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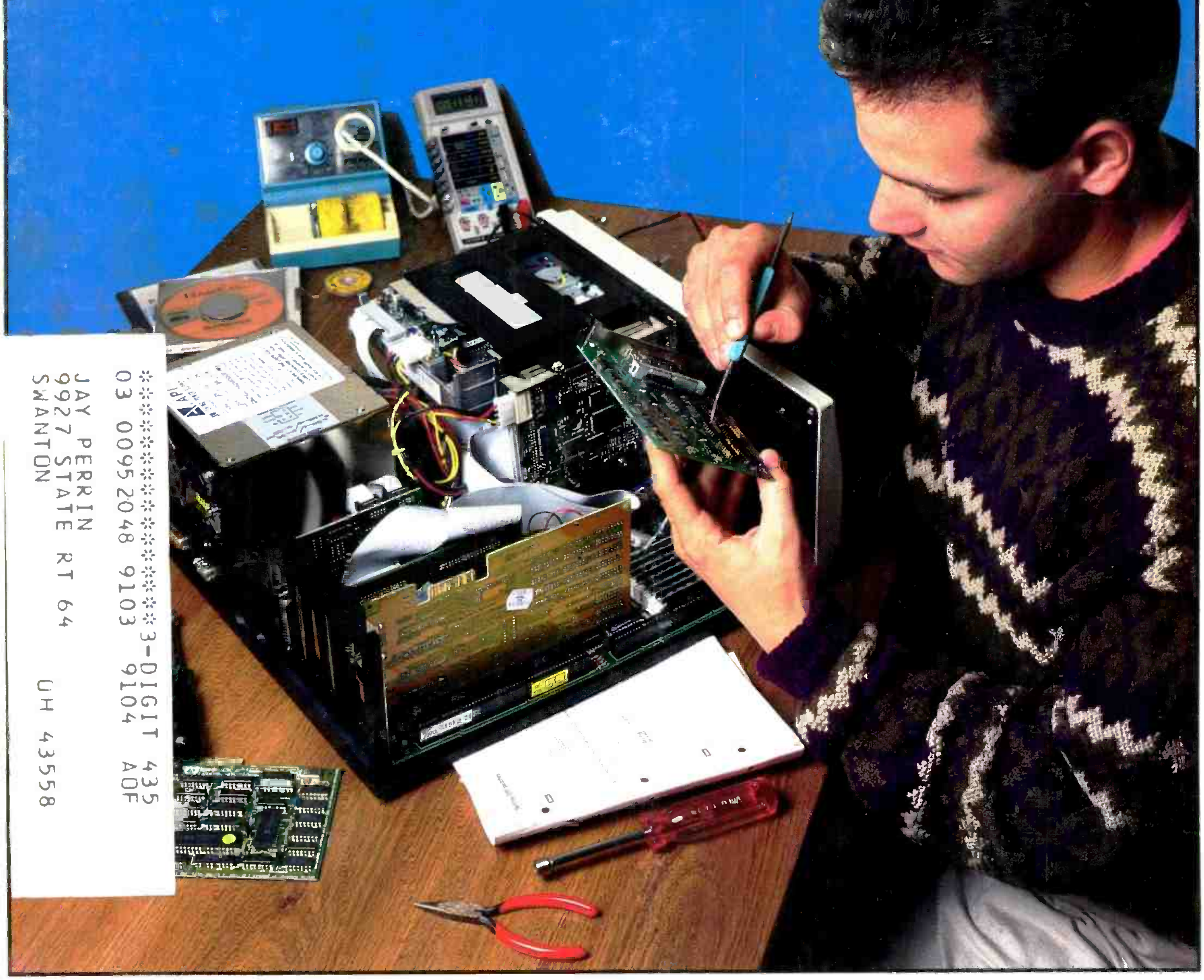

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Volume 1, No. 1 April 1991

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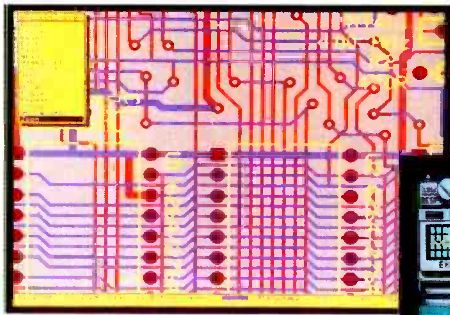

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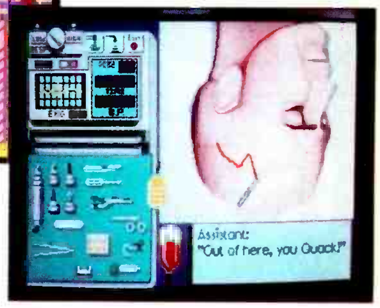

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Photo by Lorinda Sullivan

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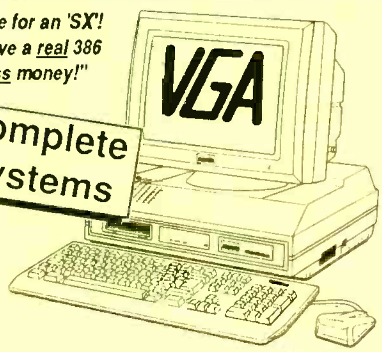

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Editorial

Here's ComputerCraft!

We have a new title, as you can see: *ComputerCraft*. This change reflects the growing dominance of microprocessors in electronic equipment, and the large role that personal computers and microcontrollers play in the electronics field. We'll be covering both aspects more deeply, as well as general digital and analog circuitry whose principles are interchangeable with that of computer technology.

As our new title indicates, we'll continue to be a practical hardware-oriented publication, although software will be addressed, too, when needed. Equally important, we're catering to computer craftsmen—readers who want to sharpen skills to apply their technically-oriented inclinations to improve and expand the performance of their equipment.

You'll still be treated to a wide range of useful construction projects that will save you money or make available to you products not easily found in the marketplace. Our resident experts will also try out new devices and show you how to mate them successfully to your current computer systems. Their hands-on experience will relieve you of a great deal of frustration in upgrading machines. And our applied servicing pointers will hone your electronics troubleshooting techniques.

Something has to drop by the wayside, of course, to make room for this fresh editorial charter. This will be consumer electronic products, such as general communications, stereo, etc., unless they relate to computer technology in some way, even obliquely. Thus, we won't write about the latest stereo music center, but we'll discuss audio where it relates to a computer-related MIDI system, and so on. Nor will we cover TV satellite reception, unless it concerns computerized control; nor the r-f and i-f aspects of a TV receiver, although the rest of a video monitor is fair game since the principles are transferable from one to the other.

You can see from our editorial line-up this issue that electronics experimenting hasn't been ignored, with Forrest Mims continuing to carry its banner. Other writers, too, march in step with this theme, such as investigating op-amp circuit design with a computer experimenter lab. Then there are applications articles like a clear discussion of Counting and Timing Circuits, and a neat construction project that shows you how to build a logic probe that employs a synthesized voice that tells you if a digital electronic test point is "high," "low" or a pulse.

Our computer-oriented articles run the hands-on gamut, from how to replace a ROM BIOS for upgrading purposes to building an enhancement device; from modifying a circuit to achieve better performance to working with a wireless pointing device and computerized printed-circuit-board design software.

Next month, *ComputerCraft* will feature how to choose and use math coprocessors, construction plans for the "ultimate" Ni-Cd battery charger, local-area network twisted-pair wire tests, working with commercially available single-board computers, keyboard circuitry, installing a large-capacity hard-disk drive, building a parallel-port EPROM programmer and playing with a terrific computerized golf game, among others.

Naturally, there will be plenty of new product, literature and book coverage, late-breaking news and your familiar columnists to round out our editorial package. We're confident that you'll find *ComputerCraft* to be an exciting media advancement that weds enduring electronics with the newest computer technology. All of this will be in easy-to-read presentations designed to increase your underlying technical knowledge and show you, step-by-step, how to put this all into practice . . . and save money and have fun while you're doing it.

Let me hear from you soon: Which article(s) did you like best? What would you like to see us cover in upcoming issues? What kind of computer do you own or plan to buy?

Art Salsberg

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More for Beginners

• You have a fine magazine, though I would like to see more construction articles. We own the very excellent series of *Modern Electronics* books, but more material would be welcome—good projects that could be completed in a few evenings.

I really admire Forrest Mims. He is a legend to me, and everything he writes is welcome. Please have him write more.

Nicholas Pearson
Alhambra, CA

ACI Revisited

• I was surprised that *Modern Electronics* did not print in the December issue the corrections for the "Computer-Controlled AC Interface" that appeared in the November issue. I am building this project for my final in school. I do not know if I have found all the bugs, but the BASIC program given on page 42 is obviously in error. Fortunately, I and some friends were able to correct the program listing and, additionally, alter it for compiling with TurboBASIC (the published version is for GW-BASIC). To correct the original listing, I had to add "else BITn = 1" to the ends of lines 240, 260, 280, 300, 320, 340, 360 and 380. For the TurboBASIC listing shown, I had to eliminate this statement from these lines. I also changed line 120 for the program to run properly under TurboBASIC.

Richard Alexander
Tijeras, NM

The correct listing appeared in the January 1991 issue. In the originally published listing, characters on the very long lines you cited (and a few others as well) truncated when run out on our laser printer. If you compare your fix with the listing given in the January 1991 issue, you will see that the author ended the lines you refer to with the values 1, 2, 4, 8, 16, 32, 64 and 128 (the truncated characters referred to above), respectively. Thanks for sharing with us your listing for TurboBASIC.—Ed.

Removable Labels

• *Modern Electronics* is a fine magazine, but those permanently fixed address labels on the front cover just have to go. My suggestion is that you leave blank space on the cover, or have the address label placed over the magazine's title. After all, I know the name of the magazine, and having the label over the title will keep it clear of other areas I would like to read.

Name Withheld

A label that can easily be peeled away without damaging the cover is in the works.—Ed.

```
10 clear: close: key off: cls: dec = 0: out 888, dec
20 byte$ = " 0   0   0   0   0   0   0   0"
30 locate 1, 21: print " ┌──────────────────────────────┐ "
40 LOCATE 2, 21: PRINT " │  PARALLEL INTERFACE PROGRAM  │ "
50 LOCATE 3, 21: PRINT " └──────────────────────────────┘ "
60 LOCATE 10, 15: PRINT "BIT NUMBER     7    6    5    4    3    2    1    0 "
70 LOCATE 11, 15: PRINT "═════════════E════E════E════E════E════E════E════4 "
80 LOCATE 12, 29: PRINT "3    3    3    3    3    3    3    3 "
90 LOCATE 13, 29: PRINT "A    A    A    A    A    A    A    A "
100 LOCATE 14, 15: PRINT "   VALUE       "; BYTE$
110 LOCATE 21, 16: PRINT "COPYRIGHT, GEORGE F. STOCKMAN, IV,   1989"
120 DELAY x = TIMER + 1: WHILE x > TIMER: WEND
130 LOCATE 21, 16: PRINT STRING$(41, 32)
140 LOCATE 21, 11: PRINT "BIT NUMBER TO TOGGLE / [CR] TO RESET / [ESC] TO
EXIT"
150 A$ = INKEY$: IF A$ = "" THEN 150
160 IF A$ = "0" THEN 240 ELSE IF A$ = "1" THEN 260 ELSE IF A$ = "2" THEN 280
170 IF A$ = "3" THEN 300 ELSE IF A$ = "4" THEN 320 ELSE IF A$ = "5" THEN 340
180 IF A$ = "6" THEN 360 ELSE IF A$ = "7" THEN 380
190 IF A$ <> CHR$(13) THEN 230
200 BYTE$ = " 0   0   0   0   0   0   0   0"
210 DEC = 0: BIT0 = 0: BIT1 = 0: BIT2 = 0: BIT3 = 0
220 BIT4 = 0: BIT5 = 0: BIT6 = 0: BIT7 = 0: GOTO 430
230 IF A$ = CHR$(27) THEN CLS: SYSTEM ELSE BEEP: GOTO 150
240 IF BIT0 = 0 THEN BIT0 = 1: DEC = DEC + 1 ELSE BIT0 = 0: DEC = DEC - 1
250 GOTO 390
260 IF BIT1 = 0 THEN BIT1 = 1: DEC = DEC + 2 ELSE BIT1 = 0: DEC = DEC - 2
270 GOTO 390
280 IF BIT2 = 0 THEN BIT2 = 1: DEC = DEC + 4 ELSE BIT2 = 0: DEC = DEC - 4
290 GOTO 390
300 IF BIT3 = 0 THEN BIT3 = 1: DEC = DEC + 8 ELSE BIT3 = 0: DEC = DEC - 8
310 GOTO 390
320 IF BIT4 = 0 THEN BIT4 = 1: DEC = DEC + 16 ELSE BIT4 = 0: DEC = DEC - 16
330 GOTO 390
340 IF BIT5 = 0 THEN BIT5 = 1: DEC = DEC + 32 ELSE BIT5 = 0: DEC = DEC - 32
350 GOTO 390
360 IF BIT6 = 0 THEN BIT6 = 1: DEC = DEC + 64 ELSE BIT6 = 0: DEC = DEC - 64
370 GOTO 390
380 IF BIT7 = 0 THEN BIT7 = 1: DEC = DEC + 128 ELSE BIT7 = 0: DEC = DEC - 128
390 BYTE$ = "": BYTE$ = BYTE$ + STR$(BIT7) + "  " + STR$(BIT6) + "  "
400 BYTE$ = BYTE$ + STR$(BIT5) + "  " + STR$(BIT4) + "  "
410 BYTE$ = BYTE$ + STR$(BIT3) + "  " + STR$(BIT2) + "  "
420 BYTE$ = BYTE$ + STR$(BIT1) + "  " + STR$(BIT0) + "  "
430 OUT 888, DEC: LOCATE 14, 28: PRINT BYTE$;: GOTO 150
```

My mandate for writing this column is to keep readers of *ComputerCraft* posted on the latest trends and developments as they occur in the PC world. This can be a surprisingly large assignment because of the vast amount of information available but, as the Washington Bureau Chief for *Newsbytes News Network*, gleaning the wheat from the chaff is what I do for a living.

Here's a quick look at some major trends I see.

Chips. Of special interest to readers of *ComputerCraft*, DRAM prices continue to free-fall. In fact, they're dropping so fast that I hesitate to list any prices here because they'll almost certainly be out of date by the time this reaches you. I look for this trend to continue, but slowly, because prices are dropping close to the profit/loss line and they can't go down much further. Barring a major upset, like an earthquake centered in Silicon Valley or another round of federal intervention, memory prices should remain relatively low unless they drop so far that some manufacturers drop out of the business, drastically reducing supply.

If you're keeping track, European chip manufacturers are doing well as a result of obtaining orders from newly opened markets in Eastern Europe, while the Japanese share of the U.S. Market has dropped from about 24% last year to 22% at present. The U.S. share of the Japanese chip market has climbed from 10% in 1989 to 10.4% today.

Of course, these low prices are on older chips. Look for very high prices on the new 64-bit DRAM chips about to be introduced by Tokyo-based NEC . . . . The new 40-ns chip should be available in small quantities by this summer. However, although no prices are being discussed, NEC has stated that it has more than $1.2-billion invested in development costs.

The drop in memory prices is an important trend because if you want to run Microsoft *Windows*, you'll definitely need a large RAM disk, unless you have lots of spare time. *Windows* 3 is a fine product, but it's still too slow.

New DOS. Also from Microsoft is a new and much improved version of MS-DOS. By now, you should be able to buy a copy of DOS 5.0, a smaller and much friendlier version of the venerable operating system produced in Redmond, Washington.

As this is being written, there are only beta copies of DOS 5.0 floating around, but look for the following changes in the latest version of DOS: File-recovery utilities, including one that will recover data from an accidentally formatted disk. • No more GW-BASIC—the standard BASIC interpreter will finally be retired in favor of one based on the QuickBASIC syntax. • Look also for much better use of memory above the standard 640K, along with a revamped DOS Shell and a new editor, although EDLIN will still be around if anyone can find a use for it.

VDT. In case you missed it, while manufacturers are still denying any health risks from VDT radiation (although several have said that they are developing new low-radiation monitors, presumably just for the fun of it), San Francisco has enacted a landmark law (scheduled to go into effect at the beginning of February). Its aimed at making heavily computerized workplaces more amenable places to work. Under the San Francisco regulations, the first such local legislation in the world, computer operators working for companies with more than 15 employees would receive mandated rest breaks and ergonomically designed keyboards and chairs, as well as better lighting, all designed to reduce stress. Also included in the legislation is the formation of an advisory panel that's charged with making recommendations concerning the need for VDTs that have reduced-radiation.

Just a year ago, the only low-emission VDTs to be found were in northern European countries, but by the end of 1990, more than a dozen companies had announced plans to market such systems in the U.S. IBM, Phoenix-based Idea Courier, and California-based Megagraphics, Sigma Designs, Sun Microsystems and Qume use a cancellation coil added to the deflection yoke at the back of the cathode-ray tube to cancel out the fields generated by the coil that causes the electron beam to scan across the screen.

The above companies are reducing 15-kHz-to-16-kHz emf radiation, but Sigma, in particular, is also attempting to cancel out a lower band of radiation that occurs between 3 and 3,000 Hz . . . . Prices for such devices can be high. Nanao USA Corp.'s Flexscan 9070U low-radiation multi-scanning monitor, a 16-inch unit with a 14.5-inch image size, provides up to 1,800 by 800 resolution, but it lists for a hefty $1,779.

All well and good for the future, but if you're worried about emf dangers now and don't want to toss out your present monitor, there's the grounded wire-mesh screen sold by Santa Monica-based Norad Corp. Of course, such a screen would eliminate emanations from only the front of the monitor.

Look also for an entirely new approach from a company located in Utah, which claims to be testing an active system that utilizes secret devices that resonate with and cancel out fields coming from VDTs.

Laptops. It looks like about 400 models of notebook and laptop computers will be on the market by the end of 1991. This tremendous surge of new systems includes a lot of 386SX systems. But this trend doesn't appear to coincide with user demand, which shows that business executives normally use laptops to make notes or do word processing. Light weight and long battery life appear to be more important than greater memory and processor efficiency.

