of CB sets for use in his small business. This was the purpose for which CB was created, to provide short-range communications for home and business uses. Even back then, the people using CB for quasi-ham hobby-type communications made it only marginally suitable for business, as we quickly discovered.

Nevertheless, using CB radio as a hobby was as attractive as using it for business, so a succession of rigs made by Lafayette Radio Electronics (the old Comsat series), E.F. Johnson and Hallicrafters passed through our operating position. As I approached my teen years, I learned of a radio service that allowed more power (legally), more frequencies and a broader range of activities; so I sought out some people who taught me what I needed to qualify, getting my ham license at 13 years old.

Still, I remember my introduction to two-way radio fondly and certainly harbor no ill towards the Citizens Band. Indeed, my recent acquisition of a CB rig is due to an appreciation of one of its unique strengths.

G-E Model 3-5909 40-channel emergency/information two-way CB transceiver with magnetic-mount, collapsible antenna.

CB Strength

The strength of CB radio lies in numbers. Although the number of CB operators is down from its heyday in the middle 1970s, when First Lady Betty Ford was on the band with the handle "First Mama" and CB-oriented songs and movies were being released by the dozen, there remains a large residual installed base of CB units.

Of late, I have had to do a lot of traveling by automobile. While chatting on the vhf ham repeaters is nice, the chance of a ham operator sitting in front of me in a traffic jam is slim. In contrast, many normally active CBers turn on their rigs when stopped in traffic and there is quite often one of them up ahead with whom I can commiserate and exchange information.

Weather and traffic reports from up ahead are useful even when the traffic is moving, and again, at any given moment I'm more likely to contact a CBer who has traveled where I'm going than a similarly situated ham operator. CB's much-lamented shortcoming (low power) is of little hindrance in this task. Usually, I only need to talk to someone a few miles or so ahead of me. With my CB antenna on the back of my car (so I won't interfere with my 2-meter antenna in the hallowed location in the middle of the car roof!), my radiation pattern is strongest in the front. Also, someone a short distance away going in the opposite direction can often supply the needed information.

Ham radio has served me well for summoning help when I've had car trouble, but a CB radio works well for this also. Since there are no license requirements, I recommend purchase of a CB unit to non-technically-inclined family and friends as justified for this purpose alone. A cellular phone can serve this purpose as well, but a CB radio is much less expensive. Furthermore, cellular phone operators must dial a specific phone number, rather than call for help shotgun style to whomever is listening within a few miles around.

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Since some people can't appreciate the beauty of an antenna on the trunk and a radio hung under the dashboard, several manufacturers offer "emergency CB radios." These units provide a protective case containing a CB radio with cigarette-lighter plug and a magnetic-mount antenna. When trouble strikes, one needs merely retrieve the radio from the trunk, glove compartment or under the seat, plug it into the cigarette-lighter socket on the dashboard, and the set is ready to operate. Even the most rabid two-way radio hater will be glad to have one of these units on hand if his car breaks down on a rural road late at night.

Score One for Smokey

The much-heralded ability of a CB radio to keep you informed as to the locations of all the State Patrolmen has dropped dramatically. During a middle-70s road trip from Raleigh to St. Louis with some fraternity brothers, our CB radio faithfully kept us apprised of all the speed traps en route, including a radar set-up in Indiana we were warned about that was located over 100 miles away.

On a more recent Raleigh-to-Memphis excursion, the CB airwaves seldom reported speed traps before I could visually spot them, if at all. If you want protection from speed traps, a radar detector is far superior to a CB (and, naturally, stick to the speed limit).

Perhaps one reason for this phenomenon is the lower profile of truckers on CB today. Certainly, there are still truckers on the CB bands. On my Memphis trip, I learned a lot about truckers' preference in food and women and the panoramic vistas they view from their high-rise driving perches, but there still aren't as many truckers to be found as in the "good old days." Some of this may be due to the truthfulness of a rumor that many truckers have begun to use marine-band vhf-FM rigs for their personal communications (not an FCC-approved use!).

Table I. CB Channel Frequencies

Channel	Frequency*	Channel	Frequency*
1	26.965	21	27.215
2	26.975	22	27.225
3	26.985	23	27.255
4	27.005	24	27.235
5	27.015	25	27.245
6	27.025	26	27.265
7	27.035	27	27.275
8	27.055	28	27.285
9	27.065	29	27.295
10	27.075	30	27.305
11	27.085	31	27.315
12	27.105	32	27.325
13	27.115	33	27.335
14	27.125	34	27.345
15	27.135	35	27.355
16	27.155	36	27.365
17	27.165	37	27.375
18	27.175	38	27.385
19	27.185	39	27.395
20	27.201	40	27.405

*All frequencies are in MHz.

CB Today

The official Citizens Band consists of 40 channels today, increased from the original 23 during the mid-70s boom. Channel 9 is the emergency channel and is often monitored by police and volunteer assistance clubs. Maximum legal power is 4 watts at 100-percent modulation, but most radios you buy off the shelf don't go quite that high because the manufacturers give themselves a safety margin to stay out of trouble with the FCC.

There are a lot of good CB transceivers available, if not as many brands as in the mid-Seventies. Back then, it seemed that everyone in the Orient with a garage and a soldering iron was cranking out CB sets. But evidently most of them have converted to manufacturing PC clones now. The brands that dominate nowadays are Midland, Cobra, Uniden and, of course, Radio Shack. Fordham Radio (260 Motor Parkway, Hauppauge, NY 11788) and Scanner World (10 New Scotland Ave., Albany, NY 12208) sell Midland and Cobra brand radios with prices starting below $40 for a dc-powered unit. These are usually called "mobile" radios. but they work fine as base units if you have a good dc source to power them.

In searching for a CB radio, don't forget hamfests and yard sales. The General Electric Weather Alert CB rig I have in my car includes reception ability for the NOAA weather broadcasts (outside the CB band), both a noise blanker and automatic noise limiter, instant access to Channel 9, and was considered hot stuff at its retail price of about $100 a little over a year ago. I purchased mine used at a hamfest for $20.

The best antenna for the money is the simple quarter-wave whip. The catch is that a quarter-wave whip for the CB frequencies is 9 feet long. Ideally, you'd like to mount it as high on your car as possible, but such antennas usually end up mounted on the bumper. Radio Shack sells these whips on the page with the accessories, not the antennas.

If you must use a shorter antenna, go for one of the base-loaded units (the load-

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ing coil is at the base); the antennas that are center loaded are the least efficient and are only slightly better than the legendary "wet noodle." Avoid magnet-mount antennas in a permanent installation if you can. In automobile configurations, you are depending on the car body to provide the "ground plane," and a direct mount increases the efficiency of the ground plane. Remember, with only 4 watts out (usually less), you need to retain all the efficiency you can. One good rule-of-thumb to keep in mind is that for CB, the shorter the antenna, the less efficient is its communication ability.

Don't fall for the "twin trucker" antenna trap. This is a pair of antennas usually seen mounted on truckers' mirrors. Two phased verticals can provide a gain (increase in effective radiated power), but they need to he one-half wavelength apart to work best. One-half wave at CB frequencies is 18 feet; your car isn't that wide. Under 9 feet apart, two antennas configured this way can actually begin to cancel each other out and *decrease* the effective radiated power, as compared to one antenna alone.

Single Sideband

A subset of the CB world is single-sideband operation. Single sideband, or SSB, is a more-effective transmitting mode that can extend effective communications range by 25 to 50 percent; it's incompatible with standard AM, though. By tradition, SSB operations are generally restricted to Channels 32 through 40. Prices of CB transceivers with SSB capability start at about $160 and range to well beyond $400.

Those people who are willing to pay to join this exclusive part of the CB hobby will find operations that are more like that on the ham bands. Since I don't have a CB set that operates on SSB, I've monitored them on my shortwave receiver (see Frequency List, Table I) and found them to be quite different than the other CB channels. Conversations were at a more serious level, without the "Good Buddy" and "Negatory" type of good-ole-boy posturing that is commonly heard on the lower CB channels.

With the recent sunspot activity enhancing 11-meter propagation, I heard stations from several western states booming in here on the east coast. With the sunspots, this is possible even if they are only running legal power, but it is illegal for CBers to make these types of contacts, even if they are achievable using legal equipment. Of course, these transcontinental contacts were being made anyway, because illegality has never put much of a damper on CB operations. In general, however, there seems to be more respect for proper and legal operations on the SSB channels than there is on the CB band at large.