Due to advance-publication writing, it will probably be old news by the time you read this, but IBM will almost certainly introduce a 7.5-lb. 386SX-based laptop priced about $5,000 with a 60-megabyte hard disk. This is far from the first attempt IBM has made to enter the portable/laptop market and, once again, it looks like the company is out of step. Zeos International already sells a 386SX notebook weighing just 6 lbs. and priced at $2,300 for a system with a 20M hard disk.

The International Arena. IBM Japan is set to introduce five new PCs in the Orient, one of them to be a new IBM notebook. Japan-based Big Blue is also loosening licensing requirements for those who wish to build clones, but the most interesting development is a joint venture with Sega Enterprises to build a home PC with dual 80286 and 68000 processor chips. The IBM PC-compatible and game machine combo is code-named "Terra" and looks like IBM's PS/1.

If you have suggestions for this column, I welcome letters either by e-mail or the Post Office. Address your comments to John McCormick, RD #1 Box 99, Mahaffey, PA 15757; or to CompuServe: 76360,44; GEnie: NB.WAS; or MCI Mail: 321-7108. No phone calls, please.

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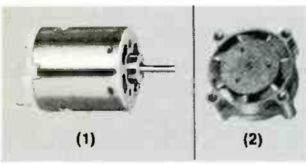

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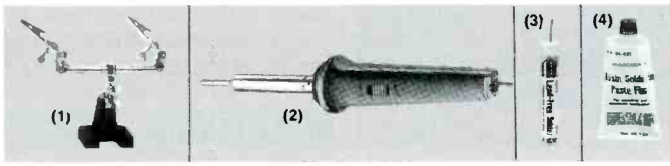
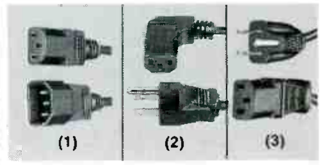


(1) Adjustable Project Holder. Our extra-sturdy "Helping Hands" holder simplifies soldering, gluing and assembly work. #64-2093 . . . . 8.19

(2) Dual-Wattage Soldering Iron. Go from 15 to 30 watts with the flick of a switch. 8¼" long. UL listed AC. #64-2055 . . . . 9.49

(3) Lead-Free Solder. Top choice for fine electronics work. 96% tin, 4% silver composition. .032"-diameter. 0.25 oz. #64-025 . . . . 1.99

(4) Soldering Paste Flux. #64-021 . . . . 1.79

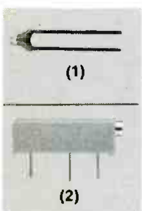


Computer/Business Machine AC Power Cords. 6 ft. HP (CEE-type) connectors. UL listed.

(1) Extension. #278-1259 . . 4.99

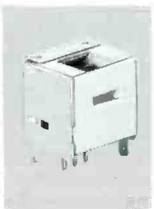
(2) 90° Type. #278-1260 . . . 5.99

(3) With Straight CEE Connector. #278-1257 . . . . 3.99

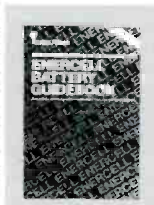


(1) Hi-Precision Thermistor. Low-cost, high-quality temperature sensor. #271-110, 1.99

(2) 15-Turn Trimmer Pots. ¾-watt. 1k, #271-342. 10k, #271-343. 20k, #271-340, **Ea. 1.49**

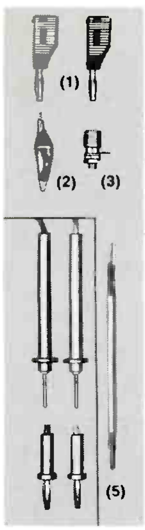


Infrared Module. Ready-to-use module for remote-control projects. Combines an IR detector, limiter and demodulator in a compact 3-lead package. 5VDC. With data. #276-137 . . . 3.49



ENERCELL® Battery Guide. Complete data on all ENERCELL batteries plus basic battery information and tips to help you choose the right battery for the job. Over 230 pages. #62-1304 . . . 5.95

Mini Audio Amplifier. Perfect for use as a test-bench amp and for computer voice/music synthesis. Built-in speaker plus ⅛" headphone jack, ⅛" input jack, volume control. #277-1008, 11.95



(1) Stackable Banana Plugs. Jack for "chain" hookup. One red and one black. #274-734, **Set 1.59**

(2) Package of 10 Jumper Leads. 14" long. Mini 'gator clips. #278-1156 . . 3.99

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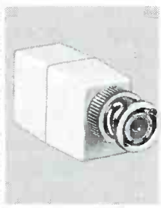
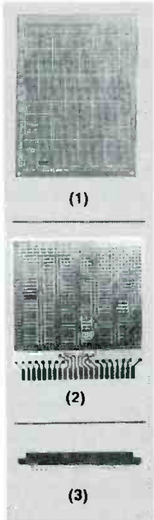


Modular Balun. BNC male connector to standard modular phone jack. Lets you use phone cable in place of more costly shielded cable in computer network hookups. #276-1410 . . 16.95



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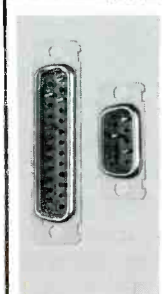

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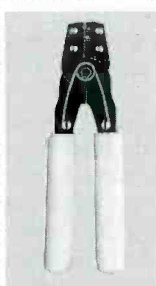

D-Sub Pin Crimping Tool. This professional steel tool makes it easy to install D-sub connectors. Accepts #20, #24 and #28 pins. Comfortable cushioned handles provide a firm, secure grip. 6⅞" long. #276-1595 . . 9.95

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CIRCLE NO. 115 ON FREE INFORMATION CARD

Radio Shack's Super-VGA SX

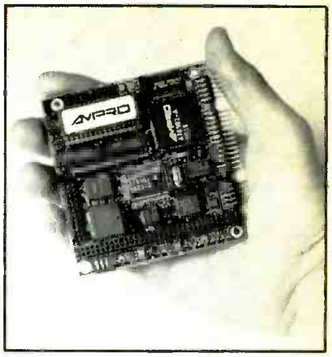
Radio Shack's Tandy 4020 SX PC is a 20-MHz 80386SX-based desktop computer with super VGA graphics. The 4020 SX comes standard with 2M of RAM (expandable up to 16M). With super VGA graphics built-in, the 4020 SX offers a resolution of 640 × 400 in 256 colors. Expanding video memory from 256K to 512K increases resolution to 640 × 480 in 256 colors or 1,024 × 768 in 16 colors.

The 4020 SX accepts high-performance, plug-in SmartDrive IDE hard-disk drives without the need of a separate controller. SmartDrives are available in either 52M or 105M capacity. SCSI hard drives and tape backup systems are also supported.

Standard features include one 3.5″ 1.44M floppy-disk drive, a 3.5″ expansion bay, three 16-bit slots, a 101-key enhanced keyboard, a socket for an 80387SX, a clock, a 100-watt power supply and ports for serial, parallel and mouse connections. Weighing only 14 pounds, dimensions are 15.5″W × 15″D × 4.25″H. Price is $2,499.

CIRCLE NO. 134 ON CARD

Embeddable PC Engine



Ampro now offers IBM-compatible CoreModules that measure only 3.86″ × 3.6″ × 0.6″. In spite of their small size, they are fully configured PC-compatible CPU modules with memory, solid-state "disk," serial and parallel I/O ports, real-time clock and keyboard and speaker interfaces. Each CoreModule can be used alone as a component-like compatible engine, or it combined with Ampro's MiniModule expansion peripherals to build complete systems.

CoreModule/XT is equipped with a CMOS-enhanced 8088-compatible microprocessor and a full complement of PC-compatible DMA controllers, interrupt controllers and timers. The microprocessor operates at 9.82 MHz. On-board sockets support 256K, 512K, 1M or 2M of DRAM, and the unit supports EMS 4.0 for full-memory access. An AT-compatible version will be available later this year. Production-quantity pricing for the XT module is $100. A CoreModule/XT development kit is available for $895.

CIRCLE NO. 135 ON CARD

Industrial Electronics For Technicians

By Same Wilson
(Tab Books. Soft cover. 318 pages. $16.95)

This is primarily a study guide for those preparing for a CET examination. Each chapter presents a discussion of material that is likely to be included on the examination. The student can judge his progress by taking the "self test" at the end of each chapter. Answers are provided for instant feedback on the exam questions. Numerous schematic and block diagrams are included. Topics covered include basic electric and electronic components, switching components, digital logic and microprocessors, power control, power supplies, motors and generators, robotics, circuit theory and measurement and troubleshooting. The writing style is clear and easy to read.

CIRCLE NO. 136 ON CARD

LaserJet Print Compression Utility

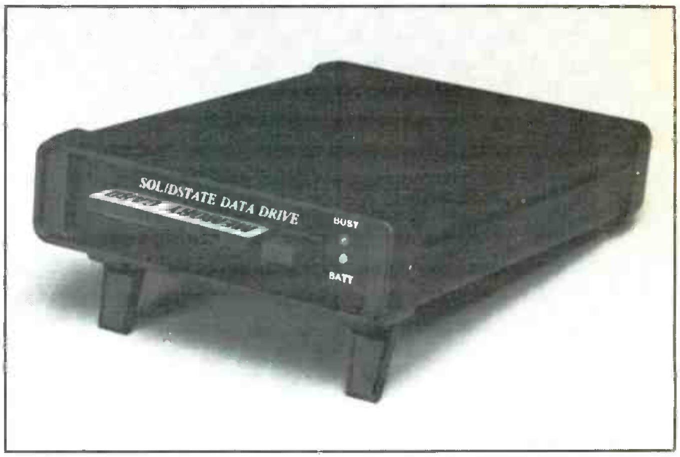
TreeSaver (Version 2) from Discoversoft allows LaserJet printers to print two or four pages on one sheet of paper, thereby saving paper, toner and time. *TreeSaver* "photo reduces" full-size pages so that users can fit output on any size page, such as those for personal organizers. Soft fonts are supported, and *TreeSaver* comes with two soft fonts. Other improvements include finer control of scaling factors and placement of text, as well as enhanced support for additional LaserJet models, including the LaserJet III. *TreeSaver* works with IBM and compatible computers running MS-DOS 2.1 or later. Price is $89.95.

CIRCLE NO. 137 ON CARD

Solid-State Data Drives

Adtron's SolidState Data Drives offer an easy way to transfer data and programs between memory cards (used in notebook computers) and desktop or host computers. The drives permit direct, effortless access to memory card technology. They are as simple to use as a floppy-disk drive and can eliminate the need for portable-to-desktop link software. Device drivers can configure the SolidState Data Drives to use the MS-DOS file structure that, in turn, permits use of such standard DOS commands as COPY, DIR and DEL. The interface protocol is available for applications that are not MS-DOS based.

SolidState Data Drives interface with standard I/O ports and floppy-disk controllers, allowing almost any computer to utilize memory cards. Adtron's drives read and write battery-backed static-RAM memory cards and incorporate programming logic control for EPROM/OTP, FLASH and EEPROM memory technologies. The drives support the 68-pin PMCIA and JEIDA 4.0 standards.



CIRCLE NO. 138 ON CARD

Print-Sharing System

Data Spec's Para-Link Plus is a modular printer-sharing system that enables up to 16 users to send data to a single parallel printer over a 1,200-ft distance. Para-Link Plus configures in a daisy-chain or backbone topol-

The system transmits data up to 6,000 characters per second without sacrificing reliability. Para-Link Plus features collision-avoidance technology, with selectable time-outs for each PC, to assure peak per-

ogy. Individual transmitters plug into the parallel ports of IBM and compatible computers, and a similar receiving unit attaches to the printer parallel port. An RJ-11 cable (included) connects the units. External power is not required.

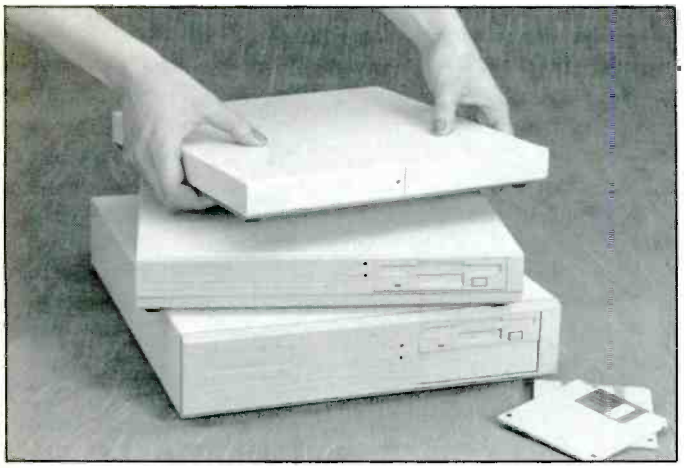
formance at high speeds. The Model PL3 has all equipment needed for sharing one printer between two PCs and sells for $199. Each expansion kit adds a single PC and costs $74.95.

CIRCLE NO. 139 ON CARD

Low-Profile Enclosures

Enclosure Technologies (ETI) has three new models of low-profile computer enclosures in

1200 measures 14.75"D × 11.9"W × 2.75"H and accommodates everything the Model



its 1000 series. Model 1000 is a disk or diskless workstation enclosure measuring 10.75"W × 10.75×D × 1.25"D. The Model 1100 measures 13.88"D × 11.5"W × 1.75"H and holds a 3.5" floppy drive, a hard disk and other options. The Model

1100 does plus two standard ISA ISA expansion boards and a second floppy drive. ETI offers custom assemblies up to full-system integration, as well as custom front panels, colors and graphics.

CIRCLE NO. 140 ON CARD

Digital And Microprocessor Fundamentals

By William Kleitz
(Prentice Hall. Hard cover. 482 pages. $52)

Aimed at the "digital novice" who must be brought up to speed on microprocessors, this book provides the fundamental concepts that are essential for a solid foundation in digital electronics and microprocessors. "Nice to know" topics have been omitted. The text starts with digital number systems and moves on to gate operation, with emphasis on combinational logic circuits and reduction techniques. Data control devices, sequential logic, counters and shift registers and interfacing to the outside world are discussed. The microprocessor chapters use the 8085A microprocessor and 8051 microcontroller to explain the fundamentals of microprocessor architecture, programming and hardware. Microprocessor coverage is approximately 50% hardware and 50% software.

CIRCLE NO. 141 ON CARD

Circuit-Design Program

BSOFT is now shipping version 2.5 of *CompDes*, a computer-aided circuit-design program. It is a menu-driven electronic cookbook software-design tool that offers menu selections from basic electricity through circuit design. Many new menu options have been added. The user's manual takes a tutorial approach. Screen displays of circuits can be printed for hard-copy. Design aids are provided for making proper selection of component size. Full input error trapping simplifies design troubleshooting. System requirements are an IBM or compatible computer with DOS 2.1 or later, at least 256K of RAM and a color graphics display. Price is $49.95.

CIRCLE NO. 142 ON CARD

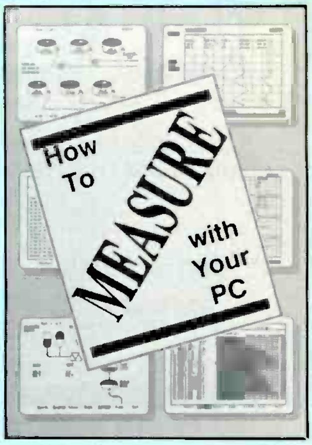
Hard Disk On A Card

Western Digital's FileCard, which plugs into an empty expansion slot, is available in two models: 20M and 30M. This easy-to-install disk-on-a-card is reliable and economical. Both models are compatible with IBM XT/ATs and compatibles, as well as the PS/2 Model 30.

CIRCLE NO. 143 ON CARD

Free Booklet

Dianachart offers a free 66-page booklet, "How To Measure With Your PC," to *Computercraft* readers. The booklet describes different types of data-acquisition hardware for PCs and explains which are best suited to different applications. Topics covered include connecting thermocouples, RTDs, thermistors strain gauges and pressure transducers. Various programs for analyzing and presenting data are discussed.



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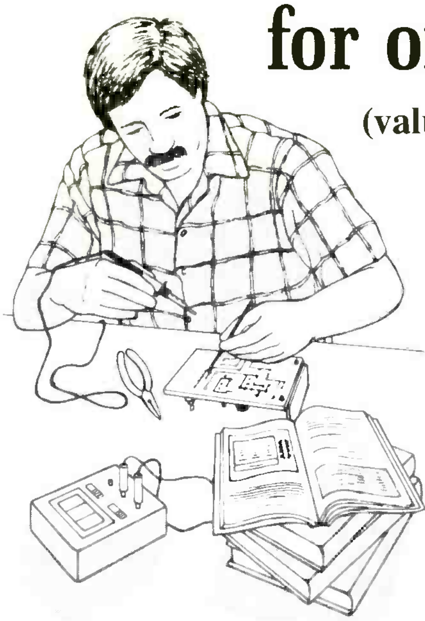

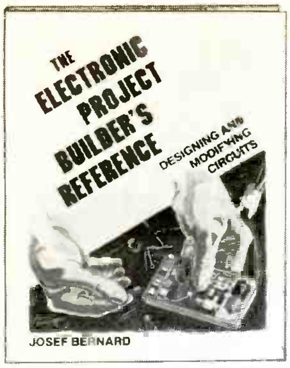

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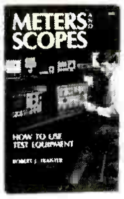

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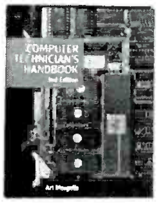

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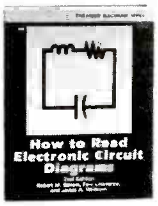

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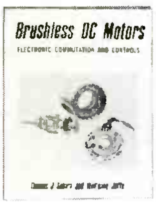

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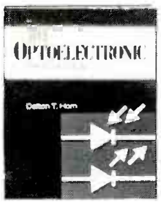

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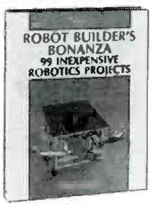

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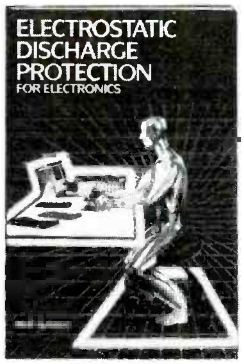

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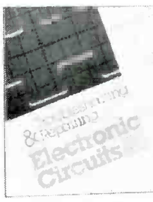

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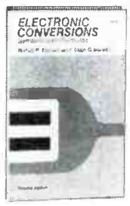

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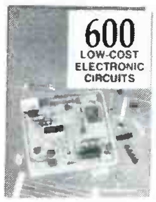

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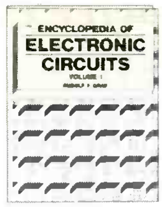

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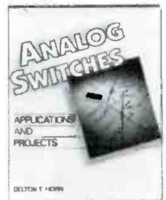

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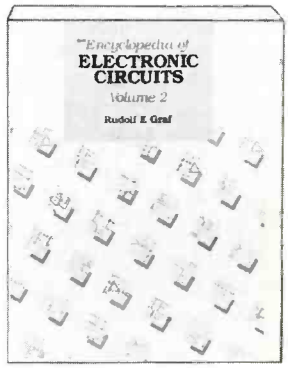

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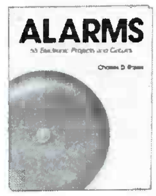

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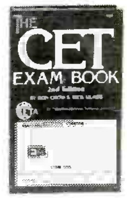

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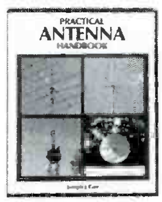

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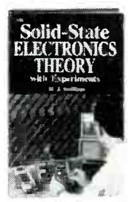

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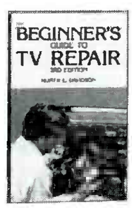

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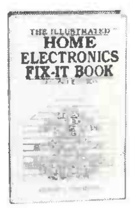

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Upgrading Your PC ROM BIOS

How to stretch your older computer's capabilities by substituting a correctly matched later-version BIOS chip

Like most PC users, you probably take the operation of your PC for granted. You install the latest program and expect it to operate according to the raves in recent reviews. You copy data files onto a diskette to give to a friend, expecting him to have a compatible disk drive.