Since there are no officially assigned callsigns for CBers now, and the sidebanders don't like to use "handles" as the AMers do, they tend to use identification numbers provided by sideband-oriented organizations. One of the more established of these groups is the SSB Net-

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work (P.O. Box 908, Smithtown, NY 11787), which issues numbers beginning with "SSB."

The Dark Side

Besides the coarse and intentionally cornpone operating procedures that are common on the CB channels, there is a dark side. With no FCC licensing procedure, anyone can become a CBer, and there is no license that can be revoked. This relatively unregulated atmosphere yields a forum for individuals to engage in what can best be described as verbal exhibitionism. This can manifest itself simply as profanity or worse.

Promoting this activity is the fact that the CB band is sometimes used as an avenue for solicitation by "Pavement Princesses," mobile practitioners of the world's oldest profession. When encountering this type of activity, it is best to simply change the channel or turn off your rig and ignore it.

Power to the People

For some, the legal 4-watt limit isn't enough transmitting power, and getting a ham license is too much work. Some of these people simply choose to operate on the CB bands with 100, 200 and even 1,000 watts. As a result, ham amplifiers that included 10 meters were so easy to use on the CB bands that the FCC now prohibits sale of new amplifiers that operate on 10 meters. Ham operators may legally modify them to operate on 10 meters, but they can't come from the factory that way. Illegal high-power operation is one area where the FCC still pays attention to the CB bands.

Several Japanese ham transceivers used to be available that would operate on 11 meters without modification at 100 to 200 watts and were widely used by illegal CBers. These ham rigs weren't channelized and could operate over a range of frequencies beyond the official CB allocations. So a group of CB renegades started operating between the bands. Known as hfers, they operate both below and above the CB band, generally from 26.515 to 27.855 MHz. Operation below the CB channels is generally in AM, and that above is usually SSB. *All* of this out-of-band operation is illegal. If the operators are caught, they will never be able to obtain an FCC license of any type. The FCC has a long memory.

REACT

Many CBers want to improve the image of CB radio, hone their communications skills and use their radio equipment for public service. An organization catering to such people is REACT International, which is the largest and oldest organization of Citizens Band operators.

Although REACT (an acronym for Radio Emergency Associated Communications Teams) isn't exclusively limited to CBers (14 percent are ham operators), the vast majority of its membership and operations utilize CB radio. Most of the non-law-enforcement organizations that monitor Channel 9 are REACT affiliates. If you drop them a card, REACT (242 Cleveland, Wichita, KS 67214) will send you a brochure and information on local REACT clubs (teams) in your area. If you send a self-addressed, stamped No. 10 envelope, REACT will send you even more information.

If you are interested in regular information on CB radio, REACT International publishes a bi-monthly magazine, *The REACTer*, and our sister publication, *Popular Communications* (76 North Broadway, Hicksville, NY 11801) carries a monthly column on CB radio.

When its strengths and limitations are taken into consideration, CB radio can make a worthwhile contribution to the total communications capability of anyone, even a long-time hard-core ham like me. Should you decide to pursue two-way communications via the CB route, don't let its unlicensed nature cause you to become careless or lazy in your operating habits. *Because* of its unlicensed and loosely regulated nature, CB has all the more need for operators to practice and support disciplined procedures.

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

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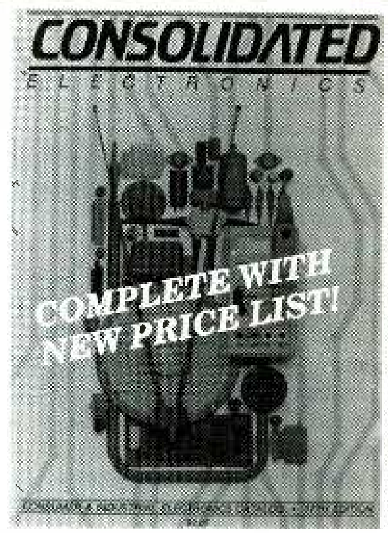

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Hands-On Look at the Hewlett-Packard LaserJet IIP

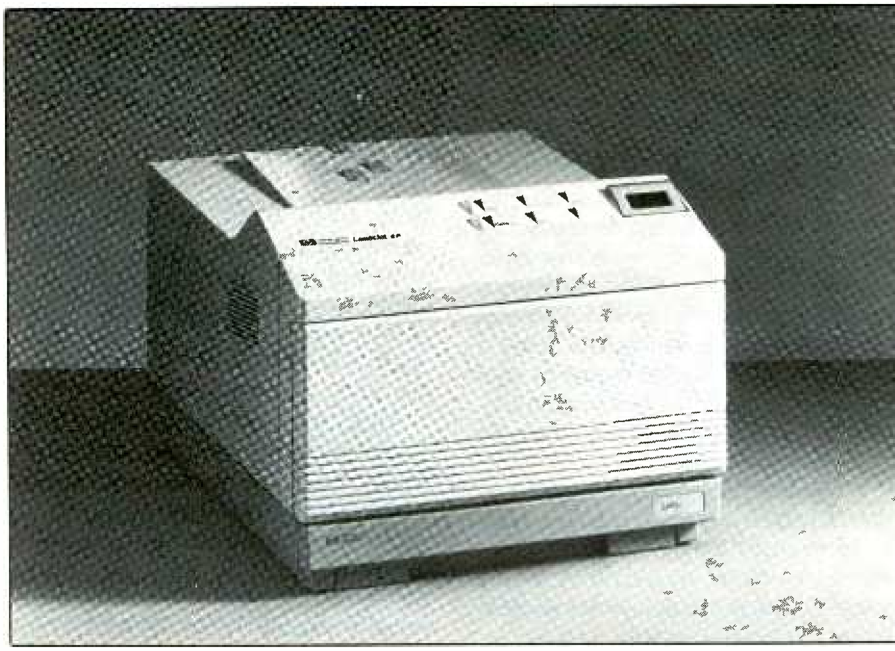
By Ted Needleman

Previous columns occasionally discussed some standards that evolved in the computer market. We've talked about operating systems, bus standards and video resolution. The way that these standards are set is an interesting process. With most of the above standards, you don't have to be first, or even best, you just have to sell the greatest numbers of your product. If you do, then your product becomes the *de facto* standard.

The same process is true in the market for peripherals, such as printers. The vast numbers of Epson printers sold in the late Seventies and early Eighties made Epson's command set the standard for dot-matrix printers. Application software was written to expect an Epson printer, or one that could emulate Epson's command set. If your printer did not offer this emulation, you may have had to forego many of the printing features your printer did offer.

The same process took place in the laser printer marketplace. When Hewlett-Packard introduced the LaserJet in 1983, it was not the first laser printer, just the first affordable one for many people. Big corporations had been using laser printers, made by vendors such as Xerox, IBM, and Kodak, for years. Printers such as the Xerox 2700, one of the least-expensive laser printers available before the LaserJet, churned out in excess of 20 pages per minute, cost well in excess of $20,000 and were difficult to program and use (especially in comparison to today's laser printers).

When H-P introduced its first LaserJet in 1983, and Apple its LaserWriter in 1984, they were amazing products. For the first time, microcomputer users could get fast, quiet, and near-typeset-quality output for little more cost than a good reasonable-quality daisywheel printer. The LaserJet and LaserWriter were instant hits, and made instant standards of their respective command and control languages. For the H-P, this was PCL (Printer Control Language), which, while it has undergone updates, has remained essentially the same over the last seven years.



Hewlett-Packard's LaserJet IIP personal laser printer.

Much of the credit, though, for both Hewlett-Packard's and Apple's success must go to a third company—Canon—for producing the CX laser engine on which both of these pioneering printers are built. The CX engine was an evolution of another popular Canon product, its PC line of personal copiers. Introduced several years earlier, the PC-10 and PC-20 copiers were inexpensive and compact and pioneered the use of a disposable cartridge that contained the drum, developer and toner. Given the similarities between photocopiers and laser printers, Canon took the basic PC copier mechanicals, eliminated the moving platen and most of the optics, enlarged the disposable cartridge to accommodate more toner, added a laser, scanning mirror and basic controller electronics, and the CX engine was born.

Other manufacturers have gotten into the laser-engine business over the years. Companies such as Ricoh, TEC, Kyocera and others have supplied thousands of laser engines to the burgeoning laser-printer market. Hewlett-Packard, however, has stuck with Canon, introducing a new printer with every refinement of the Canon engine. The 20-page-per-minute LaserJet 2000 is based on a Canon engine, as is the current Series II (based on the SX laser engine). Canon recently introduced a 4-ppm engine (and its own 4-ppm printer) and, not surprisingly, so did H-P—the LaserJet IIP.