But as your computer ages, it increasingly falls behind current technology and lacks capabilities needed for efficient usage. You find that the new program you were eagerly awaiting will not work on your system. You install a 3½-inch floppy drive for compatibility with your friend's system, only to discover that it will not work on your system. With this discovery frustration mounts.

The primary key to IBM compatibility and supporting special functions rests with the system ROM (Read-Only Memory) BIOS (Basic Input/Output System). While the hardware design of the system motherboard must also be correct to ensure complete compatibility—with the correct interrupt controllers, DMA controllers, serial ports and so on—this tends to be the easy part, and most systems are compatible hardware-wise. A large majority of the compatibility and functionality problems PC users experience come from the BIOS implementation.

Common problems that can be attributed to your BIOS include an inability to operate a 1.44M 3½-inch floppy-disk drive, the inability to run Microsoft *Windows* and being incapable of working with certain hard-disk drives, among others. Particularly in light of the growing popularity of 3½-inch drives and Microsoft *Windows* 3.0, these problems are obviously very significant. Other frustrations may include being unable to support EGA or VGA video adapters, no support for a hard drive at all and or being incapable of using more than one serial (COM) port.

Fortunately, these deficiencies can be overcome simply by installing a replacement BIOS in your system. Replacement BIOSs are readily available and are easily installed. Besides correcting compatibility problems, a replacement BIOS can also offer other desirable features, including SETUP in ROM (for 286 and 386 AT systems), improved power-up diagnostics, extended system diagnostics in ROM, larger tables of supported hard drives, a user-configurable hard drive table and system password protection. Although installing a replacement BIOS is not difficult, the important thing is to get the right replacement BIOS for you.

What Is A BIOS, Anyway?

The BIOS is a special program stored in ROM or EPROM on your system motherboard. Essentially, it determines your computer's "personality." Its primary function is to isolate the system software (your application programs and even DOS) from its hardware. Thus, the BIOS is hardware-specific, but it allows your programs to be non-hardware-specific.

For example, a program can make a call to the BIOS to get character input from the keyboard. While the keyboard interface circuitry on an XT system is substantially different from that on an AT machine, the program never knows the difference because the BIOS call is the same in either case—the BIOS itself takes care of hardware-specific details. The BIOS provides other calls for such functions as accessing disk drives and performing certain video functions. Note that higher-end video adapters, including EGA and VGA, include their own "video BIOS," which basically acts like an extension to the system ROM BIOS.

Since, being ROM-based, the BIOS is always present, it is the first thing executed by the microprocessor when the system is turned on. The BIOS initially performs a Power-On Self Test, or POST. The POST tests various system functions for proper operation and usually spends most of its allotted time testing system memory. After the POST is completed,

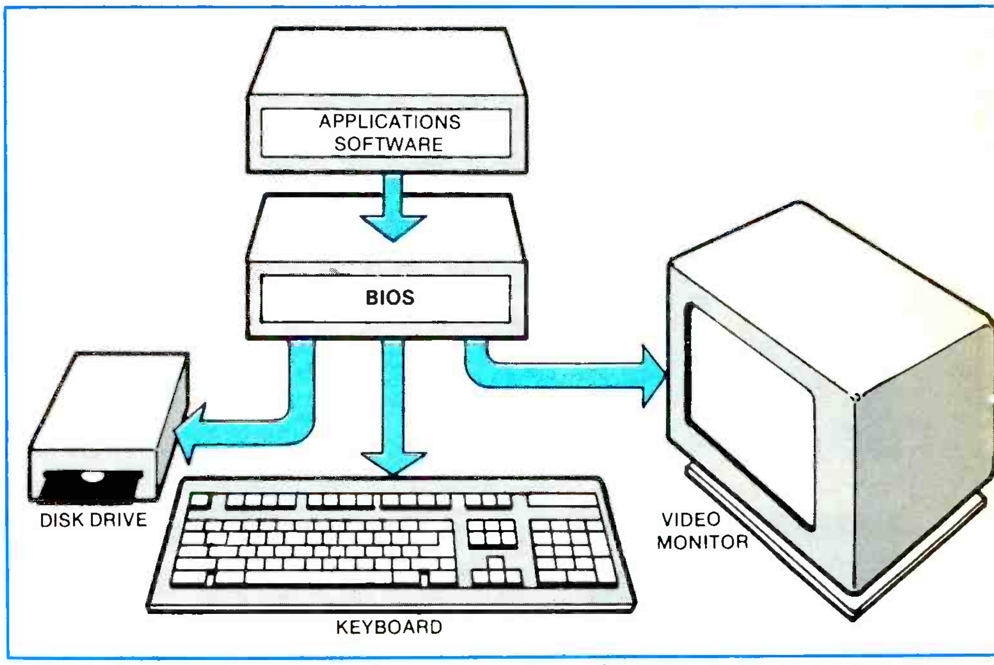


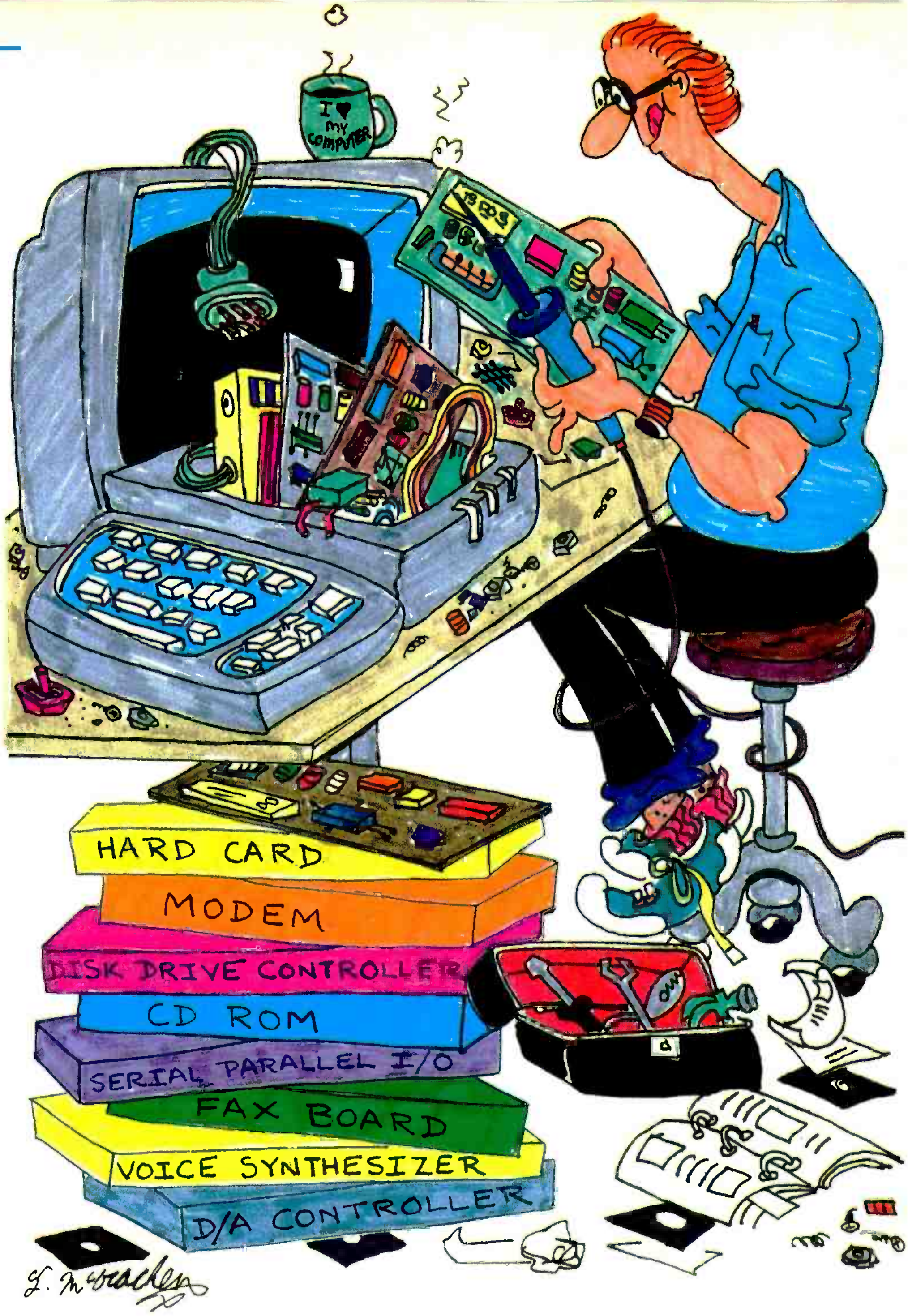
Fig. 1. The BIOS's main function is to isolate application programs (and DOS) from hardware-specific details.

the BIOS boots the system, either from an inserted diskette or from the hard drive. BIOS functionality is illustrated in Fig. 1.

In the early days of PC clones, the BIOS became a focal point of attention. Early cloners developed their own system motherboard, the hardware, and simply copied IBM's PC BIOS to achieve the desired IBM compatibility. It didn't take long, however, for the courts to agree with IBM in calling this copyright infringement and forcing the clone makers to cease copying the IBM BIOS.

Some clone makers simply closed their doors. Others, like Compaq, chose to develop and maintain their own compatible BIOS. Still other cloners began looking for a third-party alternative.

Realizing the sizable market potential, a start-up company, Phoenix Technologies Ltd., developed an IBM PC-compatible BIOS in a "clean-room" environment for sale to clone manufacturers. The BIOS was guaranteed to not infringe on the IBM copyright. The Taiwan government also supported an effort to develop a non-infringing BIOS, which was made available to Taiwanese clone manufacturers. The success of the third-party PC BIOSs, led primarily by Phoenix, paved the way for several other companies to enter the market. Now other leading PC BIOS manufacturers include Award Software, American Megatrends, Inc. (AMI), and Quadtel Software.



How Do BIOSs Differ?

When selecting a replacement BIOS, it's important to realize that BIOSs differ in many ways. You must determine what your exact requirements are in order to get the right BIOS for your system. The most fundamental differentiation between BIOSs is determined by which microprocessor or architecture your system has; the BIOS is different depending on whether you have a PC, XT, AT or 386AT (including 386SX and 486) system. Beyond processor type, you must also know the type of "chipset" on your motherboard, if any.

Chipsets are high-integration devices that are commonly used to replace the peripheral chips and control logic on a PC motherboard, such as interrupt controllers, DMA controllers and bus buffers. Older motherboard designs used discrete peripheral chips, while virtually all designs done in the past several years use either a custom or standard chipset.

Popular chipset manufacturers include Intel, Chips & Technologies (CHIPS), VLSI Technology, Western Digital (Faraday), Zymos, Headland (G-2) and Suntac. There are typically between two and five large chips in a chipset, and they can usually be easily identified on the motherboard. Look for large devices (generally in the area of the CPU) labeled with one of the names listed above. If you are not sure, you can usually get assistance from the company that sold you the computer or one of the replacement-BIOS suppliers.

In addition to chipset-specific BIOSs, most replacement BIOS suppliers offer "generic" BIOSs specific only to a particular CPU or system type. These work with non-chipset

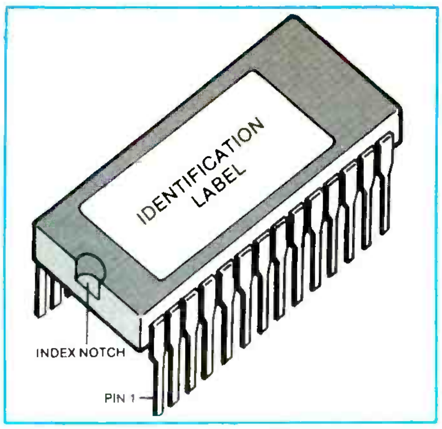


Fig. 2. Methods of identifying pin 1 of BIOS ROM chips.

motherboards, and work acceptably with many chipset-based motherboards. Most modern chipsets, however, have configuration registers that must be initialized to specify many of the system operating parameters, such as memory access timing, or to enable certain desirable features, such as shadow RAM (placing the BIOS in RAM after boot for faster operation).

Using a generic BIOS with chipsets designed to be configured usually results in compromised performance (slowest memory timing is always the chipset default) and inaccessible features (such as being unable to implement shadow RAM).

Sometimes BIOSs need to be even more specific than the particular chipset you are using. The BIOS may have to be configured for the particular speed your CPU is running or other motherboard-specific functions. To accommodate this, some replacement BIOS suppliers offer motherboard-specific replacement BIOSs for common motherboards. It is not uncommon for different clone manufacturers to use the same motherboard (such as Intel and AMI motherboards). When looking for a replacement BIOS, you should find out if a motherboard-specific BIOS is available for your system.

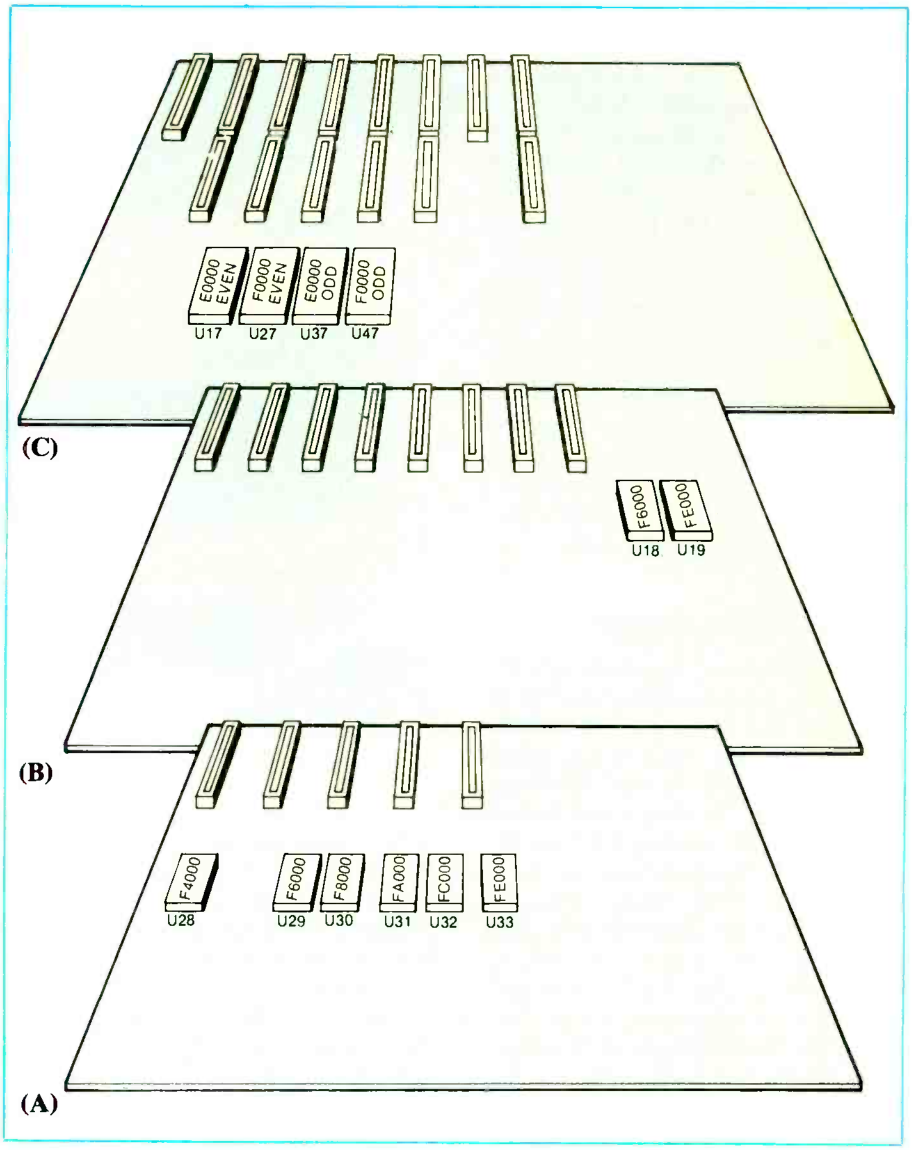
How To Select A BIOS

Before replacing your BIOS, you must decide what features you are looking for. There will most likely be a single compelling reason for upgrading, then several desirable features you would like to see in the new BIOS. The most compelling reasons for upgrading are related to compatibility. Early IBM PCs, for example, did not support an optional hard drive, but available upgrade BIOSs permit hard-drive support.

Similarly, early PC, XT and AT BIOSs support only an 84-key keyboard, while later ones can also support the newer 101- and 102-key keyboard. And while EGA and VGA video-adapter boards include their own on-board video BIOS, some ROM BIOSs do not support these adapters; so you may have to upgrade to one that does if you want to use one of these video adapters.