The LaserJet IIP

Nominally rated at half the output speed of its popular Series II, the Hewlett-Packard LaserJet IIP retains almost all of the features of the faster printer (other than speed), while costing about $1,000 less (at list prices). With a list price of $1,495, and a street price of under $1,000, the IIP is one of the least-expensive laser printers you can buy. It is also one of the smallest and lightest laser printers you can buy, measuring a compact 14″W by 16″D by 8.25″H and weighing only 22 pounds.

As small as it is, the IIP delivers performance and features far beyond what it's price tag might lead you to expect. In some cases, the printer delivers even more than the much more expensive Series II. For example, the IIP offers more built-in

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fonts, 14 to the Series II's 6. These include the same portrait and landscape Courier 10-pitch 12-point and Line Printer 16.6 condensed fonts, as well as an additional Courier font in 12-pitch 10-point. This last font is similar in size to the Elite font often found on typewriters.

The IIP is able to use both cartridge and downloaded softfonts, just like the Series II and, in fact, can use standard H-P LaserJet font cartridges. It does not, however, need separate landscape fonts. The printer can rotate and scale a portrait font into landscape mode. This means that the IIP specific font cartridges that were made available by H-P when the printer was introduced contain extra portrait fonts instead of those not-needed landscape fonts, giving you more for your money.

Hewlett-Packard's newest printer is also no slouch in the paper-handling area, either. It can handle paper from 16- to 28-pound stock, laser labels and laser transparency material—anything other laser printers can use. Its built-in paper tray, which folds down from the from panel of the printer, can handle up to 50 sheets of letter, legal, A4 or executive-size paper. This tray can also be used to feed envelopes. There is also an optional paper tray that holds 250 sheets of paper, or with an optional envelope tray, it can handle up to 20 envelopes.

Paper handling is further enhanced by the IIP's ability to output face down (in correct order) to a 50-sheet output tray on the top of the printer, or face up through the back of the printer to a tray with a 20-sheet capacity.

The LaserJet IIP comes with 512K of RAM, the same amount as the Series II. This is enough memory to print up to ½ page of 300-dpi graphics or use several downloaded softfonts. If your application requires more memory, it's easy to add. The printer has optional 1MB and 2MB memory expansion cards and will accept up to 4MB of memory, enough for just about any task.

Hewlett-Packard's printer uses the same PCL language that the other LaserJets do; so it is compatible with any application that has a Series II printer driver. In addition, if you're doing CAD or circuit-board layouts, third-party software, such as Insight Development's "LaserPlot," give the IIP (and other H-P-compatible printers) the ability to emulate an H-P plotter.

LaserJets have always been easy to set up, and the IIP is no exception. It uses an EP-L cartridge that's slightly smaller than the CX and SX cartridges, but it still contains the toner, developer and photoconductive drum. Costing a bit less at $95 than those for the Series II and earlier lasers, you just throw them away (or have them refilled) when you use them up, and pop in a new cartridge. This makes setup a snap—just remove the shipping restraints, pop in the cartridge, plug in the power and interface cables and print.

The IIP has both parallel and serial interfaces. I had the IIP printing within minutes after receiving the printer; in fact, it takes almost as long to write about as to do. Front-panel buttons let you choose fonts, orientations, interface, and when the optional Epson/IBM and PostScript emulation cartridges become available later this year, you will also be able to choose an emulation from the front panel.

Of course, for $1,000 less than the standard Series II, you have to expect to make some compromises. The IIP has only a single font cartridge slot (the Series II has two) and its rated speed is only half that of the bigger printer. Performing some informal tests, though, revealed that the IIP prints pretty close to its rated speed. This is unusual in the printer industry, where it is common to find grossly inflated speed claims.

Like the original LaserJet, Hewlett-Packard's LaserJet IIP is a landmark printer in several respects. Its street price of less than a thousand dollars puts it in the range of many 24-pin dot-matrix printers, making it an affordable purchase for many serious computer users who have been just waiting for an excuse to run out and buy a laser printer.

Given the history of the laser printer market, I'd expect to see this price fall even further given the pressures of competition. Epson has already lowered the price on its EPL-6000, a 6-ppm laser based on the TEC engine to match H-P's $1,499 list. By the end of the year, it wouldn't surprise me to see laser printers available for less than $900, which is about what my original Epson MX-80 dot-matrix printer cost in 1978. It also goes a long way in defining what a personal page printer will be like in the '90s (the "P" in IIP stands for "Personal"); a small, lightweight, quiet, fast, and affordable laser printer. I think H-P has another winner with this one. **ME**

Manufacturer Mentioned

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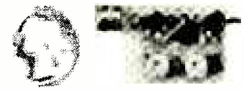

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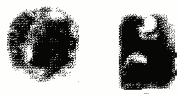

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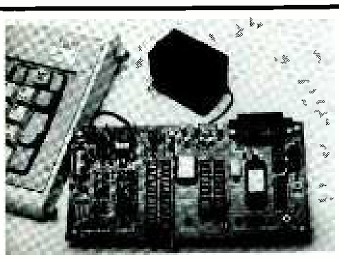

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74C932N	1.23
74C941N	1.98
74C945N	11.25
74C947N	11.25

Part	Price
80C95N	.55
80C96N	.55
80C98N	.55
82C19N	3.98

74HC00 CMOS

Part	Price
74HC00N	.28
74HC02N	.28
74HC04N	.28
74HC08N	.28
74HC10N	.28
74HC11N	.28
74HC14N	.39
74HC20N	.28
74HC27N	.28
74HC30N	.28
74HC32N	.28
74HC42N	.72
74HC73N	.39
74HC74N	.36
74HC75N	.39
74HC76N	.50
74HC85N	.85
74HC86N	.45
74HC107N	.53
74HC112N	.53
74HC113N	.53
74HC123N	.98
74HC125N	.48
74HC126N	.53
74HC133N	.38
74HC138N	.45
74HC139N	.45
74HC147N	.73
74HC151N	.55
74HC153N	.55
74HC154N	1.13
74HC157N	.63
74HC158N	.63
74HC160N	.88
74HC161N	.63
74HC162N	.63
74HC163N	.63
74HC164N	.63
74HC165N	.63
74HC166N	.63
74HC174N	.58
74HC175N	.58
74HC190N	.78
74HC191N	.78
74HC192N	.78
74HC193N	.78
74HC194N	.78
74HC195N	.78
74HC221N	1.10
74HC237N	.78
74HC240N	.75
74HC241N	.75
74HC242N	.78
74HC243N	.75
74HC244N	.75
74HC245N	.82
74HC251N	.80
74HC253N	.65
74HC257N	.65
74HC259N	.75
74HC266AN	.38
74HC280N	.90
74HC299N	1.35
74HC354N	1.10
74HC356N	1.10
74HC365N	.78
74HC366N	.78
74HC367N	.78
74HC368N	.78
74HC373N	.75
74HC374N	.75
74HC390N	.70
74HC393N	.70
74HC533N	.98
74HC534N	.98
74HC564N	1.53
74HC574N	1.10
74HC640N	1.75
74HC643N	1.75
74HC688N	.88
74HC4002N	.28
74HC4017N	.93
74HC4020N	.93
74HC4040N	.93
74HC4049N	.70
74HC4050N	.70
74HC4060N	1.10
74HC4075N	.28
74HC4078N	.30
74HC4306	1.64
74HC4514N	1.50
74HC4538N	1.05
74HC4543N	1.37

4000 CMOS

Part	Price
4001BCN	.27
4002BCN	.40
4006BCN	.63
4007CN	.28
4008BCN	.65
4009CN	.35
4010CN	.38
4011BCN	.28
4012BCN	.28
4013BCN	.38
4014BCN	.70
4015BCN	.70
4016BCN	.35
4017BCN	.60
4018BCN	.70
4019BCN	.35
4020BCN	.60
4021BCN	.60
4022BCN	.75
4023BCN	.28
4024BCN	.50
4025BCN	.28
4027BCN	.50
4028BCN	.55
4029BCN	.75
4030CN	.40
4031B	.83
4032BCN	1.13
4035BCN	.75
4040BCN	.60
4041CN	.63
4042BCN	.63
4043BCN	.63
4044BCN	.63
4046BCN	.65
4047BCN	.75
4048BCN	.33
4049CN	.33
4050BCN	.33
4051BCN	.55
4052BCN	.55
4053BCN	.55
4060BCN	.58
4066BCN	.33
4069BCN	.28
4070BCN	.28
4071BCN	.28
4072BCN	.28
4073BCN	.28
4075BCN	.28
4076BCN	.55
4077BCN	.28
4078BCN	.28
4081BCN	.28
4082BCN	.28
4089BCN	1.00
4093BCN	.50
4098BCN	1.00
4099BCN	.93
4503BCN	.60
4510BCN	.80
4511BCN	.80
4512BCN	.80
4514BCN	1.08
4515BCN	1.08
4516BCN	.83
4518BCN	.83
4519BCN	.48
4520BCN	.73
4522BCN	.90
4526BCN	1.03
4527BCN	.83
4528BCN	.83
4529BCN	.83
4541BCN	.78
4543BCN	.90
4723BCN	.95
4724BCN	.83

Linear

Part	Price
LF347N	1.20
LF351N	.60
LF353N	1.05
LF355N	1.20
LF356N	1.20
LF357N	1.50
LF398N	3.36
LF411CN	1.05
LF412CN	1.74
LF441CN	.90
LF444CN	1.80
LF13741N	.78
LM10CLN	2.70
LM11CLN	2.55
LM34CZ	6.00
LM35CZ	6.00
LM301AN	.57
LM307N	.75
LM308N	.90
LM311N	.54
LM317K	4.95
LM317LZ	.97
LM317MP	.86
LM317T	.99
LM318N	1.65
LM319N	1.50
LM320LZ-5.0	.72
LM320LZ-12	.60
LM320LZ-15	.72
LM320MP-5	2.25
LM320MP-12	1.90
LM320MP-15	1.95
LM322N	2.40
LM323K	8.25
LM324N	.54
LM325N	5.12
LM326N	6.00
LM327N	3.38
LM329DZ	.81
LM331N	5.25
LM334Z	1.65
LM335Z	2.10
LM336Z-2.5	1.20
LM336Z-5.0	1.20
LM337K	7.65
LM337MP	1.80
LM337T	1.95
LM338K	10.20
LM339N	.51
LM340KC-5	2.10
LM340KC-12	2.10
LM340KC-15	2.10
LM340T-5	.87
LM340T-12	.87
LM340T-15	.87
LM341P-5	.90
LM341P-12	1.00
LM341P-15	.90
LM346N	1.65
LM348N	.90
LM349N	1.35
LM350K	4.95
LM350T	4.95
LM358N	.51
LM359N	2.40
LM380N	1.50
LM380N-8	1.50
LM381N	2.61
LM382N	1.86
LM383AT	4.05
LM384N	2.55
LM386N-1	.81
LM387N	1.65
LM389N	1.32
LM390N	1.32
LM391N-60	2.00
LM391N-100	2.40
LM392N	.75
LM393N	.51
LM395P	2.40
LM395T	3.00
LM395K	10.50
LM396K	21.00
LM555CN	.75
LM556CN	.90
LM565CN	1.95
LM566CN	1.95
LM567CN	1.11
LM709CN	.75
LM723CN	.75
LM725CN	2.70
LM733CN	.84
LM741CN	.51
LM747CN	.72
LM748CN	.72
LM1458N	.54
LM1496N	1.50
LM1800N	1.95
LM1801N	1.35
LM1812N	12.30
LM1830N	2.55
LM1870N	3.00
LM1871N	2.40
LM1872N	2.55
LM1875T	5.25
LM1889N	2.16
LM2900N	1.50
LM2901N	.60
LM2902N	.60
LM2903N	.57
LM2904N	.57
LM2905N	3.90
LM2907N	1.80
LM2907N-8	2.70
LM2917N	2.25
LM2917N-8	2.25
LM2924N	2.61
LM2931Z-5.0	.66
LM2931T-5.0	.95
LM2931CT	1.65
LM3046N	1.35
LM3080N	1.26
LM3086N	.84
LM3089N	2.55
LM3301N	.99
LM3302N	.99
LM3401N	1.02
LM3524N	3.75
LM3900N	.69
LM3905N	1.80
LM3909N	1.50
LM3911N	2.25
LM3914N	2.85
LM3915N	2.85
LM3916N	2.85
LM78L05ACZ	.48
LM78L12ACZ	.54
LM78L15ACZ	.54
LM7905CT	.93
LM7912CT	.96
LM7915CT	.96
LM13080N	1.80
LM13600N	1.44
MF10CCN	4.20
AN7805	.75
AN7806	.75
AN7807	.75
AN7808	.75
AN7809	.75
AN7810	.75
AN7812	.75
AN7815	.75
AN7818	.75
AN7820	.75
AN7824	.75
AN78L04	.43
AN78L05	.43
AN78L06	.43
AN78L07	.43
AN78L08	.43
AN78L09	.43
AN78L10	.43
AN78L12	.43
AN78L15	.43
AN78L18	.43
AN78L20	.43
AN78L24	.43
AN78M05	.63
AN78M06	.63
AN78M07	.63
AN78M08	.63
AN78M09	.63
AN78M10	.63
AN78M12	.63
AN78M15	.63
AN78M18	.63
AN78M20	.63
AN78M24	.63
AN7905	.75
AN7906	.75
AN7907	.75
AN7908	.75
AN7909	.75
AN7910	.75
AN7912	.75
AN7915	.75
AN7918	.75
AN7920	.75
AN7924	.75
AN79L05	.43
AN79L06	.43
AN79L07	.43
AN79L08	.43
AN79L09	.43
AN79L10	.43
AN79L12	.43
AN79L15	.43
AN79L18	.43
AN79L20	.43
AN79L24	.43
AN79M05	.63
AN79M06	.63
AN79M07	.63
AN79M08	.63
AN79M09	.63
AN79M10	.63
AN79M12	.63
AN79M15	.63
AN79M18	.63
AN79M20	.63
AN79M24	.63

Memory

Part	Price
MM2147N	1.50
MM5257N	2.40
74C200N	9.37
74C910N	6.87
74S188N	1.70
74S189N	2.10
74S287N	2.00
74S288N	1.70
74S289N	2.10
74S387N	1.95
74S472AN	4.80
74S473AN	4.80
74S474AN	4.80
74S475AN	4.80
74S570N	3.75
74S571N	3.75
74S572N	4.50
74S573N	4.50

Micro.

Part	Price
COP402N	7.75
COP470N	4.13
COP498N	5.38
COP499N	5.38
DP8212N	3.38
DP8216N	2.75
DP8224N	3.75
DP8226N	2.25
DP8228N	6.88
DP8238N	6.88
DP8300N	6.87
DP8303AN	2.13
DP8304BN	1.88
DP8307AN	3.25
DP8308N	2.74
DP8310N	5.88
DP8311N	5.88
INS8035LN-6	3.50
INS8035N-11	3.38
INS8039N-6	3.25
INS8039LN-11	5.63
INS8154N	17.50
ISP-8A/352	25.00
MM58167AN	10.63
MM58174AN	10.25
NSC800N	18.25
NSC800-1	9.25
DM8334N	2.25

A/D & D/A

Part	Price
ADC0803LCN	7.38
ADC0804LCN	4.50
ADC0805LCN	5.00
ADC0808CCN	8.13
ADC0809CCN	4.75
ADC0816CCN	11.00
ADC0817CCN	11.25
ADC0833CCN	5.00
ADC1001CCJ	32.00
ADC3511CCN	6.25
ADC3711CCN	6.25
ADD3501CCN	6.88
ADD3701CCN	6.88
DAC0800LCN	1.85
DAC0807LCN	1.58
DAC0808LCN	1.65
DAC0830LCN	6.90
DAC0832LCN	5.88
DAC1020LCN	7.50
DAC1022LCN	5.75
MM5369AAN	1.63
MM5369EST	1.63

Interface

Part	Price
DS1488N	.85
DS1489AN	1.20
DS1489N	.85
75450N	.87
75451N	.70
75452N	.70
75453N	.70
75454N	.70
75491N	1.00
75492N	1.12
75493N	1.37
75494N	1.37