Many older PCs were designed around the standard 5¼-inch floppy-disk drives. PC and XT systems, for example, typically include a floppy controller and BIOS that supports only the double-sided, double-density (DSDD) 360K floppy-disk drives. There is no support for the 1.2M floppy drives or the newer 3½-inch drives. Similarly, while the floppy disk controller (hardware) in most early AT systems supports the popular 3½-inch floppy drives, in addition to the 360K and 1.2M 5¼-inch drives, the AT BIOS often lacks support for the high-density 1.44M 3½-inch drives.

In the case of PC and XT systems, you can purchase a replacement floppy-disk controller board for your system that can support all of standard floppy drives. It includes an on-



Outlines of the IBM PC (A), XT (B) and AT (C) motherboards show positions of the ROM BIOS sockets. These are only for true IBM computers.

board BIOS extension (executed automatically at power-up) that permits your system to support these drives. The same controller/BIOS can be used in AT systems as well, if the AT ROM BIOS does not already support the 3½-inch drives. If you later upgrade your PC, XT or AT ROM BIOS to support these drives directly, you can disable the BIOS extension on the floppy controller.

Note also that DOS version 3.0 or later is required to support the 1.2M drives, version 3.2 or later is required to support the 720K 3½-inch floppy drives, and version 3.3 or later is required to handle the 1.44M drives. According to the replacement-BIOS suppliers, 1.44M floppy-drive support is one of the biggest reasons for users to upgrade their system BIOS.

Most AT systems use an (MFM) ST-506 hard-drive interface, as used by IBM in its original AT. The AT BIOS includes support for the ST-506 hard-disk controller and includes a "drive type" table which determines the hard drive types or configurations supported. Each entry in the hard-drive table specifies the number of cylinders, heads, sectors/track and precompensation (precomp) for a drive. When you install a hard drive, you must specify the drive type using the system SETUP utility, which then stores the drive type in battery-backed CMOS memory (in the real-time clock).

Unfortunately, the original AT BIOS included support for a only handful of drive types. If you try to install a drive that is not fully supported by the BIOS, you end up using a drive type that is close to the one you're installing, but usually with fewer cylinders. As a result, you cannot use the full capacity of your drive.

Newer replacement BIOSs include an extensive drive-type table, often with 35 to 40 entries to choose from. Some Award BIOSs now include some user-definable hard-drive table entries; so you can even specify the exact parameters for your hard drives if they are not already present in the table. So do some Phoenix BIOSs, one of which has 47 drive entries plus two user-definable ones that can be set up by a user. Hard-drive-type support is a popular reason for moving up to a newer BIOS.

As I mentioned, support for Microsoft *Windows* 3.0 is another major reason for moving up to a newer BIOS. In order to do its magic, *Windows* takes advantage of the protected-mode operations of 286 and 386 processors. Microsoft developed its DOS Protected Mode Interface (DPMI) for coordinating protected-mode operation with other system software. Many system BIOSs, however, do not handle protected-mode operation to the satisfaction of *Windows* and, therefore, must be replaced with a newer version for proper support. Replacement BIOS suppliers are doing brisk business in supporting *Windows*.

All 286 and 386 AT systems come with some form of SETUP utility to specify memory configuration, drive types, real-time clock settings and other information. While in the past this has been primarily offered as a disk-based utility, it has now become standard practice to put SETUP in ROM with the BIOS itself. Consequently, make sure your replacement BIOS includes SETUP in ROM. In addition, one supplier—Upgrades, Etc.—even offers extended system diagnostics in ROM as an option with its AMI BIOSs.

For folks desiring greater system security, Award now offers password protection with its AT BIOSs. Once the password-protection feature has been enabled, the BIOS requires a user to enter the proper password before it will complete system boot. If the correct password is not entered, the system will not boot.

Table 1 provides a summary of what you need to know and what to look for in a replacement BIOS.

Table 1. Replacement BIOS ROM Considerations

Processor Type	8088, 8086, V20, V30, 80286, 80386, 80386SX, 80486
Processor Speed (MHz)	4.77, 6, 8, 10, 12.5, 16, 20, 25, 33
Chipset Manufacturer	None Chips & Technologies (CHIPS) VLSI Technology Western Digital (Faraday) Zymos Headland (G-2) Suntac
Motherboard Manufacturer	Intel or look-alike American Megatrends, Inc. (AMI) Compaq IBM
BIOS-Supported Functions	Windows 3.0 High-density floppy drives (especially 3½-inch, 1.44M) SETUP in ROM Improved POST diagnostics Extended diagnostics in ROM Multiple COM ports Hard drives (in general) Specific hard drives (must know cylinders, heads, sec/track, precomp) Password protection

Replacement BIOS

Once you determine what you want in your replacement BIOS, the obvious next step is to find the BIOS. Several suppliers sell replacement BIOSs (see Table 2). It is best to contact at least a couple of them and compare offerings and prices. Most suppliers include a money-back guarantee if the BIOS does not work with your motherboard. *This is highly recommended.* In addition to the suppliers

Table 2. Replacement BIOS Suppliers Sampler

Komputerwerk, Inc.
(Award BIOS & some specials)
851 Parkview Blvd.
Pittsburgh, PA 15215
Orders: 800-423-3400
Technical: 412-782-0384

Komputerwerk of Virginia, Inc.
(Phoenix BIOS and upgraded original IBM PC)
8133 Forest Hill Ave.
Richmond, VA 23235
804-320-8835

Unicore Software
(Award BIOSs)
599 Canal St.
Lawrence, MA 01840
800-800-BIOS
800-800-2467
Fax: 508-683-1630

Upgrades, Etc.
(AMI, AWARD & Phoenix BIOSs)
15822 NE 165 St.
Woodinville, WA 98072
800-541-1943
Fax: 206-881-8294

listed in Table 2, many local computer stores and service centers also offer replacement BIOSs for systems they sell or service.

Depending on particular BIOS, supplier and target system, replacement BIOSs vary in price from about $25 to about $95. For example, Komputerwerk of Virginia's ROM BIOS retail prices are: upgraded original IBM PC, 1989: $79.95; AT: $89.95. The company says it has identified BIOSs for 150 computer brands.

To get the right replacement BIOS, you must also know what type of EPROM is used to store your existing BIOS. Most PC and XT machines have a single BIOS EPROM that may be a 2764 or 27128 ROM. Some XT machines are developed around the 16-bit 8086 (or NEC V30) processor instead of the eight-bit 8088 (or NEC V20) processor. These 16-bit machines typically include two 2764 EPROMs instead of one, since the BIOS is split into even bytes and odd bytes for the 16-bit data bus. Likewise, 80286-based machines generally contain two EPROMs (usually 27256's) split into even and odd bytes. This is also true for most 386s even though the 386 itself has a 32-bit data bus. Most 386 chipsets provide for a 16-bit data path for the BIOS, since the BIOS is typically shadowed (placed in a reserved area of RAM) after boot, anyway. The supplier can help make sure you get the right replacement BIOS for your system.

Though most replacement BIOS suppliers offer BIOSs from only a single manufacturer (often Award), some offer BIOSs from multiple manufacturers (including Award, Phoenix and AMI). Some PC users prefer to replace their system BIOS with one from the same BIOS manufacturer as already used in their system. They know it will work with their system, and they are familiar with the "personality" of the BIOS—including the particular error messages that are displayed and information shown on the screen during the POST. Award, for example, displays a fairly complete screen of test results as it proceeds through it POST.

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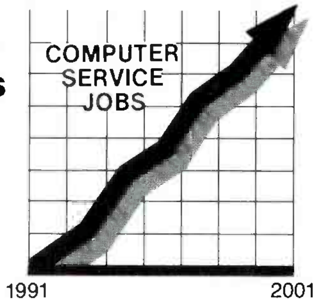

Jobs for computer service technicians will almost double in the next 10 years, according to the latest Department of Labor projections. For you, that means unlimited opportunities for advancement, a new career, or even a computer service business of your own.

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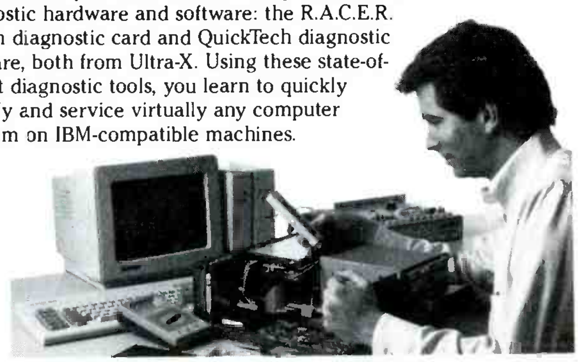

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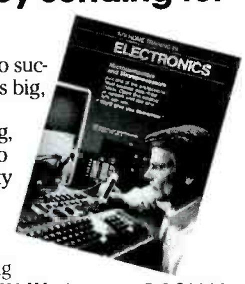

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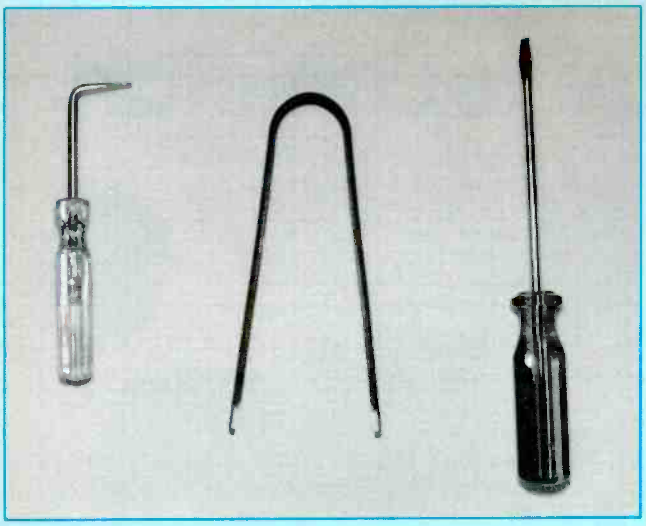
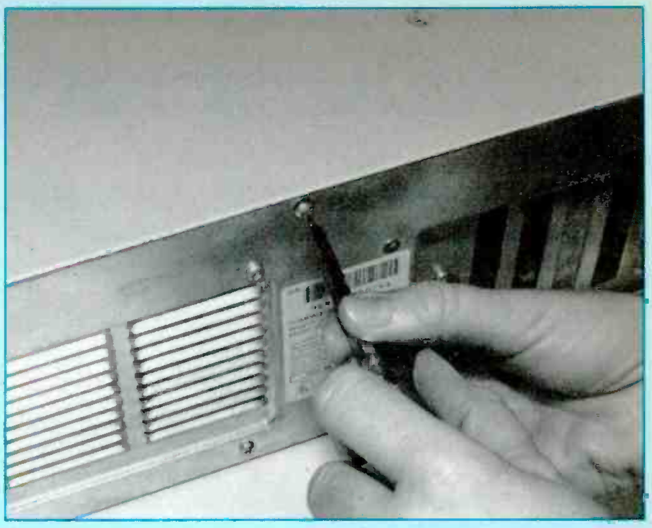


(A)



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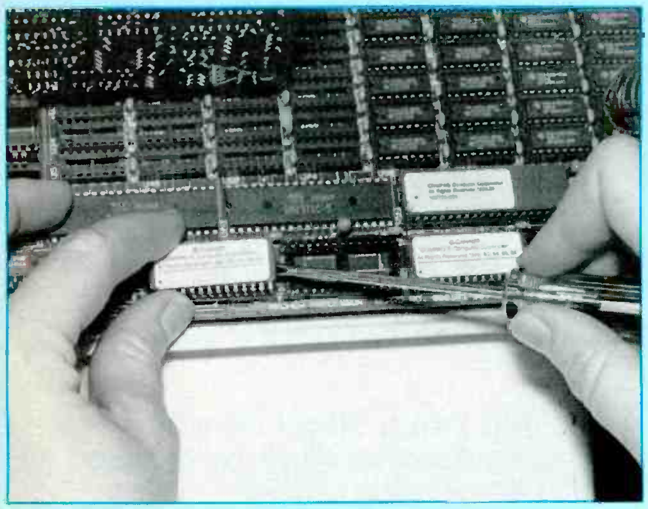
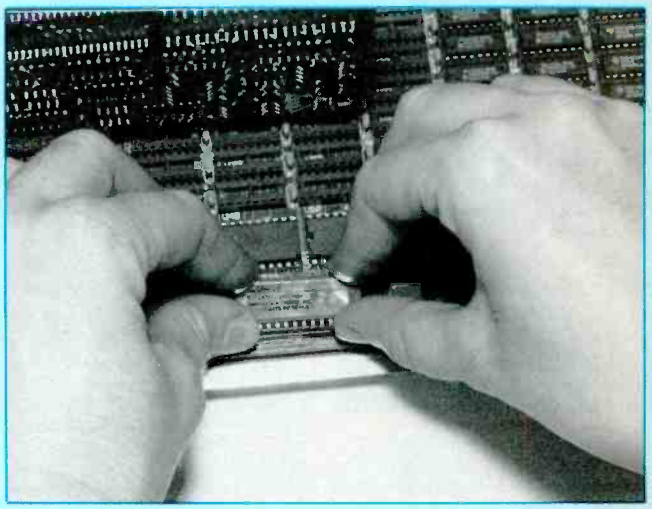


(C)



(D)

You need only the simple tools shown in **photo A** to remove the BIOS ROM in your computer and replace it with the upgrade ROM. Once you have these tools, your next step is to power down your computer and remove the cover of the system unit, as in **photo B**. Next, locate the ROM chips and carefully remove them from their sockets, as in **photo C**. Make a note of the pin 1 locations. Finally, exercising normal safe-handling procedures for MOS devices, plug the new ROM chips into the vacated sockets (**photo D**). Make certain that you properly orient each chip and that no pins overhang the sockets or fold under between ICs and sockets. When you are done, power up your computer to make sure the ROM chips are working properly. If they are, replace the system unit cover, and you are in business.

Phoenix, in contrast, displays less information during the POST but typically boots a little quicker as a result.

Replacing the BIOS

Once you have your replacement BIOS, the replacement procedure is fairly straightforward. Keep in mind that BIOS EPROMs are static-sensitive devices and require normal static precautions to be exercised (touching a grounded surface before picking up an EPROM, for one thing). Ideally, it is best to wear a properly grounded ground strap to keep yourself grounded throughout the entire replacement procedure. Some anti-static spraying in the work area cannot hurt, either.

Make sure the power to your system is turned off before you start. Remove your system's cover to provide access to the motherboard. Then remove add-in boards and/or disk drives as required to gain access to the BIOS EPROMs in your system. These 28-pin devices are generally easy to identify. They are usually socketed (which is important for the replacement procedure) and typically have a label on top that indicates a BIOS manufacturer copyright and BIOS version number.

More Information

The functionality of your ROM BIOS is related to its release date. You can determine the release date of your BIOS in any of several different ways. A number of PC utility programs will display the BIOS release date, including the SI (System Information) utility that is part of the popular *Norton Utilities*. If the DOS DEBUG utility does not intimidate you, you can enter DEBUG and type:

```
D F00:FFF0
```

and follow with an Enter.

DEBUG displays the 16 bytes at location FFF0 in the BIOS, where the release date is kept. If you look at the ASCII translation to the right of the 16 bytes, you will find a date in the format "05/09/86" (or something similar, depending on the actual date), which is the BIOS release date. (You must enter Q and then Enter to exit DEBUG.) You can also display your IBM BIOS release date by executing the following BASIC program:

```
10 DEF SEG = &HF000
20 FOR X = &HFFF5 TO &HFFFF
30 PRINT CHR$(PEEK(X);
40 NEXT
```

Listed in the accompanying Table are the release dates, and the relative BIOS-ROM positions for the three basic *IBM* motherboards (PC, XT and AT) are shown in the accompanying drawings. Keep in mind that these drawings apply to only IBM systems, and logic boards from other manufacturers may have the BIOS ROMs at entirely different locations.

Common IBM PC, XT and AT BIOS Releases

System	Date*	Additional Support Over Previous Release
PC	04/24/81	(Initial release, 64K motherboard, PC-1)
PC	10/19/81	256K motherboard (PC-2), with support for IBM's Expansion Unit
PC	10/27/82	Added BIOS "extensibility"—ability to add other ROMs in system to create extensions to standard ROM BIOS. Allowed support for 256K-bit DRAMs and memory greater than 544KB, as well as several IBM add-in functions, including the Cluster Adapter, 3278/79 Emulator Adapter, EGA Video Adapter, PC Network Adapter and hard-disk drives
XT	08/16/82	(Initial release)
XT	11/08/82	PC 3270 Workstation support
XT	01/10/86	Enhanced (101-key) keyboard support
XT	05/09/86	3½-inch, 720K drives
AT	01/10/84	(Initial release, 6 MHz, 20M hard disk)
AT	06/10/85	8 MHz
AT	11/15/85	Support for enhanced (101-key) keyboard, 30M hard drives, 6 MHz (!)

*This is the BIOS release date.

Using an IC remover or a small flat-blade screwdriver, carefully remove the existing BIOS chips from their sockets. Note the pin 1 position of the existing BIOS chips before removing them. This is often determined by a notch in the chip package, as shown in Fig. 2. For two-chip BIOSs, note which socket contains the even chip and which contains the odd chip (they may be identified as "low" and "high" instead of "even" and "odd," respectively).

Once the parts have been removed, carefully insert the replacement BIOS chips into the vacant sockets—again keeping the odd and even chips in the appropriate sockets. You must also make sure that pin 1 of each device is properly oriented. There is usually an orientation mark in the socket itself to identify the pin-1 side of the socket. If you are not sure, surrounding chips on the motherboard should also have the same pin-1 orientation. If necessary to install the new BIOS chips, bend the pins of the BIOS EPROMs slightly to permit a good fit into the BIOS sockets.

Reinstall the drives and boards you removed. You do not have to replace the system cover quite yet. Turn on the system and watch for signs of life. If the BIOS begins executing its POST, the ROMs are installed correctly. In an AT system, you may have to run SETUP with the new BIOS to save the correct checksum information in the battery-backed CMOS memory.

If after a few seconds you see no sign of life, turn off system power and inspect the installed BIOS EPROMs. First confirm that all of the EPROMs are correctly oriented with pin 1 in the proper place. Also verify that the replacement EPROMs are of the same type as those that were originally installed in your system. The most common problems are pins not correctly inserted in the socket. Look for pins sticking outside the socket or bent under between chips and sockets. Correct any problems and retry system boot. If this does not work and you have a two-EPROM system, try swapping the two EPROMs—you may have plugged the even and odd EPROMs into the wrong sockets. If you are still having difficulty, contact you replacement BIOS supplier for further technical support.

Conclusion

A replacement BIOS can add a lot of new life to an aging machine. Additionally, even an existing late-model BIOS could prove to be quirky when working with a large hard-disk drive (80M or more) and require replacement. With a new BIOS, you can take advantage of hardware and software functions that were previously off limits to you. Take the plunge and see what expanded functions and greater efficiency can do for you. ■

Roger C. Alford

Build A *Talking* Logic Probe

This vocal digital troubleshooting tool lets you concentrate on the circuit under test, rather than on a LED display, when making logic-level tests

A logic probe is an especially useful test device for checking out digital circuits. In its basic form, it indicates logic levels (1 or 0). This is commonly revealed by the proper LED lighting. The "Talking Logic Probe" goes a giant step further. As its name implies, it talks you through tests, rather than requiring you to take your eyes off the circuit point under test to look at a LED or other display.

This super logic probe uses a digitally synthesized voice to vocalize the condition of the circuit to which its probe is connected. Its four-word vocabulary consists of "high" to indicate a logic high, "low" to indicate a logic low, "open" to indicate a tri-state or high-impedance condition and "clock" to indicate a pulse stream. Furthermore, it handles TTL and CMOS components.

About the Circuit

Our Talking Logic Probe utilizes a unique combination of analog and digital circuitry to mimic a sophisticated microprocessor-based system. Using only the best of both types of technology, it lets you build a very sophisticated yet simple unit.

At the heart of the Logic Talker is a novel technique for digitally reproducing human speech patterns. This is accomplished by digitally recording an actual voice and burning (programming) isolated words as templates directly into an EPROM. This method of synthesizing speech isn't the most efficient way to go, but low EPROM prices let you be a little wasteful when it comes to memory space. In addition, this approach permits a much simpler circuit.

To reconstruct the speech pattern for a particular word, the address is selected on pins 2 and 26 of EPROM *U1* in Fig. 1. These two-bit combinations let you select one of the four words you want the project to vocalize. When the Logic Talker senses a change of input condition at the probe, it enables the CD4040 counter, which begins to sequence all possible addresses in *U1*. In this manner, the recorded voice "core image" is reconstructed through the simple "R-2R" digital-to-analog converter ladder. The changing analog speech signals are filtered and routed through the LM386 audio amplifier IC and reproduced through the speaker. This basic process is the heart of the Logic Talker's simplicity. All that remains is for the analog "logic" to decide what constitutes a high, low, open or clock-type input signal condition.

With the black test probe connected to circuit ground and red "hot" probe touching any other point in a

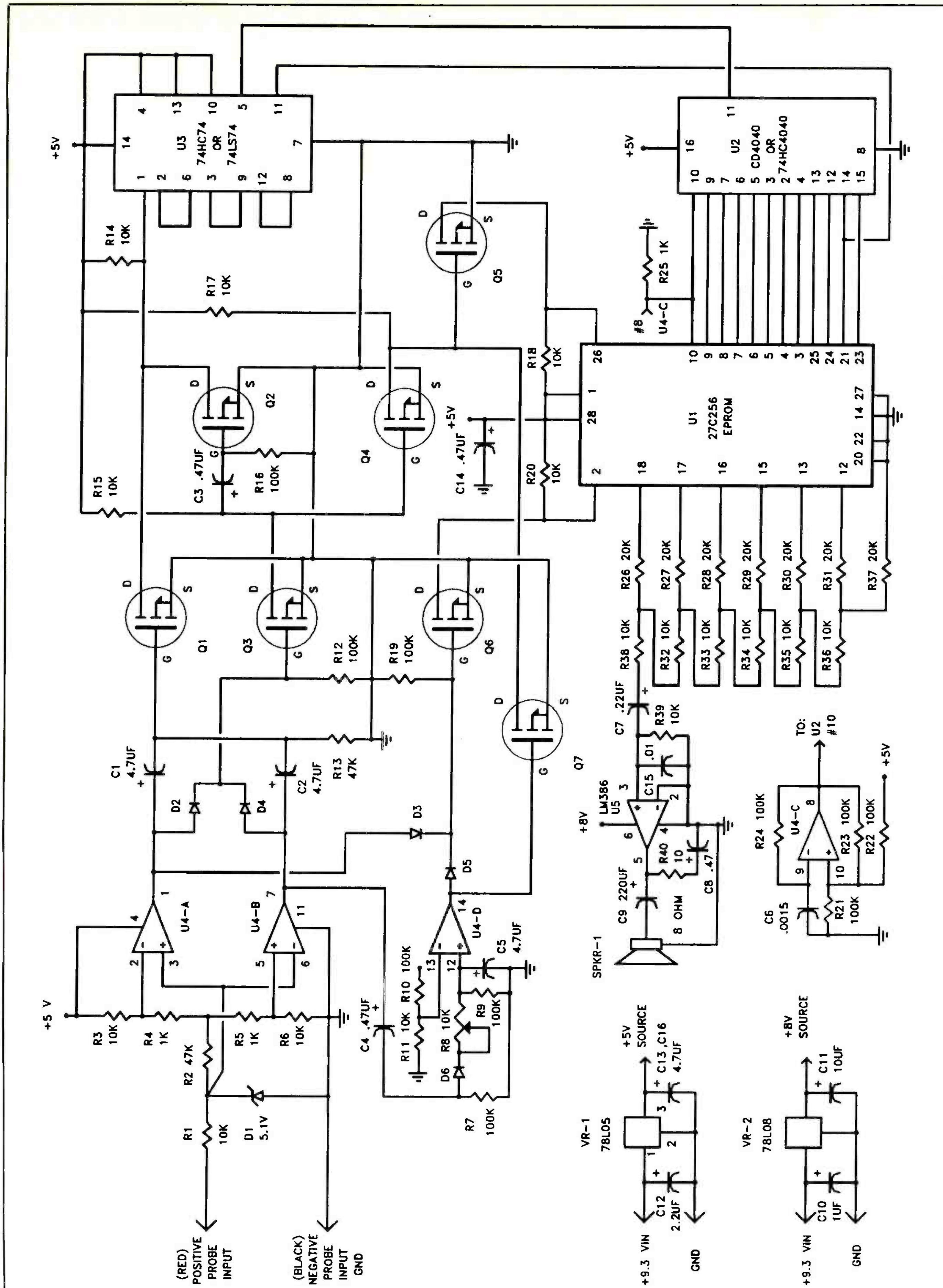


Fig. 1. Complete schematic diagram of Talking Logic Probe circuitry.

PARTS LIST

Semiconductors
D1—5.1-volt zener diode
D2 thru D6—1N4148 signal diode
U1—27C256 EPROM
U2—CD4040 or 74HC4040 counter
U3—74HC74 or 74LS74 flip-flop
U4—LM324 quad operational amplifier
U5—LM386 audio amplifier
Q1 thru Q7—VN0300 field-effect transistor (Siliconix)
VR1—78L05 fixed +5-volt regulator
VR2—78L08 fixed +8-volt regulator

Capacitors
C1,C2—4.7-μF, 16-volt axial-lead tantalum or electrolytic
C3,C4,C8,C14—0.47-μF radial-lead tantalum or electrolytic
C5,C13,C16—4.7-μF, 16-volt radial-lead tantalum or electrolytic
C6—0.0015-μF Mylar
C7—0.22-μF, 16-volt radial-lead tantalum or electrolytic
C9—220-μF, 16-volt radial-lead electrolytic
C10—1-μF, 16-volt radial-lead tantalum or electrolytic
C11—10-μF, 16-volt radial-lead tantalum or electrolytic
C12—2.2-μF, 16-volt radial-lead tantalum or electrolytic
C15—0.01-μF Mylar

Resistors (¼-watt, 5% tolerance)
R1,R3,R6,R11,R14,R15,R17,R18, R20,R39—10,000 ohms
R2,R13—47,000 ohms
R4,R5,R25—1,000 ohms
R7,R9,R10,R12,R16,R19,R21 thru R24—100,000 ohms
R40—10 ohms
R26 thru R31,R37—20,000 ohms (⅛-watt, 1% tolerance)
R32 thru R36,R38—10,000 ohms (⅛-watt, 1% tolerance)
R8—10,000-ohm upright pc-mount trimmer potentiometer

Miscellaneous
PS1—9-volt dc, 100-mA plug-in power supply (12 volts dc can be used)
SPKR1—8-ohm speaker with 2-inch Mylar cone
Printed-circuit board; dual banana-jack connector; enclosure (Pac-Tec No. 60247-1 front, No. 60246 back); hookup wire; solder; etc.

Note: The following items are available from U.S. Cyberlab, Inc., Rte. 2, Box 284, West Fork, AR 72774 (tel.: 501-839-8293): Mini kit containing critical and hard-to-find components, pc board, ICs, FETs, enclosure and front panel, $49.95. Also available separately: ready-to-wire pc board, $9.95; voice ROM (specify male or female), $9.95. An assembled Logic Talker with test leads and power supply is also available for $79.95. Add $2.95 P&H for ROMs, $3.95 for all other orders, except $4.95 for kit and assembled Logic Talker. Arkansas residents, please add 3% state sales tax.

circuit under test, a voltage is routed through the latter probe, which serves as the input to the Talking Logic Probe, through the over-voltage protection circuit consisting of resistor *R1* and 5.1-volt zener diode *D1*. Any voltage that exceeds the zener threshold is clamped at about 5 volts to prevent damage to *U4*. Values for *R1* and *R2* were chosen to minimize loading down the circuit under test.

The input voltage from the probe drives the noninverting (+) op-amp input of *U4A* at pin 3 and the inverting (−) input of *U4B* at pin 2. The reference ladder made up of *R3* through *R6* provides two voltages that are applied to pin 2 of *U4A* and pin 5 of *U4B*. This dual-comparator arrangement is called a "window" comparator because a dead zone or "window" is created in the output response at pins 1 and 7 of *U4*. This window comparator is the heart of the input logic.

When the "hot" input probe of the Talking Logic Probe isn't connected to any point in a circuit, *R2* sources enough current to the inputs of *U4* to hold the comparator output at pins 1 and 7 in the window or dead zone, with no output generated. Thus, with no input, the outputs of both comparators will be near 0 volt.

When the "hot" probe is brought near ground, the voltage at pin 6 of *U4* drops below the reference input at pin 5. This causes the output of *U4B* to switch on (+5 volts). Conversely, when the input probe is brought near +5 volts, it causes the output of *U4A* to swing high. In this manner, the Logic Talker can determine whether the input probe is connected to a low-voltage source, a high-voltage source, or if it isn't connected to anything. These "trip" (threshold) voltages can be adjusted to suit special requirements by changing the values of the reference ladder resistors.

Any time the input condition at the "hot" probe changes from the high impedance or open condition, to either high or low, the outputs at pins 1 and 7 of *U4* also change. This dynamic action is coupled through *C1* and *C2* to *Q1*. In turn, any high-to-low or low-to-high transitions in the window comparators produce short-duration pulses at the switching FET gate, which are subsequently inverted and level-shifted into pin 1 of 74HC74 flip-flop *U3*. This clearing pulse resets the speech latch circuit and permits the Logic Talker to vocalize a one-word response. As mentioned above, this is accomplished by the counting action of CD4040 up counter *U2* and master oscillator *U4*.

When *U2* has reached its upper count and the associated oral response has been vocalized, pin 14 of *U2* creates the timing pulses required to signal *U3* to latch (stop) the counting process. This one-shot action keeps the Talking Logic Probe from rambling on and on about the condition of the circuit under test.

The word to be vocalized is selected by circuit action on pins 2 and 26 of *U1*. A high input at the "hot" probe forces the output of *U4* at pin 1 to go high. This voltage is sourced through *D3* to the gate of *Q6*. The output of *Q6* is routed directly to pin 2 of *U1*. When the input to the "hot" probe is high, pin 1 of *U1* is low. This sets the appropriate address to locate the word "high." If the input is open or low, the output of *Q6* is high, which is also the logic level delivered to pin 2 of *U1*.

As described to this point, the Logic Talker will produce the audible words "high" and "low" for those respective inputs at the "hot" probe. To make the project respond to open-circuit and clock conditions requires additional circuitry.

From the above, you will recall that the window comparator responds to input status by creating an appropriate high or low output at pins 1 and 7 of *U4*. However, when the input signal is neither high nor low, the outputs of both comparators fall to 0 volt. This dead-zone action is sensed by *D2* and *D4*. While in this open condition, no current flows

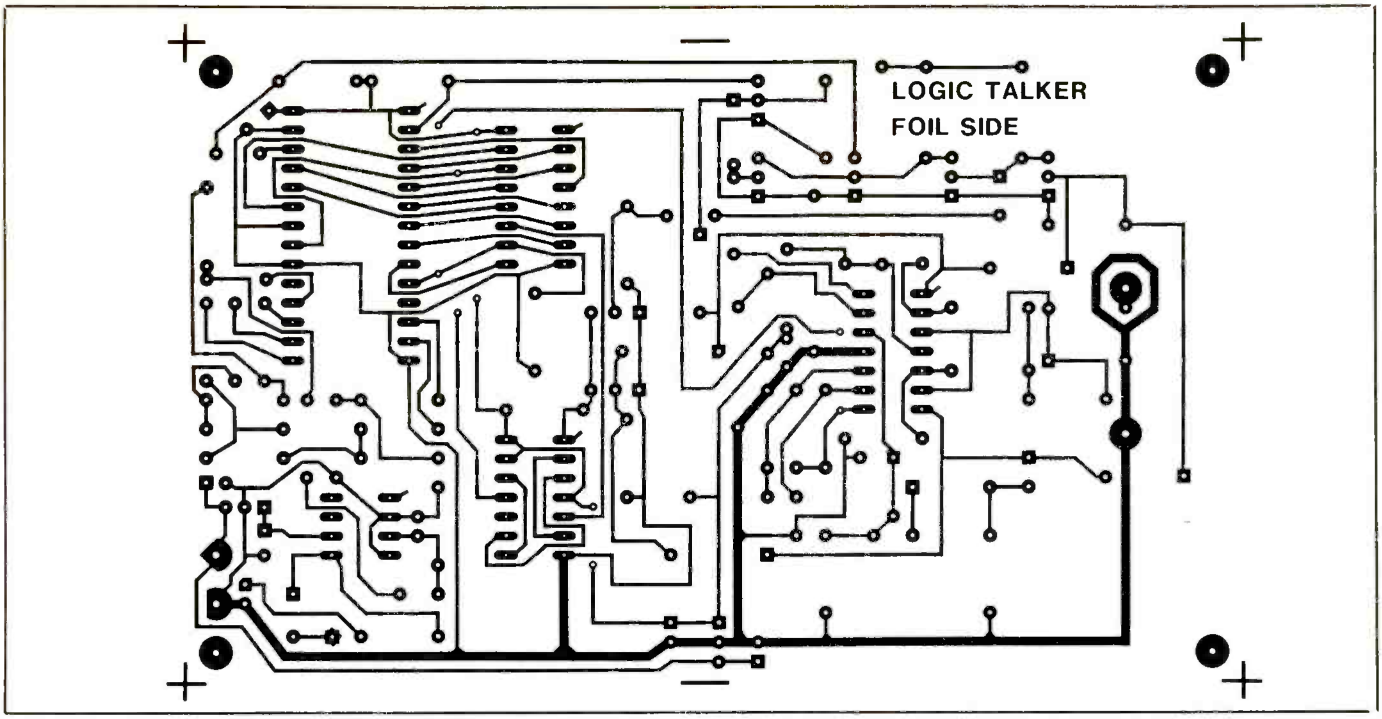


Fig. 2. Actual-size etching-and-drilling guide for printed-circuit board.

through either diode. As a result, the gate of *Q3* is pulled to ground by *R12*. The inverting action of *Q3* switches off the device, and the drain of *Q3* moves toward the +5-volt rail as current again flows through pull-up resistor *R15*. This positive-going voltage is coupled through *C3* into the gate of *Q2*.

Note that the drain of *Q2* connects directly across the drain of *Q1*. This permits both FET switches to be used in an open-drain, wired-OR configuration very similar to open-collector designs used in bipolar designs. By paralleling these two electronic switches, the voice of the Talking Logic Probe can be triggered anytime an open condition is sensed at the "hot" probe tip.

To select the word "open," one additional logic input state must be created at pin 26 of *U1*. This is accomplished by inverting open-drain sense transistor *Q4*. Again, the open-drain logic technique is used at the drains of *Q4* and *Q7*. This should

(Continued on page 80)

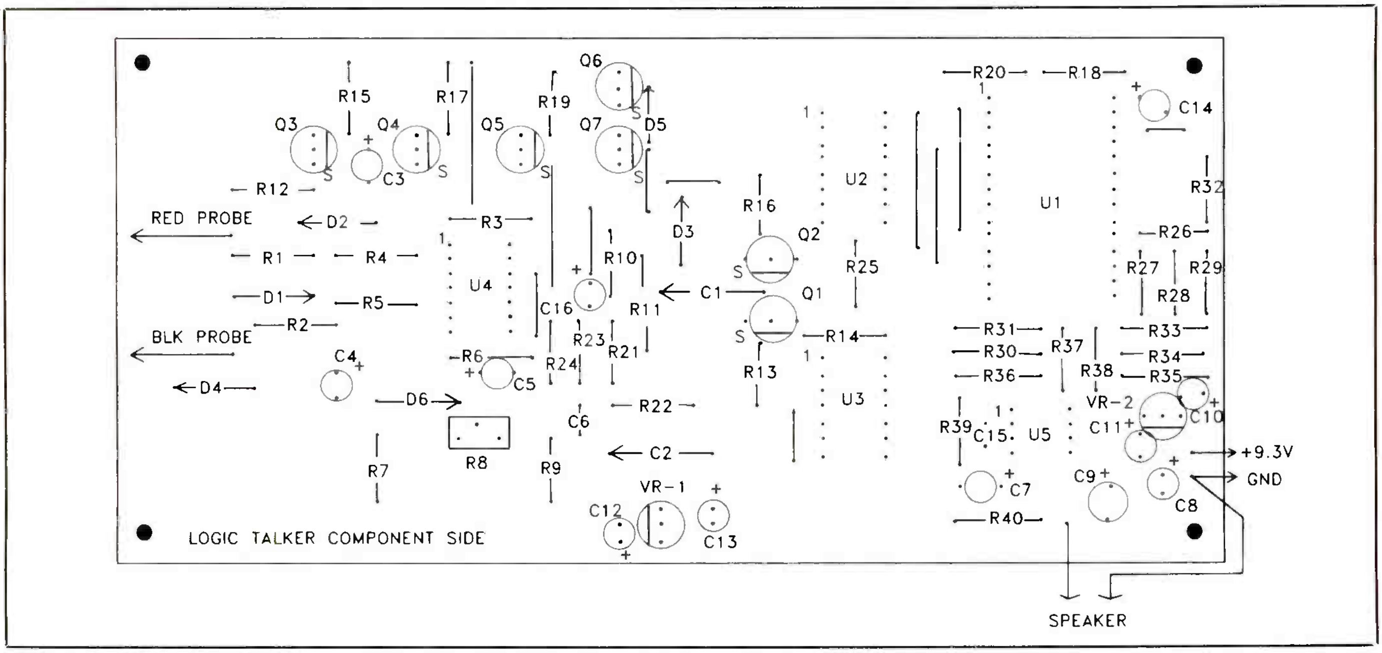


Fig. 3. Wiring guide for printed-circuit board.