SILICON TRANSISTORS

Digi Key Part No.	Price
2N3117	.37
2N3055	1.37
2N3439	1.75
2N3440	1.40
2N3700	1.00
2N3724	1.06
2N3903	.23
2N3904	.23
2N3905	.23
2N3906	.23
2N3962	1.16
2N4030	1.16
2N4032	1.42
2N4033	1.24
2N4036	1.00
2N4037	1.40
2N4123	.23
2N4124	.23
2N4125	.23
2N4126	.23
2N4208	1.25
2N4209	2.10
2N4234	2.10
2N4235	2.30
2N4236	2.30
2N4237	2.30
2N4238	2.30
2N4239	2.30
2N4400	.23
2N4401	.23
2N4402	.23
2N4403	.23
2N4410	.23
2N4896	2.90
2N5086	.25
2N5087	.25
2N5088	.28
2N5089	.28
2N5210	.29
2N5224	.29
2N5225	.23
2N5226	.23
2N5227	.23
2N5320	2.00
2N5321	2.00
2N5322	2.30
2N5323	1.84
2N5400	.31
2N5401	.31
2N5415	1.80
2N5416	2.00
2N5457	.60
2N5550	.30
2N5679	2.55
2N5680	2.50
2N5681	2.80
2N5682	2.60
2N5769	.32
2N5771	.25
2N5772	.31
2N5830	.85
2N5831	.70
2N5833	.75
2N5961	.51
2N6715	.35
2N6725	.49
2N6727	.35
2N697	1.30
2N706	1.15
2N718A	1.15
2N1132A	2.04
2N1613	.92
2N1893	1.14
2N2218	.95
2N2218A	.95
2N2219	.76
2N2219A	.76
2N2221	.80
2N2221A	.80
2N2222	.60
2N2222A	.60
2N2369	.60
2N2369A	.60
2N2405	1.45
2N2484	.84
2N2904	.95
2N2904A	.95
2N2905	.76
2N2905A	.76
2N2906	.80
2N2906A	.80
2N2907	.60
2N2907A	.60
2N3013	.90
2N3014	1.10
2N3019	1.04
2N3020	1.04
2N3053	1.04
2N3107	1.30
2N3108	1.30
MPS2907A	.23
MPS2924	.28
MPS3392	.24
MPS3393	.27
MPS3565	.23
MPS3638A	.23
MPS3641	.30
MPS3646	.52
MPS3704	.27
MPS5172	.23
MPS5551	.65
MPS6514	.24
MPS6515	.28
MPS6520	.24
MPS6560	.41
MPS6561	.45
MPS918	.45
MPSA10	.27
MPSA12	.52
MPSA13	.52
MPSA14	.30
MPSA18	.45
MPSA20	.45
MPSA42	.45
MPSA43	.49
MPSA92	.36
MPSA93	.24
MPSL01	.36
PN2222	.23
PN2222A	.25
PN2369	.25
PN2369A	.30
PN2484	.23
PN2907	.23
PN2907A	.39
PN3251	.28
PN3565	.31
PN3566	.28
PN3567	.24
PN3569	.30
PN3638	.30
PN3640	.30
PN3641	.23
PN3643	.32
PN3644	.32
PN3645	.35
PN4121	.32
PN4122	.34
PN4248	.34
PN4249	.34
PN4250	.40
PN4250A	.30
PN4258	.29
PN4274	.29
PN4275	.36
PN4355	[illegible]

1 AMP SILICON RECTIFIERS

Part No.	Description	Pkg.	1	10	1000	1,000
1N4001	50 PIV	DO-41	—	.70	5.60	49.00
1N4002	100 PIV	DO-41	—	.75	6.00	52.50
1N4003	200 PIV	DO-41	—	.80	6.40	56.00
1N4004	400 PIV	DO-41	—	.85	6.80	59.50
1N4005	600 PIV	DO-41	—	.88	7.00	61.25
1N4006	800 PIV	DO-41	—	.98	7.80	68.25
1N4007	1000 PIV	DO-41	—	1.08	8.60	75.25

5% CARBON FILM RESISTORS
Available in 1/8, 1/4 & 1/2 Watt

How To Order: Take any standard resistor value (i.e. 3.2) and add an "E" for 1/8 watt or a "Q" for 1/4 watt or an "H" for 1/2 watt (i.e. 3.2Q for 3.2Ω 1/4 watt). this is the Digi-Key part number.

Pricing	5	200	1,000
1/8 Watt	.25	6.40	25.00
1/4 Watt	.25	3.40	13.00
1/2 Watt	.25	3.50	16.00

1/8 Watt Resistor Assortments

RS112 Set of 5 each of the 73 standard 5% 1/8 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohm (365 total pieces) — $9.90

RS212 Set of 5 each of the 72 standard 5% 1/8 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces). — $9.90

1/4 Watt Resistor Assortments

RS125 Set of 5 each of the 73 standard 5% 1/4 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohm (365 total pieces). — $9.90

RS225 Set of 5 each of the 72 standard 5% 1/4 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces). — $9.90

1/2 Watt Resistor Assortments

RS150 Set of 5 each of the 73 standard 5% 1/2 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohms (365 total pieces) — $9.90

RS250 Set of 5 each of the 72 standard 5% 1/2 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces). — $9.90

5% WIREWOUND REC. RESISTORS
Available in 5 & 10 Watt

How To Order: Take any standard resistor value (i.e. 7.5) and add "W5" for 5 watt, or add a "W10" for 10 watt (i.e. 7.5W5 for 7.5Ω 5 watt), this is the Digi-Key part number.

Pricing	1	10	100	500	1,000
5 Watt	.36	3.25	26.90	100.80	162.00
10 Watt	.41	3.78	31.90	118.00	212.00

5 Watt Metal Resistor Assortments

RS105 5 each of values 0.30Ω to 0.91Ω (300 total pieces) — $20.10

RS205 4 each of values 1.0Ω to 9.1Ω (384 total pieces) — $31.30

RS305 4 each of values 10Ω to 91Ω (384 total pieces) — $31.30

RS405 4 each of values 100Ω to 2.0KΩ (288 total pieces) — $31.30

10 Watt Resistor Assortments

R110 2 each of all 10 watt standard resistor values listed in the Digi-Key catalog. (168 total pieces) — $58.95

5% METAL OXIDE FILM RESISTORS
Available in 1 & 2 Watt

How To Order: Take any standard resistor value (i.e. 1.5K) and add a "W1" for 1 watt, or add a "W2" for 2 watt (i.e. 1.5KW1 for 1.5KΩ 1 watt), this is the Digi-Key part number.

Pricing	1	5	100	500	1,000
1 Watt (0.47-0.91Ω)	.21	.98	12.60	56.00	101.50
1 Watt (1.0-1.0MΩ)	.15	.70	9.00	40.00	72.50
2 Watt (0.47-0.91Ω)	.23	1.06	13.15	59.40	109.40
2 Watt (1.0-1.0MΩ)	.18	.85	10.50	47.50	87.50

1 Watt Metal Resistor Assortments

RS101 5 each of values 0.47Ω to 56Ω (255 total pieces) — $26.95

RS201 5 each of values 62Ω to 7.5KΩ (255 total pieces) — $26.95

RS301 5 each of values 8.2KΩ to 1.0M (255 total pieces) — $26.95

2 Watt Resistor Assortments

RS102 5 each of values 0.47Ω to 56Ω (255 total pieces) — $29.95

RS202 5 each of values 62Ω to 7.5KΩ (255 total pieces) — $29.95

RS302 5 each of values 8.2KΩ to 1.0M (255 total pieces) — $29.95

1% METAL OXIDE FILM RESISTORS
Available in 1/4 Watt

How To Order: Take any standard resistor value (i.e. 1.69K) and add an "X" (i.e. 1.69KX), this is the Digi-Key part number.