Evaluating PCB Software for PCs (Part 2)

A close look at nine popular printed-circuit-board layout programs for PC/MS-DOS computers

In this installment of our series on circuit design software for the personal computer, we take a close look at popular printed-circuit board (PCB) layout programs and evaluate them for performance and features. The nine programs examined are intimately related to the eight schematic capture programs we reviewed in the January 1991 issue of *Modern Electronics*. They are *EE Designer III*, *HiWIRE II*, *OrCAD/PCB II*, *PCBoards*, *ProCAD*, *Protel-Autotrax*, *Protel Easytrax*, *Schema-PCB Layout* and *Tango-PCB Plus*. Three of them—*EE Designer III*, *HiWIRE* and *ProCAD*—also include schematic capture software, while the other six are stand-alone PCB layout programs. *EE Designer III* further provides analog and digital circuit simulation.

Prices of the programs range from $99 to $1,495. However, some require optional programs, like an autorouter, to make them fully functional. Average price of a fully-configured system is between $1,300 and $1,600, with one package (*Schema*) checking in at over $2,300. Buying the schematic capture software that it takes to make five of the nine complete circuit design systems adds another $500 or so to the cost. But before you throw up your hands, let us tell you that you can, indeed, buy a complete circuit design system, with schematic capture and an autorouter, that's suitable for hobby projects for under $300.

The link between the schematic capture and PCB software is critical in many ways. For example, three of the programs can't extract device outlines from the schematic netlist, forcing you to get the parts from their PCB libraries by hand. Forward and back annotation is also important, because it lets you keep up with changes made to either or both the schematic or PCB layout. This is particularly important when swapping gates or reassigning device references. Four programs have no annotation capabilities. One program, *Protel Easytrax*, is truly stand-alone since it doesn't interface with any schematic programs.

Of those programs that can extract device outlines from the netlist, all but one require that you define the board outline before parts can be placed. The one exception, *OrCAD/PCB II*, has you define a working area first. *Schema* requires both a board outline and a parts matrix before it can import parts from a netlist. Board outlines can be saved in a file, making it a simple matter of loading a stored outline from the database when it's needed. Most programs support boards up to 32 × 32 inches. One program can only support 9 × 13 and two can support up to 64 × 64 inches.

Three of the programs have an automatic parts placement routine that not only extracts the devices from the netlist, but places them on the circuit board. As a rule, the placement isn't as good as if you did it yourself, but it sure saves a lot of time. Seven of the nine support SMDs (surface-mounted devices). All the programs have a ratsnest to aid in placement and track routing; two programs have both a ratsnest and force vectors.

Four programs come with an autorouter that automatically draws tracks for you, and four offer an autorouter as an option. Only *Protel Easytrax* forces you to do it by hand, but even it has a pad-to-pad autorouter that makes the job easier. The number of copper layers support ranges from two to 64, with several of the mid-priced packages supporting six to eight layers. All but one lets you select the color of the layer. All let you change pad and via size, shape and orientation, but only two programs, *Schema* and *ProCAD*, let you use blind and buried vias. Seven of the nine programs have a design rule check function that catches broken tracks and spacing violations.

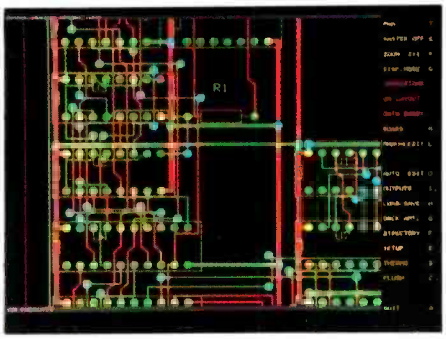
To test the effectiveness of the autorouters, we designed a benchmark circuit with 18 ICs and a handful of resistors and capacitors. We purposely mixed IC types to include linear, TTL logic and PROM chips. A schematic was drawn in the respective schematic capture program and the netlist imported to the PCB software for placement and routing. The results of the benchmark are reported in the individual reviews.

A hardware security device called a "dongle" that must be plugged into the parallel printer port before the program will load is required by five of the programs. One program, *ProCAD*, is copy protected, allowing a copy to be loaded onto only one hard disk at any one time.

Hard-copy printout varies considerably among the programs, but all support a dot-matrix or laser printer and HP or HI plotters, but you may have to pay extra for it. Gerber and Excellon N/C drill files used for automated manufacturing of circuit boards is supported by all but one program, but, again, these may be extra-cost items.

Here's how the programs stack up and compare individually.

EE Designer III from Visionics Corp.



EE Designer III ($1,900)
Visionics Corp.
3032 Bunker Hill Ln., Ste. 201
Santa Clara, CA 95054
408-492-1440
CIRCLE NO. 50 ON READER SERVICE CARD

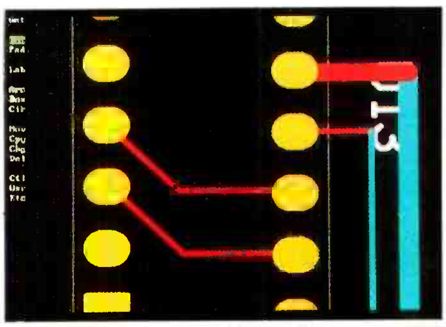
EE Designer III is a fully-integrated circuit design package. In addition to schematic capture and PCB layout, this package also contains automatic parts placement, an autorouter and analog and digital circuit simulators that test the performance of the circuit before it becomes hardware. Best of all, the package costs only $995—considerably less than many PCB layout programs without schematic capture.

Although the program will run with 640K of RAM, any serious user should consider installing expanded RAM. Up to 8M of LIM 3.2 or LIM 4.0 is supported. A hard disk is required, and an included copy-protection hardware connector (a dongle) must be installed in the parallel printer port before the program will load.

Both the schematic capture and PCB layout programs are accessible from a common menu that forms a seamless link between the two programs. But learning and using *EE Designer* isn't easy. There's a labyrinth of hierarchical menus to follow, all of which must be negotiated in rigid order. Fortunately, each command has a related keyboard key or macro that reduces the number of

(Continued on page 32)

HiWIRE II from Wintek Corp.



HiWIRE II ($1,995)
Wintek Corp.
1801 South St.
Lafayette, IN 47904
317-742-8428
CIRCLE NO. 51 ON READER SERVICE CARD

Like *EE Designer III*, *HiWIRE II* comes with both schematic capture and PCB layout software and lists for the same low $995. But unlike *EE Designer*, the link between the schematic capture and PCB programs is tenuous at best, and using *HiWIRE* is like working with two unrelated packages, rather than a single seamless program.

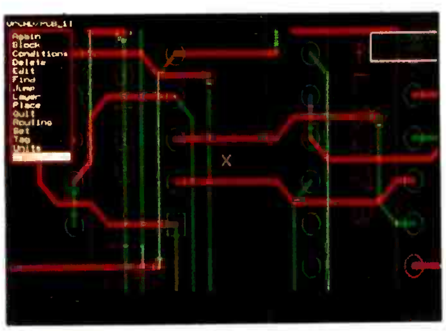
Although the program itself doesn't support expanded memory, the optional autorouter can use up to 15M of extended memory or 32M of expanded LIM memory. A hard disk is required, and the dongle that accompanies the package must be installed for the program to work.

Before we proceed with the review, it's only fair to warn you that the *HiWIRE II* software we received for review is a "beta" copy. And while Wintek assures us that this is close to what to expect, some particulars may change between now and press time.

Both the schematic capture and PCB software are available from a common screen. Both programs use identical menu formats and commands so that you have to learn the routine only once. But tersely labeled commands and a quirky menu selec-

(Continued on page 87)

OrCAD/PCB II from OrCAD Systems



OrCAD/PCB II full-featured PCB layout program contains everything from an autorouter to a rip-up router, yet it lists for a moderate $1,495. The program is easy to learn and use and has a tight link with OrCAD's *STD III* schematic capture program.

Although *OrCAD/PCB II* doesn't support expanded memory, the new release, *OrCAD/PCB III* (due in March 1991), will have support for up to 4M of LIM EMS. The program can run on a dual-floppy system, but for serious work a hard disk is required. A dongle is *not* required.

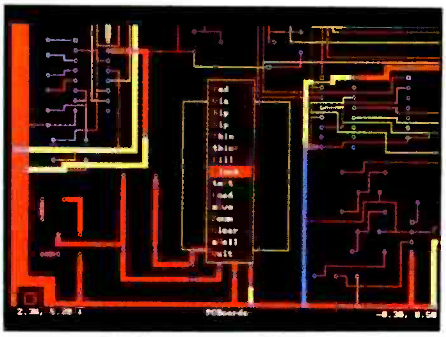
The fact that you can extract device outlines from the schematic netlist makes the program very easy to use. Everything you need is in pull-down menus, and once the router starts, the program is on autopilot. Those who wish to have both *OrCAD/STD III* and OrCAD/PCB II programs accessible from a common menu can buy a third-party program

(Continued on page 87)

Intelligent Menu System (IMS)
Voltec, Inc.
3156-A E. La Palma
Anaheim, CA 92806
714-632-8856
CIRCLE NO. 52 ON READER SERVICE CARD

OrCAD/PCB II ($1,495)
OrCAD Systems
3175 N.W. Aloclek Dr.
Hillsboro, OR 97124
503-690-9881
CIRCLE NO. 53 ON READER SERVICE CARD

PCBoards from PCBoards



PCBoards is a manual PCB layout program that sells for an astonishingly low $99. But as its price suggests, it has limitations that make it applicable only for simple designs, like hobby projects.

The program is one in a trio sold by three different vendors that together form a complete circuit design package. The companion packages are *SuperCAD*, a schematic capture program from Mental Automation (reviewed in the January 1991 issue of *Modern Electronics*) and *PCRoute*, an autorouter from RGH Software Design. All three are designed to stand alone or interface via common netlists to form an integrated circuit-design package. Each module sells for $99, making the combination the cheapest complete design package currently available.

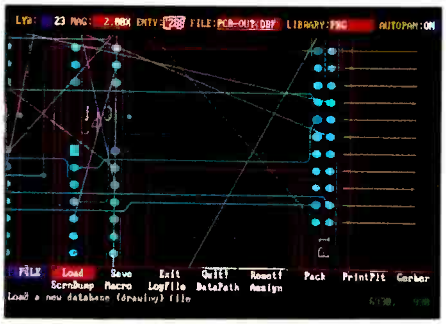
The underlying theme among the trio is affordability—both in hardware and software. As such, *PC-*

(Continued on page 88)

PCBoards ($198)
PCBoards
2110 14 Ave. S.
Birmingham, AL 35205
205-933-1122
CIRCLE NO. 54 ON READER SERVICE CARD

PCRoute
RGH Software Design
11219 Muriel Ave. Ste. 430
Baton Rouge, LA 70816
504-765-3560
CIRCLE NO. 55 ON READER SERVICE CARD

ProCAD from Interactive CAD Systems



ProCAD is a fully-integrated circuit design package that includes schematic capture and PCB layout in one $695 program. For $100 more, you can buy *ProCAD Xtra* that includes EMS *-XL* support with design rule check software, and another $795 nets you an autorouter. Yes, this is a nickel-and-dime package, but it ends at $1,995 and, for your money, you get more performance than most modular systems provide.

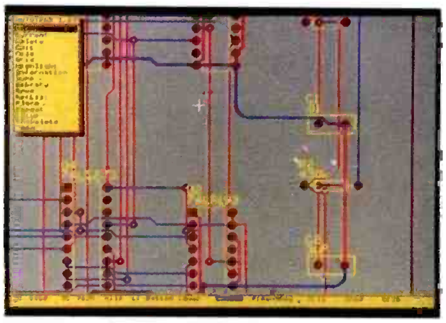
At least 128K of extended or expanded (LIM 4.0) memory is needed for *ProCAD Xtra* and *ProCAD Xtra-XL*, but all versions of *ProCAD* will support up to 8M of expanded RAM. While a dongle isn't needed, the program is copy-protected using the old Lotus scheme that transfers the protection code from floppy to hard disk so that it can be used on only one PC at a time. Obviously, a hard disk is required.

Unlike the other integrated packages in this review, *ProCAD* doesn't have a common menu, forcing you to call the utilities from the DOS prompt. However, the program supports both schematic capture and PCB layout from the same program, which means all you have to do is change the data-

(Continued on page 89)

ProCAD XL ($1,995)
Interactive CAD Systems
2352 Rambo Ct.
Santa Clara, CA 95054
408-970-0852
CIRCLE NO. 56 ON READER SERVICE CARD

Protel-Autotrax from Protel Technology, Inc.



Protel-Autotrax is a moderately-priced $1,295 PCB layout program that has both automatic parts placement and autorouting. Easy to use, the program recognizes several schematic capture netlist formats and is ideal for fast-to-copper prototype and limited production boards. But it lacks the routing conveniences found in more sophisticated PCB programs.

Autotrax will make use of up to 4M of LIM memory if available, but it's not needed for most layouts because of *Autotrax*'s relaxed hardware requirements, which is 640K of RAM and two floppy-disk drives. A math coprocessor is of little value, too, because the program uses CPU-intensive integer processing, rather than floating-point math-coprocessor calculations. The included dongle must be installed for the program to load.

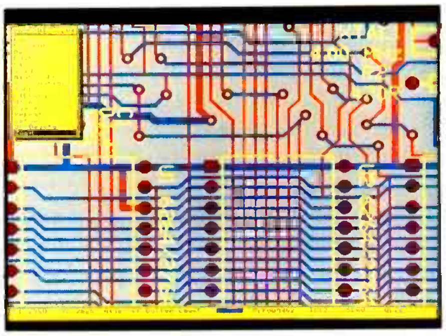
Because it has both automatic parts placement and autorouting, the program is extremely easy to learn and use. A few mouse clicks and you're on your way; unless, of course, you want or need to do some of the board layout on your own.

Protel has designed this package to be fully compatible with its other en-

(Continued on page 90)

Protel-Autotrax ($1,295)
Protel Technology Inc.
50 Airport Pkwy.
San Jose, CA 95110
408-437-7771
CIRCLE NO. 57 ON READER SERVICE CARD

Easytrax from Protel Technology, Inc.



Protel-Easytrax ($450)
Protel Technology Inc.
50 Airport Pkwy.
San Jose, CA 95110
408-437-7771
CIRCLE NO. 58 ON READER SERVICE CARD

Easytrax is Protel's low-end PCB layout package. The program is essentially the same as *Autotrax*, except that it's totally manually-operated, with no contact with the outside world save its output files. However, it does have a very sophisticated point-to-point autorouter that may well justify its $450 price tag for occasional users.

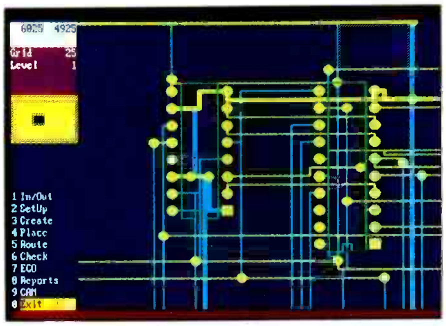
The program is easy to learn and use. However, everything on the board is put there by hand one part or track at a time, because, unlike *PCBoards*, the software doesn't interface with any schematic capture or router program—or any type of netlist, for that matter. It's strictly a stand-alone package.

The component library contains about 100 device outlines, which is 50% less than *Autotrax*, but decent. Missing are SMD outlines and several connectors. Like *Autotrax*, you can add your own parts or create new libraries using the library editor.

A part is placed on the board by either typing its name from the keyboard or selecting the device from a scrolling library menu. While you can rotate the part during and after placement, parts can be placed only

(Continued on page 90)

Schema-PCB Layout from Omation



Schema-PCB Layout ($2,395)
Omation
801 Presidential Dr.
Richardson, TX 75081
800-553-9119
CIRCLE NO. 59 ON READER SERVICE CARD

For real PCB layout power, it's hard to do better than *Schema-PCB Layout*. It supports automatic placement, three autorouters and a trove of editing tools. But brace yourself, because although the program lists for a low $975, you'll end up spending at least $2,395 by the time you piece together the packages needed.

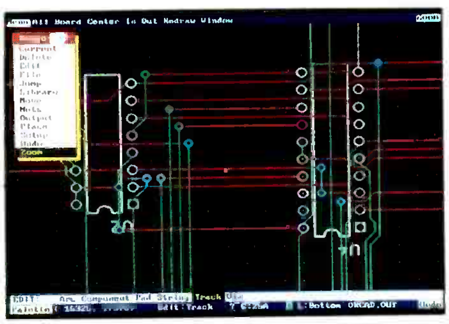
The program supports up to 8M of expanded RAM. A hard disk is required, and the supplied dongle must be installed for the software to load.

Both the schematic capture and PCB layout programs are accessible from a common main menu. The PCB software is easy enough to learn but tedious to use because the commands are stacked in a hierarchic structure that has you accessing layer after layer when searching for a command and when returning to the main menu. Although you can use the mouse to click on a command, it's actually faster to use the keyboard.