Pricing	5	200	1,000
1/4 Watt	.50	7.80	30.00

1/4 Watt Metal Film Resistor Assortments

RS1X 5 each of values 10Ω to 97.6Ω (480 total pieces) — $29.95

RS2X 5 each of values 100Ω to 976Ω (480 total pieces) — $29.95

RS3X 5 each of values 1.00KΩ to 9.76KΩ (480 total pieces) — $29.95

RS4X 5 each of values 10.0KΩ to 97.6KΩ (480 total pieces) — $29.95

RS5X 5 each of values 100KΩ to 1.00MΩ (480 total pieces) — $29.95

PANASONIC® SU SERIES
Miniature Aluminum Electrolytic Capacitors

WV/Cap. (VDC)/(µF)	Axial Lead Digi-Key Part No.	Axial Price 1	Radial Lead Digi-Key Part No.	Radial Price 1
6.3/47	P6301	.25	—	
6.3/100	P6302	.26	P6201	.16
6.3/220	P6303	.35	P6202	.21
6.3/330	P6304	.42	P6203	.22
6.3/470	P6305	.46	P6204	.23
6.3/1,000	P6306	.64	P6205	.38
6.3/2,200	P6307	.81	P6206	.62
6.3/3,300	P6308	.95	P6207	.81
6.3/4,700	P6309	1.13	P6208	1.01
6.3/6,800	P6310	1.48	P6209	1.22
6.3/10,000	P6311	1.97	P6210	1.62
6.3/15,000	P6312	2.67	P6211	2.64
6.3/22,000	P6313	3.82	—	—
10/22	P6314	.21	—	—
10/33	P6315	.27	P6212	.14
10/47	P6316	.28	P6213	.14
10/100	P6317	.33	P6214	.16
10/220	P6318	.41	P6215	.22
10/330	P6319	.49	P6216	.24
10/470	P6320	.53	P6217	.33
10/1,000	P6321	.73	P6218	.42
10/2,200	P6322	.99	P6219	.75
10/3,300	P6323	1.16	P6220	.87
10/4,700	P6324	1.49	P6221	1.19
10/6,800	P6325	1.86	P6222	1.62
10/10,000	P6326	2.65	P6223	2.31
10/15,000	P6327	3.79	—	—
10/22,000	P6328	5.10	—	—
16/22	P6329	.27	P6224	.14
16/33	P6330	.28	P6225	.15
16/47	P6331	.33	P6226	.16
16/100	P6332	.29	P6227	.21
16/220	P6333	.47	P6228	.24
16/330	P6334	.53	P6229	.31
16/470	P6335	.63	P6230	.39
16/1,000	P6336	.82	P6231	.50
16/2,200	P6337	1.13	P6232	.95
16/3,300	P6338	1.49	P6233	1.24
16/4,700	P6339	1.75	P6234	1.62
16/6,800	P6340	2.14	P6235	2.31
16/10,000	P6341	4.04	—	—
16/15,000	P6342	5.16	—	—
25/10	P6343	.21	—	—
25/22	P6344	.26	P6236	.15
25/33	P6345	.29	P6237	.16
25/47	P6346	.34	P6238	.20
25/100	P6347	.42	P6239	.22
25/220	P6348	.49	P6240	.33
25/330	P6349	.57	P6241	.42
25/470	P6350	.66	P6242	.50
25/1,000	P6351	.89	P6243	.82
25/2,200	P6352	1.35	P6244	1.24
25/3,300	P6353	1.71	P6245	1.74
25/4,700	P6354	2.55	P6246	2.48
25/6,800	P6355	3.79	—	—
25/10,000	P6356	4.95	—	—
35/4.7	P6357	.21	P6247	.14
35/10	P6358	.26	P6248	.14
35/22	P6359	.29	P6249	.20
35/33	P6360	.35	P6250	.21
35/47	P6361	.42	P6251	.23
35/100	P6362	.46	P6252	.26
35/220	P6363	.56	P6253	.42
35/330	P6364	.66	P6254	.53
35/470	P6365	.72	P6255	.65
35/1,000	P6366	1.03	P6256	.97
35/2,200	P6367	1.71	P6257	1.74
35/3,300	P6368	2.24	P6258	2.48
35/4,700	P6369	3.47	—	—
35/6,800	P6370	4.88	—	—
50/0.47	—	—	P6259*	.13
50/1.0	—	—	P6260*	.13
50/2.2	—	—	P6261*	.13
50/3.3	P6371	.21	P6262*	.14
50/4.7	P6372	.26	P6263*	.14
50/10	P6373	.29	P6264*	.16
50/22	P6374	.35	P6265*	.22
50/33	P6375	.41	P6266*	.23
50/47	P6376	.45	P6267*	.24
50/100	P6377	.49	P6268*	.38
50/220	P6378	.70	P6269*	.53
50/330	P6379	.79	P6270*	.77
50/470	P6380	.95	P6271*	.90
50/1,000	P6381	1.38	P6272*	1.34
50/2,200	P6382	2.52	P6273*	2.38
50/3,300	P6383	3.63	—	—
50/4,700	P6384	4.79	—	—
63/0.47	P6385	.21	P6274	.14
63/1.0	P6386	.21	P6275	.14
63/2.2	P6387	.21	P6276	.15
63/3.3	P6388	.26	P6277	.16
63/4.7	P6389	.29	P6278	.16
63/10	P6390	.34	P6279	.18
63/22	P6391	.42	P6280	.24
63/33	P6392	.47	P6281	.27
63/47	P6393	.47	P6282	.40
63/100	P6394	.59	P6283	.53
63/220	P6395	.78	P6284	.77
63/330	P6396	.92	P6285	.97
63/470	P6397	1.12	P6286	1.14
63/1,000	P6398	1.75	P6287	1.74
63/2,200	P6399	3.53	—	—
63/3,300	P6400	4.83	—	—
100/0.47	P6401	.21	P6288	.21
100/1.0	P6402	.21	P6289	.22
100/2.2	P6403	.26	P6290	.23
100/3.3	P6404	.29	P6291	.24
100/4.7	P6405	.34	P6292	.26
100/10	P6406	.42	P6293	.31
100/22	P6407	.48	P6294	.40
100/33	P6408	.54	P6295	.46
100/47	P6409	.57	P6296	.52
100/100	P6410	.82	P6297	.81
100/220	P6411	1.22	P6298	1.09
100/330	P6412	1.54	P6299	1.32
100/470	P6413	2.02	P6300	1.89
100/1,000	P6414	3.94	—	—
160/0.47	—	—	P6415	.23
160/1.0	—	—	P6416	.24
160/2.2	—	—	P6417	.27
160/3.3	—	—	P6418	.36
160/4.7	—	—	P6419	.37
160/10	—	—	P6178	.46
160/22	—	—	P6179	.65
160/33	—	—	P6180	.85
160/47	—	—	P6181	1.13
160/100	—	—	P6182	1.25
160/220	—	—	P6183	2.15
250/1.0	—	—	P6184	.40
250/2.2	—	—	P6185	.42
250/3.3	—	—	P6186	.43
250/4.7	—	—	P6187	.43
250/10	—	—	P6188	.61
250/22	—	—	P6189	.87
250/33	—	—	P6190	.98
250/47	—	—	P6191	1.28
250/100	—	—	P6192	2.19
450/1.0	—	—	P6193	.47
450/2.2	—	—	P6194	.55
450/3.3	—	—	P6195	.73
450/4.7	—	—	P6196	.79
450/10	—	—	P6197	.98
450/22	—	—	P6198	1.57
450/33	—	—	P6199	2.04

DISC CAPACITORS

Part No.	Cap./Volt. (pf)/(V)	Price 10
P4000	10/500	.71
P4002	15/500	.64
P4003	18/500	.64
P4004	22/500	.64
P4005	27/500	.64
P4006	33/500	.64
P4007	39/500	.64
P4008	47/500	.64
P4009	56/500	.64
P4010	68/500	.71
P4011	82/500	.71
P4141	1000/25	.98
P4142	1500/25	.98
P4143	2200/25	.98
P4144	3300/25	.98
P4145	4700/25	1.09
P4146	6800/25	1.09
P4147	10000/25	1.13
P4148	15000/25	1.20
P4149	22000/25	1.20
P4150	33000/25	1.76
P4152	1000/50	1.09
P4153	1500/50	1.09
P4154	2200/50	1.09
P4155	3300/50	1.09
P4156	4700/50	1.20
P4157	6800/50	1.24
P4158	10000/50	1.24
P4159	15000/50	1.35
P4160	22000/50	1.95
P4100	100/500	.68
P4102	150/500	.68
P4103	180/500	.68
P4104	220/500	.68
P4105	270/500	.68
P4106	330/500	.68
P4107	390/500	.68
P4108	470/500	.79
P4109	560/500	.79
P4110	680/500	.79
P4111	820/500	.79
P4112	1000/500	.94
P4114	1500/500	.94
P4116	100/1K	1.28
P4117	120/1K	1.28
P4118	150/1K	1.28
P4119	180/1K	1.28
P4120	220/1K	1.28
P4121	270/1K	1.28
P4122	330/1K	1.99
P4123	390/1K	1.99
P4124	470/1K	1.99
P4125	560/1K	1.99
P4126	680/1K	1.99
P4127	820/1K	2.25
P4128	1000/1K	2.25
P4129	1200/1K	2.25
P4130	1500/1K	2.25
P4131	1800/1K	2.25
P4132	2200/1K	2.93
P4133	2700/1K	2.93
P4134	3300/1K	2.93
P4135	3900/1K	4.46
P4136	4700/1K	5.36
P4137	5600/1K	5.36
P4138	6800/1K	8.44
P4139	8200/1K	8.44
P4140	10000/1K	8.44
P4161	10000/50	.86
P4162	22000/50	.94
P4163	47000/50	1.01
P4164	100000/50	1.13
DH682	6800/50	.90
P4200	1000/100	.68
P4202	1500/100	.68
P4203	2200/100	.79
P4205	3300/100	.79
P4206	4700/100	1.09
P4209	6800/100	.71
P4300	.01µf/25	.56
P4303	.022µf/25	.64
P4305	.033µf/25	.64
P4307	.047µf/25	.79
P4311	.1µf/25	1.61
P4418	1000/25	.75
P4419	1500/25	.75
P4420	2200/25	.75
P4421	3300/25	.75
P4422	4700/25	.75
P4423	6800/25	.83
P4424	10000/25	.83
P4425	15000/25	.90
P4426	22000/25	.94
P4427	33000/25	.94
P4428	47000/25	1.55
P4429	68000/25	1.73
P4430	100000/25	1.91
P4431	1000/50	.86
P4432	1500/50	.86
P4433	2200/50	.86
P4434	3300/50	.86
P4435	4700/50	.86
P4436	6800/50	.94
P4437	10000/50	1.01
P4438	15000/50	1.01
P4439	22000/50	1.09
P4440	33000/50	1.73
P4441	47000/50	1.73