Schema-PCB Layout is tightly linked with the *Schema III* schematic capture package, with both forward and backward annotation supported. *FutureNet* netlists can also be read, but not without some manual editing of the netlist. Two optional

(Continued on page 91)

Tango-PCB Plus from Accel Technologies



Tango-PCB Plus ($1,790)
Accel Technologies, Inc.
6825 Flanders Dr.
San Diego, CA 92121
800-433-7801
CIRCLE NO. 60 ON READER SERVICE CARD

Tango-PCB Plus is an $895 PCB layout program that can be used alone or in conjunction with Tango's other circuit design products. The program recognizes only Tango netlists and can't extract device outlines from the schematic. However, the component library size and routing features are above average, and an optional autorouter is available.

The program supports up to 8M of LIM 3.2 or 32M of LIM 4.0 expanded memory. A hard disk is required, and the included dongle must be installed in the parallel port. A math coprocessor is of no value because the program uses integer processing.

The *Windows*-like interface is easy to learn and use. You can choose the commands from either pull-down menus or the keyboard. A speed palette offers one-click access to the most common commands and is useful for doing repetitive jobs.

Only Tango netlists are recognized, and then only the pin connections of the list, not the device outlines. Consequently, there's no forward or backward annotation of the schematic and PCB layout like the more expensive *Tango-PCB* 2.0 offers.

The component library consists of

(Continued on page 92)

EE Designer *(from page 29)*

times you have to drag and click on the mouse. Automatic parts placement and autorouting routines also make using the program easier.

Because the software is integrated, the PCB program accepts only *EE Designer* netlists; no format conversion utility is included. But for $195 extra you can buy the NESTIE option that converts *OrCAD* and *Schema* netlists into *EE Designer III* format. The schematic capture and PCB netlists are very tightly linked, using both forward and back annotation. A change in either the circuit board or schematic prompts a user-approved update to the other's netlist so that the two are never different.

The 1,250-device PCB component library is inextricably tied to the schematic capture component library, and any part that doesn't exist in the schematic capture library can't be placed on the circuit board. For PCB layout, this intimacy is stifling because it doesn't permit the freedom of specifying generic devices. In fact, our benchmark design wouldn't load because the library doesn't have an LM555 timer chip or blank eight-pin DIP outline, forcing us to modify an eight-pin voltage regulator for the job. Visionics says a larger library will be shipping by press time.

Before you can extract device outlines from the schematic netlist, you must define a circuit-board outline. With this program, maximum board size is 32 × 32 inches.

EE Designer has an excellent automatic placement routine that determines a part's location by counting the number of attached wires and placing those with the higher closer together. Parts can be manually positioned and locked in place, forcing the placement program to work around them. Parts can rotated before or after placement and flipped to the other side of the board for SMD layouts. A ratsnest is available for placement, with the power-supply lines changing connectivity from part to part as the device moves away from and closer to another part.

Two Lee-based autorouters are included, both with fixed-cost functions that can't be changed. The first is a totally automatic router that routes the traces on a 0.025-inch grid. You simply enter the signal and power track widths, and the router takes it from there. Even via optimization, removal of temporarily placed vias created during the initial routing pass, is performed automatically. Unfortunately, the router is limited to just two layers: component side and solder side. But because of the tight 0.025-inch grid spacing, this router often achieves 100% completion—usually at the cost of a high via count. On automatic placement and our benchmark placement layouts, the router missed only one track.

The second router is interactive on a 0.050-inch grid. This autorouter permits routing up to 12 copper layers to be routed using a variety of routing routines that include supply, signals, pin-to-pin and windows-only tracks. The router can be programmed for nonstop routing or halted for intervention on a route failure. Like the above router, you can specify different track widths for power, ground, signal and memory tracks. You can also designate protected zones where placing of traces is prohibited.

During initial routing, temporary vias are placed on the board, which can be removed using the optimize command. Although the completion rate of this router is less than the 0.025-inch router because of the larger grid, producing six failed tracks with automatic placement and seven failed traces on our benchmark layout, it permits greater user control (though not as much as if the cost functions were programmable).

Although the menu displays a rip-up router option, it isn't available in the U.S. But for $750 you can buy a *MaxiRoute* (list price $6,000) rip-up router interface.

Either router requires manual handling of the following items. Neck-down is done by adjusting trace width on the fly during manual routing of the track. Curved tracks with a constantly variable radius, ortho tracks with 45° bends and free tracks (no ortho restrictions) are also manually placed. A single track can contain any or all four of the above-mentioned elements. Tracks are started by clicking the mouse button once and moving the track to its designation and clicking again to change direction or width.

You can change layers while routing a track, with the program automatically inserting a via. Placed tracks can also be moved from one layer to another. Ground planes can be placed on any of the 12 layers and tied to any net, making it easy to create input guards for high-impedance analog circuits. Up to eight different ground planes are possible. Gate and pin swapping are supported, as is component renaming.

EE Designer's pan is manual and not automatic, having you move around the screen by selecting the pan command from a menu and indicating how far you wish to move, *AutoCAD* style. However, pan can be used during manual part and track placement without interrupting the placement procedure, as can zoom. Zoom range is 100:1 with a 5:1 magnifier that scopes in to fill the screen with just three pads of a standard 14-pin DIP.

While there's no help screen, there's a command description bar at the top of the screen that explains enough about the highlighted command to keep you from constantly running to the user's manuals to obtain help. Block functions provided include delete, move and rotate for both parts and tracks.

The design check rule sections are thorough, but they leave something to be desired. Although it lists unconnected nets and track violations, you have to toggle between a netlist display and the board layout to locate the problems. Too bad the two aren't integrated in one screen.

EE Designer generates a full range of output files, including component, solder and silkscreen masks. *AutoCAD* DXF format is supported. The program also produces a Gerber and two N/C drill files (Drill Data and Drill Template).

A dot-matrix or laser printer can be used to produce hard copy of the artwork. The artwork can be sized to fit the page, scaled to a model size or printed actual-size. However, track width isn't realistically reproduced, making printer outputs useful for proofing only. Pen plotters, on the other hand, draw perfect patterns. All printer and plotter adjustments, such as offset and pen velocity, can be set from the software.

EE Designer III is a very sophisti-

(Continued on page 87)

A Quick PC Buying Tour

What to look for when shopping for a personal computer, from novice to advanced

Buying your first computer can be uncertain business due to the large selection of different systems and manufacturers. Here are some quick thoughts that may help adults.

What's It For?

The first step toward buying a computer is planning. What will it be used for? Games? Small business? Computer-aided drafting? Answers to these questions will largely determine what kind of system you'll get and how much it will cost. A system that runs mostly text-based business programs can be less equipped than one that's intended to run high-resolution graphics.

Where To Buy

Consumers are tempted to take whatever costs less. For those who have computer experience and know exactly what to look for, bargain hunting can be a boon. There are many mail-order and computer-store owners who want your business. It's a competitive market where profit sometimes gets lean. Therefore, computer dealers occasionally appear and disappear in just a few months or a year.

Select a reputable computer supplier who has been in business for a few years. Ask your friends who own computers for their recommendations. Check your local computer user groups, who can usually provide reliable and friendly help. Visit prospective computer stores and ask plenty of questions about warranty and service. Buy some small item(s) from a computer mail-order house and see what kind of delivery and customer service you get. Many offer some kind of service warranty of their own for products they sell.

The Minimal System

Often, the single most important buying consideration is cost. That concern has become more poignant in view of recent economic events. The minimal system can be a fine starting place for users on a tight budget. From there, it can be upgraded as the need and finances arise. This system will run many business applications, including spreadsheets and database programs. You just won't be able to use the best software available with it.

The Medium System

This system is a fair balance between cost and performance. Computer resources, such as disk storage space, memory and processor speed, begin to become more important than cost. This system has the capability to run most of anything, albeit not exceedingly fast. It may also have some space limitation on disk and/or memory for use with some programs.

The Advanced System

For those of you who want it all and can afford it, this system has the latest graphics, lots of memory, a large and speedy hard-disk drive and a fast processor (and perhaps even a math coprocessor for CAD/CAM and other applications that support it). It may have extra add-on video, audio or data-acquisition devices. Cost runs high, depending on what you add to the system.

Processor Preference

8088 & 8086. Don't buy systems that use these processors. Cheap can be dear, even in the short run. Systems built around these processors are quite inexpensive, but they don't have the power for today's software. These venerable processors are antiquated for use as personal computers.

80286. The industry workhorse for the last few years, the 80286 has plenty of life left but is being supplanted by more-powerful processors. Even so, a 20-MHz '286 is no slouch. It's a good choice of processor for an upper minimal system.

80386SX. Intended as a middle step between the 80286 and full-blown 80386, this processor is often viewed as a crippled version of the 386. Nevertheless, it works well with many of the newest, hottest programs and promises greater use longevity than a '286. If you want the advantage of a full '386, don't stop short with this in an effort to save money if you can manage it.

80386DX. Now pervading the computer market, the 80386DX can be found on newer system boards that have space for several megabytes of memory to reside on-board. This memory space pre-empts the need for an additional memory card and allows for 32-bit access of all memory.

80486. The power processor on the horizon, the 80486 is now out of the price range for most individual users. Wait for prices to drop.

Graphics

Monochrome. This is all you need for a minimal system. Most monochrome graphics cards support the Hercules graphics standard. Cost is low for both monitor and graphics card. VGA monochrome is an alternative, too, and is also low in cost.

CGA. The original color graphics option was impressive when it debuted. However, since it first appeared, the four-color resolution has been dwarfed. If you can afford to do so, avoid CGA. If you must use CGA, make sure it's double-scanned.

EGA. Sixteen colors and better resolution are offered by this alternative to CGA. This type of performance is acceptable for an average-type system. However, recent price drops in VGA cards and monitors make VGA the more attractive alternative.

VGA. This is presently the industry standard for graphics. But if you want performance for complex graphics, you'll get a graphics card and monitor that support a resolution of 1,024 × 768 in 256 colors. This should suffice for all but specialized applications. Super VGA, with higher resolution, may be eclipsed soon; so go beyond plain VGA.

Beyond VGA. There are products for increased resolution, definition and speed in this category. But no official or even *de facto* standard has emerged. Wait before you spend your money, however, unless you have a particular need. A non-interlaced color monitor is best . . . and most expensive. The 8514 and the newer IBM intro, Extended VGA, may be the choice, though costly.

Memory

'286 Memory. Newer motherboards have provisions for enough memory on-board. If you have an older motherboard, or if you just want more memory, you'll have to buy an additional memory card. The main cost of a memory card is the memory itself. The cost of memory goes up with the operating speed of the memory devices used.

'386 Memory. Avoid buying a motherboard that requires an additional memory card. Newer motherboards have provisions for an abundance of on-board memory. If you have to get an additional memory card, try to get the 32-bit card that was designed for your motherboard. If not, buy a good 16-bit memory card. This will have a slowing effect on your system, but it's still a workable solution.

Floppy Drives

360K. These 5¼-inch drives are no longer necessary since higher-capacity drives came along. If you intend to share data with an older IBM XT-style computer, use the 360K drive. XT systems can have trouble trying to read a 360K disk that was formatted on a 1.2M floppy drive.

1.2M. This is the standard 5¼-inch drive for '286 and '386 systems. It can also read 360K floppies (most of the time).

1.44M. The smaller 3½-inch disk size of this drive is better for physically handling diskettes. It also reads and writes 720K format and is compatible with IBM PS/2 and other 3½-inch data formats.

Hard Drives

MFM. This was the lone standard since the inception of the personal computer. Faster throughput is achieved with other hard-drive controller technologies, but you won't go wrong with this choice if you have a slow processor. Its advantages are low cost and wide support.

RLL. New encoding packs greater data density onto disk(s) and half again faster data transfer time. With the desire for faster speed and more storage, it may be the way to go for AT computer types. Be sure that the drive is RLL-certified, though.

SCSI. "Scuzzy," as it's called, was employed almost exclusively in larger mainframe computer systems, Its advantages are intelligent control on the drive itself, resulting in faster throughput, and the ability to install several SCSI devices on the same bus.

IDE. This is a recent controller technology for personal computers that came to the fore on laptops. It's like MFM in that it doesn't require special considerations when installing and setting it up. The controller is on the drive itself. A major advantage of this technology is fast throughput.

CD ROM. Information in this medium is stored on a compact laser disc. The main advantage of this scheme is extremely large storage capacity in a relatively small volume. This add-on is quite costly but nice to have. Prices are coming down, though.

Caching Controllers. These hard-drive controllers come with a lot of RAM that automatically stores your hard-drive data in memory. The aim with this scheme is to reduce disk access time. This method is costly because fast RAM is expensive. It's nifty, though, for those people who can afford it. ■

The Minimal System

80286 (20 MHz) or
80386SX (16 MHz, 2M RAM)
1.2M floppy drive
20M hard drive
Monochrome graphics
Keyboard

The Medium System

80386 (20 MHz, 3M RAM)
1.2M floppy drive
1.44M floppy drive
40M hard drive
VGA graphics
Keyboard
Mouse

The Advanced System

80386 (33 MHz, 16M RAM)
1.2M floppy drive
1.44M floppy drive
100M + hard drive
VGA or EVGA graphics
Keyboard
Mouse

Timing & Counting Circuits

How they work and some hands-on ways to exercise the signals

Like living animals, computers have a heartbeat that keeps them alive and functioning. The heartbeat synchronizes the parts of the computer, keeps the CPU functioning and is responsible for keeping the time and date current. Part of this heartbeat is accessible to programmers in a number of ways. Once you understand how it works, you can time events with millisecond or even microsecond accuracy, make sounds through the speaker and understand how DOS keeps track of time.

I'll describe the technical aspects of the heartbeat first. Then I'll show you some examples of how you might use it in your own programs. We'll begin at the lowest electronic level and work up toward the higher levels of BIOS and DOS processing.

Starting With the Crystal

The heartbeat begins with a crystal oscillator. Its output is conditioned and groomed, and often divided one or more times, until it reaches the CPU speed that the manufacturer claims for your computer. On an original IBM PC, PC/XT or clone, CPU speed is 4.77 MHz. Later computers have faster pulses, with the most modern DOS machines running at 25 MHz of faster.

The crystal output is further divided until it becomes a steady 1.19318-MHz pulse. This signal is accessible to programmers and is the beginning of our journey through the computer's clock and counting circuits.

The 1.19-MHz signal is fed into an Intel 8235 timer chip (the AT uses an 8254, and many compatibles provide the same functions on a multi-function ASIC chip). The timer chip has three separate channels, but all receive the same input signal inside the computer. The channels are labeled from A to C or, in true computer fashion, from 0 to 2. Each channel has a gate that turns on and off the input signal, a pair of data latches, a counter and an output line (see Fig. 1). A single control register, which is not shown in Fig. 1, controls all three channels.

In most operating modes, a channel loads a value from its input data latch, counts down toward 0 on each input pulse, outputs a signal when the counter reaches 0 and then loads the value again and repeats the operation as long as the input gate is open.

Designers of the original IBM PC assigned Channel A to the real-time clock, Channel B to DRAM refresh circuitry and Channel C to the speaker and other general purposes. Channel A is also used by many disk-drive controllers. If you exercise caution, you can use Channel A and Channel C for your own purposes.

Each channel can operate in six different modes (numbered 0 through 5), which are summarized in Table 1. However, you will almost always want to use mode 3, and you can usually ignore the others. The timer is wired into the computer so that its control register, which is write-only, is accessible at port 43H. The read/write data latches are visible at ports 40H, 41H and 42H for channels A through C, respectively.

Using the timer chip is easy. You first issue a command through the control port, then read or write values through the channel data latch. When you read values, you get the current value in the counter. You can also instruct the chip to copy the contents of the counter into the output data latch and hold it there so that it won't change while your program reads it.

Turning the Channels

Before you use any of the timer chan-

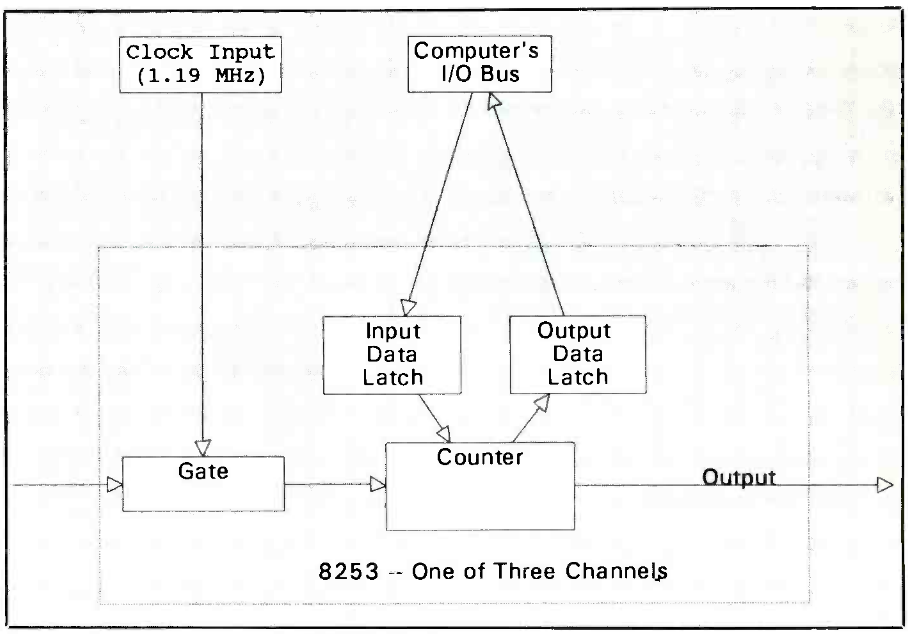


Fig. 1. One channel of the 8253/8254 timer chip.

 Say You Saw It In ComputerCraft

nels for your own purposes, you must understand how they are normally used by the computer and its BIOS. Channel B is the easiest to understand and the one you're least likely to change. Its input gate is wired open so that the counter is always active. During power-up initialization, the BIOS sets a value in the data latch that will generate pulses from the DRAM refresh circuitry. Whenever a pulse occurs, your computer takes a few microseconds to keep the information in RAM from fading away into chaos.