NPO NPO NPO NPO NPO NPO NPO NPO

Part No.	Cap./Volt.	Price
P4400	10/500	.68
P4402	15/500	.79
P4403	18/500	.79
P4404	22/500	.79
P4405	27/500	.79
P4406	33/500	.98
P4407	39/500	.98
P4408	47/500	1.13
P4409	56/500	1.13
P4410	68/500	1.28
P4411	82/500	1.91
P4412	100/500	1.91
P4413	120/500	1.91
P4414	150/500	2.03
P4415	180/500	2.70
P4416	220/500	2.70

TANTALUM CAPACITORS

Part No.	Cap./Volt. (µF)/DC	Price 1
P2011	4.7/6.3	.31
P2012	6.8/6.3	.34
P2013	10/6.3	.42
P2014	15/6.3	.50
P2015	22/6.3	.60
P2016	33/6.3	.72
P2017	47/6.3	.85
P2018	68/6.3	1.18
P2019	100/6.3	1.82
P2020	150/6.3	3.60
P2094	220/6.3	7.85
P2095	330/6.3	11.65
P2022	2.2/10	.28
P2023	3.3/10	.31
P2024	4.7/10	.34
P2025	6.8/10	.42
P2026	10/10	.50
P2027	15/10	.60
P2028	22/10	.72
P2029	33/10	.85
P2030	47/10	1.18
P2031	68/10	1.82
P2032	100/10	3.60
P2083	150/10	6.98
P2084	220/10	9.63
P2033	1.5/16	.23
P2034	2.2/16	.31
P2035	3.3/16	.33
P2036	4.7/16	.42
P2037	6.8/16	.50
P2038	10/16	.60
P2039	15/16	.74
P2040	22/16	.88
P2041	33/16	1.18
P2042	47/16	1.82
P2043	68/16	3.60
P2086	150/16	9.08
P2096	100/16	6.98
P2044	1.5/25	.31
P2045	2.2/25	.34
P2046	3.3/25	.42
P2047	4.7/25	.54
P2048	6.8/25	.65
P2049	10/25	1.06
P2050	15/25	1.19
P2051	22/25	1.68
P2052	33/25	2.36
P2053	0.1/35	.27
P2054	0.15/35	.27
P2055	0.22/35	.27
P2056	0.33/35	.27
P2057	0.47/35	.27
P2058	0.68/35	.28
P2059	1.0/35	.31
P2060	1.5/35	.34
P2061	2.2/35	.42
P2062	3.3/35	.51
P2063	4.7/35	.65
P2064	6.8/35	.90
P2065	10/35	1.19
P2066	15/35	1.88
P2099	.047/35	.43
P2100	.068/35	.43
P2101	22/35	2.56
P2102	33/35	4.46
P2103	47/35	13.36
P2067	0.1/50	.28
P2068	0.15/50	.30
P2069	0.22/50	.30
P2070	0.33/50	.30
P2071	0.47/50	.33
P2072	0.68/50	.37
P2073	1.0/50	.50
P2074	1.5/50	.84
P2075	2.2/50	.90
P2076	3.3/50	1.48
P2077	4.7/50	1.89
P2078	6.8/50	3.90
P2104	10/50	5.40
P2093	15/50	8.37

PANASONIC® V SERIES
Stacked Metalized Film Capacitors

Part No.	Cap./Volt. (µF)/VAC	Price 10
P4513	0.01/50	1.23
P4514	0.012/50	1.26
P4515	0.015/50	1.28
P4516	0.018/50	1.32
P4517	0.022/50	1.35
P4518	0.027/50	1.38
P4519	0.033/50	1.41
P4520	0.039/50	1.44
P4521	0.047/50	1.47
P4522	0.056/50	1.54
P4523	0.068/50	1.63
P4524	0.082/50	1.73
P4525	0.1/50	1.69
P4526	0.12/50	1.88
P4527	0.15/50	1.95
P4528	0.18/50	2.01
P4529	0.22/50	2.10
P4530	0.27/50	2.45
P4531	0.33/50	2.79
P4532	0.39/50	3.10
P4533	0.47/50	3.45
P4534	0.56/50	4.14
P4535	0.68/50	4.83
P4536	0.82/50	5.74
P4537	1.0/50	6.62
P4713	0.01/100	1.81
P4714	0.012/100	1.38
P4715	0.015/100	1.81
P4716	0.018/100	1.81
P4717	0.022/100	1.85
P4718	0.027/100	1.89
P4719	0.033/100	1.93
P4720	0.039/100	1.96
P4721	0.047/100	2.03
P4722	0.056/100	2.10
P4723	0.068/100	2.23
P4724	0.082/100	2.25
P4725	0.1/100	2.30
P4726	0.12/100	2.57
P4727	0.15/100	2.65
P4728	0.18/100	2.75
P4729	0.22/100	2.94
P4730	0.27/100	3.34
P4731	0.33/100	3.81
P4732	0.39/100	4.22
P4733	0.47/100	4.71

PANASONIC® B SERIES
Polyester Capacitors

Part No.	Cap./Volt. (µF)/VAC	Price 10
P4551	.001/50	1.05
P4552	.0012/50	1.05
P4553	.0015/50	1.05
P4554	.0018/50	1.05
P4555	.0022/50	1.05
P4556	.0027/50	1.05
P4557	.0033/50	1.05
P4558	.0039/50	1.05
P4559	.0047/50	1.05
P4560	.0056/50	1.05
P4561	.0068/50	1.05
P4562	.0082/50	1.05

QUARTZ CRYSTALS

Freq. MHz	Digi-Key Part No.	Case	Pricing 1	Pricing 10
1.000	X045	HC-33	10.08	84.00
1.0000	X066	HC-18	9.65	79.50
1.8432	X046	HC-33	3.96	33.00
1.8432	X067	HC-18	3.42	28.50
2.000	X001	HC-33	3.78	31.50
2.0000	X068	HC-18	3.24	27.00
2.4576	X047	HC-33	3.78	31.50
2.4576	X069	HC-18	3.06	25.50
2.5000	X070	HC-18	3.42	28.50
3.000	X048	HC-33	3.78	31.50
3.2768	X022	HC-18	1.73	14.40
3.579545	X005	HC-33	2.34	19.50
3.579545	X049	HC-18	1.62	13.50
3.6864	X071	HC-18	1.62	13.50
3.700	X012	HC-6/U	2.60	22.00
4.000	X006	HC-18	1.62	13.50
4.0320	X072	HC-18	1.62	13.50
4.194304	X007	HC-18	1.62	13.50
4.91520	X050	HC-18	1.62	13.50
5.000	X051	HC-18	1.62	13.50
5.0688	X052	HC-18	1.62	13.50
5.1850	X053	HC-18	1.62	13.50
5.9904	X073	HC-18	1.62	13.50
6.000	X026	HC-18	1.62	13.50
6.144	X054	HC-18	1.62	13.50
7.3728	X074	HC-18	1.62	13.50
8.000	X056	HC-18	1.62	13.50
9.2160	X075	HC-18	1.62	13.50
10.000	X057	HC-18	1.62	13.50
11.0592	X078	HC-18	1.98	16.50
12.000	X058	HC-18	1.62	13.50
15.000	X059	HC-18	1.62	13.50
16.000	X077	HC-18	1.62	13.40
18.000	X060	HC-18	1.80	15.00
18.432	X061	HC-18	1.80	15.00
20.000	X062	HC-18	1.98	16.50
22.1184	X063	HC-18	1.98	16.50
48.000	X065	HC-18	1.98	16.50

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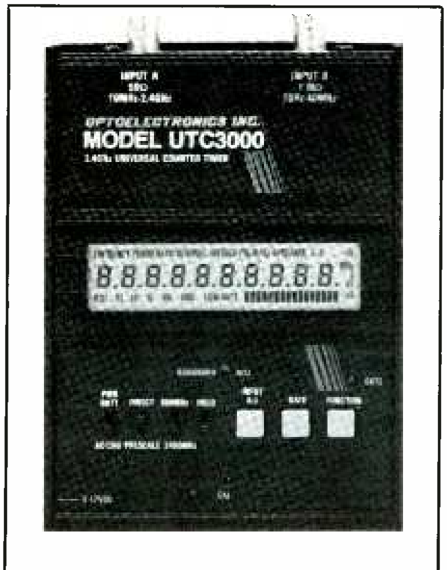

The Model UTC3000 provides period, period-average and time-interval average (0.1 ns) and ratio functions. Both 50-ohm and 1-megohm input amplifiers are provided as well.

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[illegible]	NPN	TO-92	[illegible]
[illegible]	PNP	TO-92	[illegible]
[illegible]	NPN	TO-92	[illegible]
[illegible]	PNP	TO-92	[illegible]
[illegible]	PNP	TO-92	4 for [illegible]
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MJE3055T	NPN	[illegible]	[illegible]
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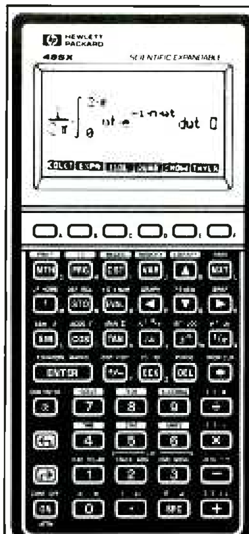

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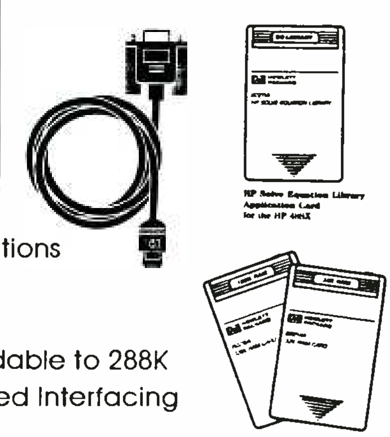

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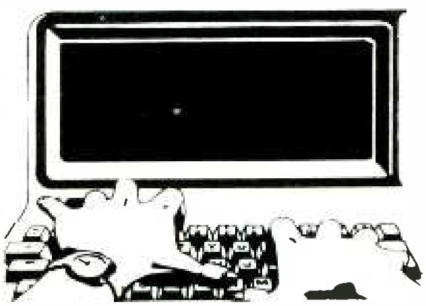

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Three Phase Motor Protector *(from page 61)*

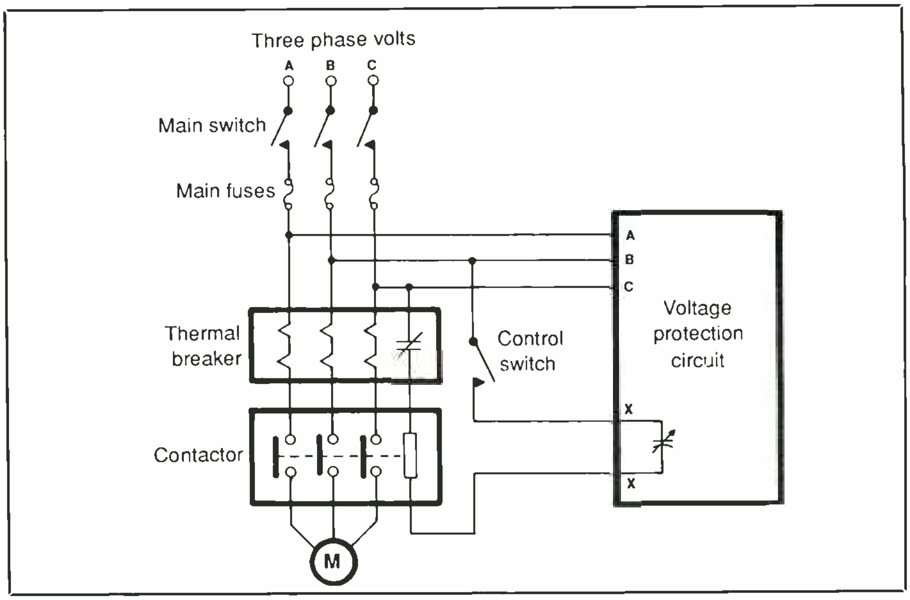

Fig. 5. Installation details for project in existing or new three-phase motor-control circuit.

this verification process with each phase of the circuit.

You are now ready to connect the Three-Phase Motor Protector into the motor circuit with which it is to be used. Before starting, however, remember that when making the connections that you will be working with potentially lethal voltages. Therefore, follow local electrical codes for any wiring you make. In fact, if you are not certain of what you are doing, have a licensed electrician make the installation. *Never* attempt to touch live electrical circuits or otherwise come in contact with them!

Prior to making any connection, review the schematic diagram of a typical three-phase motor-control circuit shown in Fig. 4. Power is fed to the fuse box via the main disconnect switch. It passes through the thermal (actually, thermomagnetic) breakers.

In the event of an overload, the breakers do not interrupt current flow; instead, they open an auxiliary contact (the symbol that looks like a capacitor with a diagonal line through it) that is wired in series with the coil of the power relay (also known as a contactor). This is where the interruption in current flow occurs. In series with the relay coil are also any control switches that turn on and off the motor.

To include the Three-Phase Motor Protector in an existing or new motor-control circuit, connect each Phase input to a different phase of the ac line feeding the motor *after* the motor's fuses, as shown in Fig. 5. Sequence of phase connection is not important.

Afterwards, cut the line that feeds the contactor's coil and wire the cut ends of the conductor to points X (the relay contacts) in the project. Close the Control Switch. After a few moments, the motor should start up. Open the switch and remove the fuse from any phase circuit in the project. Close the switch again and note that the FAULT LED lights and the motor fails to start. You now know that your Three-Phase Motor Protector project is working as it should and can have confidence that, should a problem arise, the motor will automatically shut down to prevent costly damage.

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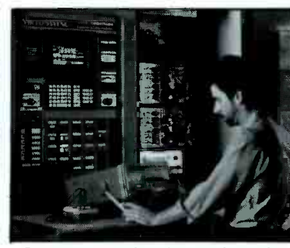
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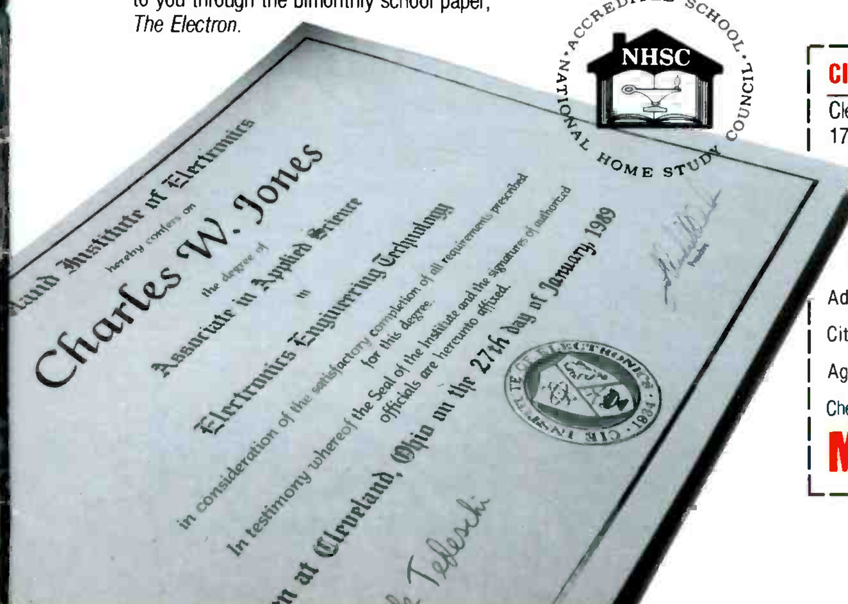

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