It's possible to speed up some older computers slightly by decreasing the frequency of DRAM refreshes and, therefore, the amount of time the computer spends taking care of itself instead of doing your work. However, whether this will work on your computer or will make your RAM chips fail is anybody's guess. I recommend you don't even try.

Channel A is a bit more interesting. During power-up, the BIOS loads it with a value of 0 (which the chip the chip interprets as 20161 or 65536). The input pulse of 1.19318 MHz, when divided by 65,536, is 18.20648193359 Hz. About 18.2 times a second, the Channel A counter generates a hardware interrupt, IRQ0. Normally, code in the computer's BIOS is activated by this interrupt (which appears as software INT 08H) and updates a four-byte counter in memory. This counter is the real-time clock. DOS uses it to display the date and time, place a time stamp on every file when it's created or updates and to supply the date and time to software programs.

It's tempting, and quite feasible, to write your own INT 08H code and speed up the real-time clock ticks. Instead of a resolution that's less than 1/20 of a second, you could have a real-time clock that has a resolution of 1/100 of a second or better.

You must be careful of two potential problems, however. First, some disk controllers use Channel A as a watchdog timer and your computer might suffer erratic (or worse) disk operations if a disk is accessed while

Table 1. Addressing and Modes for 8253

```
Control Word (write to command register at Port 43h)

 |Bit  Bit | Bit Bit  |Bit Bit Bit | Bit  |
 | 7    6  |  5   4   | 3   2   1  |  0   |
 |---------|----------|------------|------|
 | Counter |Read/Load | Counting   | BCD  |
 | Select  |Command   |  Mode      |Select|
  ---------  ---------  ------------ ------

Counter Select:
    0   0     -- Select Counter 0 (Channel A -- Port 40h)
    0   1     -- Select Counter 1 (Channel B -- Port 41h)
    1   0     -- Select Counter 2 (Channel C -- Port 42h)
    1   1     -- [illegal value]

Read/Load Command:
    0   0     -- Copy counter register to output data latch
    0   1     -- Read/Load most-significant-byte (MSB) only
    1   0     -- Read/Load least-significant-byte (LSB) only
    1   1     -- Read/Load LSB and then MSB

Counting Mode:
    (all modes count from loaded value down to 0)

    0   0   0  -- Mode 0: Interrupt on terminal count

    0   0   1  -- Mode 1: Programmable one-shot

    0   1   0  -- Mode 2: Rate generator

    0   1   1  -- Mode 3: Square wave generator (normally used
                          for Channel A and speaker on Channel C)

    1   0   0  -- Mode 4: Software triggered strobe

    1   0   1  -- Mode 5: Hardware triggered strobe

  Modes 2 & 3 are most commonly used on the PC.  The difference is
  that Mode 2 counts down to 0 and triggers a 1-clock low pulse.  Mode 3
  counts down by 2's, setting the output low for one entire cycle and
  high for the next cycle, in order to create a square wave.

BCD Select:

    0        --  Use binary counter (16-bit).
    1        --  Use Binary-coded decimal (BCD) counter (4 decades).
```

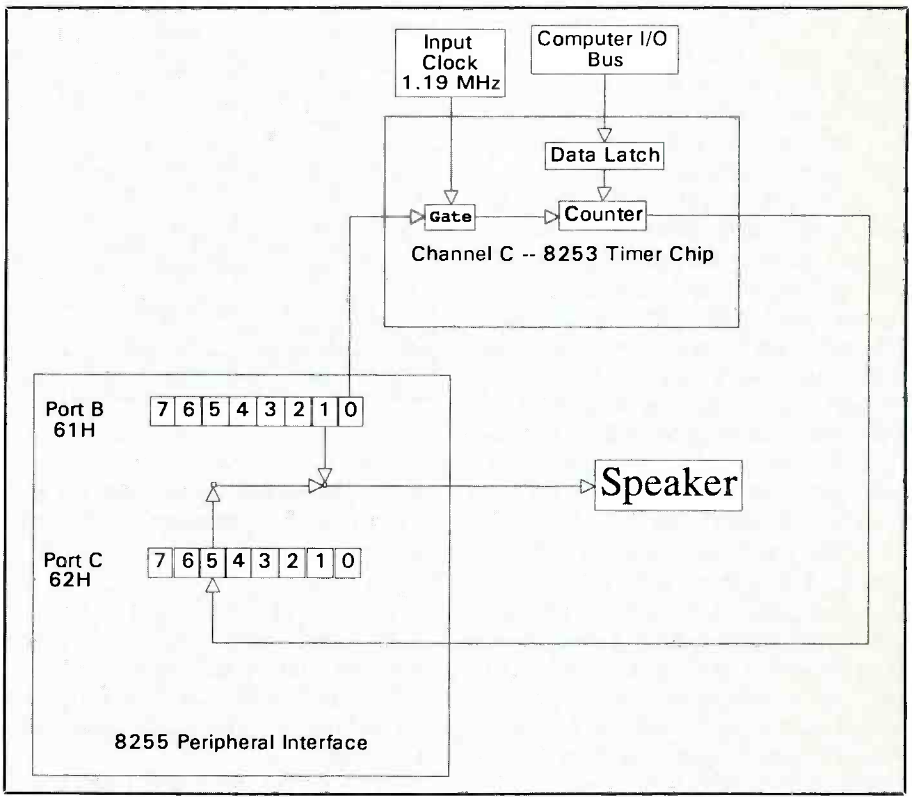


Fig. 2. Details of connections to the speaker in a PC.

the timer is changed. Second, you have only one CPU. If your new INT 08H code is long or complex, you'll be stealing CPU cycles from your main applications and your computer may appear to have slowed down. On the other hand, it's certainly possible to use Channel A and INT 08H temporarily for high-resolution timing. I'll explain how to do this a little later.

Sounds Through the Speaker

Channel C is potentially the most complex of the three channels, especially if you want to use it to produce square-wave sounds through the speaker. This is the only channel that has an input gate that can be under program control. Also, you can control the speaker's sound in a variety of ways. Before you run ahead, look at Fig. 2. It shows how the connections are made between Channel C and Ports B and C of the 8255 peripheral interface adapter chip.

As Fig. 2 illustrates, there are two ways to turn on the speaker. The first is to simply toggle bit 1 of Port B under program control. When bit 1 is set to 1, the speaker receives current. When bit 1 is set to 0, current is blocked. Typically, a program would open the bit-1 gate, sit in an idle loop and then close the gate and sit in another loop. The length of the two loops determines the frequency of the tone produced through the speaker. The process would be repeated for the desired duration of the tone.

There are several drawbacks to this simple technique. First, the frequency of the tone is dependent not only on the loop counters, but also on the clock speed of the CPU. If you move the program from a slow XT to a fast '386 machine, a pleasant tone might become an ultrasonic dog whistle. Second, your program will be periodically interrupted by background interrupts. For example, 18.2 times a second, the BIOS real-time clock will steal the computer for a few milliseconds. These interruptions will produce noticeable distortions of tone. Third, a software timing loop forces the computer to focus all of its attention on producing a tone.

Instead of trying to work around all of these problems, you can let the electronics handle most of the menial work of toggling the speaker on and off while the computer does something more useful. The process is fairly simple:

(1) Turn off bits 0 and 1 of Port B.

(2) Load the Channel C register with your frequency value.

(3) Turn on bit 5 of Port C (it's on by default; so you can usually skip this step).

(4) Turn on bits 0 and 1 of Port B to start the counter and enable the speaker.

(5) Go do something else until the tone has lasted long enough.

To determine the correct frequency value, divide 1.19 MHz by the tone frequency you wish to hear. For example, to produce a 440-Hz concert A tone: 1,193,180/440 = 2,712. You can use the real-time clock to decide how long to let the tone continue. Ta-

Table 2. Creating a 1-Second Tone

```
;  Listing 1
;    This example shows how to create a 1-second
;    tone on the computer's internal speaker.

;  To compile:
;    save as EX1.ASM
;            MASM EX1;
;            LINK EX1;   (ignore stack segment warning)
;            EXE2BIN EX1.EXE EX1.COM


port_b          equ     61h             ;8255 Peripheral Interface ports
port_c          equ     62h

command_reg     equ     43h             ;8253 Timer chip ports
channel_c       equ     42h

code    segment
        assume cs:code
        org     100h

start:  in      al,port_b               ;Get Port_B bits
        and     al,11111100b            ;Turn off bits 0 & 1
        out     port_b,al

        mov     al,10110110b            ;Timer command:
                                        ;  Counter C, Load 2 bytes
                                        ;  Use Mode 3 as a binary counter
        out     command_reg,al

        mov     ax,2712                 ;Count value: 1,193,180/440
        out     channel_c,al            ;Send LSB to counter
        xchg    al,ah                   ;Move MSB to AL register
        out     channel_c,al            ;Send MSB to counter

        in      al,port_c               ;Get Port_c
        or      al,00100000b            ;Turn on bit 5 (usually on
        out     port_c,al               ;  by default anyway)

        mov     ah,0                    ;Function: read time
        int     1ah                     ;Ask BIOS for time of day
        mov     bx,dx                   ;Save low value
  lp1.  int     1ah
        cmp     bx,dx                   ;Wait for a change
        jz      lp1                     ;Cycle until time changes

        in      al,port_b               ;Get Port_b value
        or      al,3                    ;Turn on bits 0 & 1
        out     port_b,al               ;Start timer & sound
        add     bx,18                   ;Wait for 1 second or 18 counts
        mov     ah,0                    ;Function: read time
  lp2:  int     1ah                     ;Get time count
        cmp     dx,bx                   ;Ready to quit?
        jne     lp2                     ;Loop until they are equal

        in      al,port_b               ;Get Port_b value
        and     al,11111100b            ;Turn off the timer & speaker
        out     port_b,al

        mov     ax,4c00h                ;Exit to DOS with no error
        int     21h
code    ends
        end     start
```

CIRCLE NO. 128 ON FREE INFORMATION CARD

ble 2 shows how the job can be done in assembly language.

Split-Second Timing

Making tones can be fun and even useful if your high-level language doesn't have built-in sound commands. But for many of us, the real use of the 8253 chip is for millisecond-resolution timing. There are a couple of standard ways to perform timing. You'll have to pick the ones that serve you and your applications. Because you'll be working with very short times and must handle housekeeping with a minimum of interference to obtain accurate measurements, you must write the low-level timing routines in assembly language.

The simplest way to time with millisecond accuracy is to create a new

Table 3. Assembly Code for Millisecond Counting

```
;   Example code for millisecond counting
;   Note -- this code disables the real time clock
;                while it is installed.
;
;   Save as EX2_A.ASM
;
        .model small,c
        .data
        public      ms_count
ms_count            dw        0
old_int8            equ this dword
old_int8_off        dw        ?
old_int8_seg        dw        ?

        .code

command_reg         equ       43h              ;8253 Timer chip ports
channel_a           equ       40h
intr_cntrl          equ       20h              ;Port for interrupt controller

        ;Install the millisecond counter
        ;as a new Int 08h handler
        ;NOTE -- there should be NO DISK ACCESS
        ;  while the counter is installed

ms_install          proc
        push        ds                         ;Save segment register
        mov         ax,@data                   ;Point DS to our data
        mov         ds,ax
        mov         ax,3508h                   ;Get Int 8 vector
        int         21h                        ;  with DOS's help
        mov         old_int8_off,bx            ;Save the address
        mov         old_int8_seg,es
        mov         ax,cs                      ;Get our code segment
        mov         ds,ax                      ;  into DS
        mov         dx,offset new_int8         ;DS:DX ==> our timer routine
        mov         ax,2508h                   ;Set new Int 8 vector
        int         21h                        ;  with DOS's help
        mov         al,00110110b               ;Channel A, Load 16-bit value,
                                               ;  run in Mode 3, use binary count.
        out         command_reg,al
        mov         ax,1193                    ;1,193,180/1000 for 1/1000 sec
                                               ;  interrupts
        out         channel_a,al               ;Send LSB
        xchg        ah,al
        out         channel_a,al               ;  and MSB to counter
        pop         ds
        ret
ms_install          endp

        ;Be sure to uninstall the timer
        ;before your program exits or
        ;when you want to access a disk.

ms_release          proc
        push        ds                         ;Save segment register
        mov         al,00110110b               ;Channel A, Load 16-bit value,
                                               ;  run in Mode 3, use binary count.
        out         command_reg,al
        sub         al,al                      ;AL = 0
        out         channel_a,al               ;Set count to 0000h
        out         channel_a,al
```

INT 08H handler. INT 08H receives control each time Channel A of the timer chip finishes its count, usually 18.2 timer per second. If you write a new INT08H handler, you can change the count value in Channel A to 1,193. Your new handler will receive control of the computer 1,000 times per second.

Since it will be called so often, your INT 08H handler must operate very quickly and return—perhaps pausing only to update a count of milliseconds. Table 3 shows how such a counter might be implemented and used. If it's also important to you to keep the BIOS's time-of-day count accurate, you can keep one count of milliseconds and another that will tell you when to call the original INT 08H. You could also rely on the CMOS real-time clock on AT compatibles and later machines and forget about the DOS clock until your timing is completed. I'll discuss CMOS memory and how to use it in a future article.

```
        lds     dx,old_int8             ;DS:DX has orig. Int 8 vector
        mov     ax,2508h                ;Set new Int 8 vector
        int     21h                     ;  with help from DOS
        pop     ds
        ret
ms_release      endp

new_int8        proc
        push    ds                      ;Save all registers
        push    ax                      ;  that we will use
        mov     ax,@data                ;Point DS to our data area
        mov     ds,ax
        inc     ms_count                ;Increment the counter
        mov     al,20h                  ;Tell the interrupt controller
        out     intr_cntrl,al           ;  to clear the interrupt
        pop     ax                      ;Recover registers
        pop     ds
        iret
new_int8        endp

        end


/* This example C program will test the
 *  millisecond timing routine.  It constantly
 * reads the millisecond counter and prints
 * the value it finds in the upper-left corner
 * of the screen.
 *   The program ends when the user presses a key.
 *
 *   Written for Quick C 2.01 (but should work with
 * all versions of C)
 * Save as EX2_C.C
 * In Quick C 2.01:
 *     Create a program list called EX2.MAK
 *     Include 2 programs: EX2_C.C and EX2_A.ASM
 *     Set compiler flags for SMALL model
 *     QC will complete the link and the programs properly for you
 */

#include <conio.h>

/* Prototypes for external functions:  */
extern void   ms_install(void);
extern void   ms_release(void);

/* Data declarations:                  */
extern unsigned ms_count;
       unsigned count_val;

void main(void)
{
  ms_install();
  while(!kbhit())                    /* Loop until user hits a key  */
     {
     count_val = ms_count;           /* Copy the count value        */
     cprintf("\n\r%u",count_val);
     }
  getch();                           /* Remove keystroke from buffer*/
  ms_release();                      /* Remove millisecond timer    */
}                                     /*    and end                  */
```

If you have very short events to time, you can simply start a counter and, at the end of the event, read back the value in the counter register. With all speaker output turned off, Channel C is ideal for this technique. Table 4 demonstrates how the timer could be used. However, there may be small errors in the results returned by routines like those in Table 4 because the computer could be interrupted for a DRAM refresh cycle just when it should be starting or stopping the clock. The error will be noticeable if you're trying to use the computer for very precise event timing. If you run the listing in Table 4 several times, you'll see the results vary by a couple of microseconds on different runs.

The AT Difference

Luckily, the timing and counting techniques I've shown will work for both XT- and AT-compatible computers, including those based on Intel '386 and '486 CPUs. There are a few differences, however, which you should be aware of if you have an unusual application.

First, AT and later computers use an 8254 timing chip instead of the 8253. The two chips are essentially the same from a programmer's point of view. However, the 8254 has a couple extra instructions that are seldom needed for timing on a DOS computer.

Second, the 8255 peripheral interface adapter chip isn't used on AT and later computers. However, the speaker is accessible as if the 8255 is present. So you don't have to worry about what kind of machine your program runs on. Designers of AT and later computers have gone to a great deal of trouble to ensure that programs won't break as they're moved from one computer to another.

Conclusion

The timer chip is a small part of a PC computer and receives little attention, except for its ability to create primitive sounds through the computer's speaker. The original design-

```
/* Example of microsecond timing.
 * This program first measures the overhead it needs to
 * to start and stop the timer.
 *   Then it starts the timer, prints a string, reads the timer
 * and calulates the approximate number of microseconds required
 * for the print operation.
 *   On slower 8088 computers, the print operation may take so long
 * that the timer wraps around and the results will be incorrect.
 *
 * Written for Quick C 2.01, but should work with most versions
 *   of C
 */

#include <conio.h>
#define COMMAND_REG  0x43
#define CHANNEL_C    0x42
#define PORT_B       0x61
#define LOAD_CMD     0xb6     /* Channel C, Read/load 16 bits, mode 3 */
#define GET_COUNT    0x80     /* Channel C, copy counter to output latch */

void setup_timer(void);
void release_timer(void);

void start_timer(void);
long stop_timer(void);

unsigned port_b_value;

void main(void)
{
  long overhead;
  long event_time;

  setup_timer();                 /* Do the necessary set up */
  start_timer();                 /* Start the timer         */
  overhead = stop_timer();       /* Stop it immediately to get overhead */

  start_timer();                 /* Time the following cprintf call     */

  cprintf("\n\rOverhead is %u timer ticks",overhead);

  event_time = stop_timer() - overhead;    /* Find the elapsed time        */

  cprintf("\n\rLast print used %u timer ticks",event_time);
  cprintf("\n\r  or about %lu microseconds", (long)(event_time / 1.19318));

  release_timer();               /* We're done; release the timer       */
}
void setup_timer(void)
{
  port_b_value = inp(PORT_B);
  outp(PORT_B,port_b_value | 1);   /* Turn on gate for counter */
}

void release_timer(void)
{
  outp(PORT_B,port_b_value);       /* Turn off gate for counter  */
}

void start_timer(void)
{
  outp(COMMAND_REG, LOAD_CMD);
  outp(CHANNEL_C,0);
  outp(CHANNEL_C,0);
}

long stop_timer(void)
{
  unsigned b1, b2;

  outp(COMMAND_REG, GET_COUNT);
  outp(COMMAND_REG, LOAD_CMD);
  b1 = inp(CHANNEL_C);
  b2 = inp(CHANNEL_C);
  return 65536L - ((b2 << 8) | b1);
}
```

ers of the PC never thought the machine would be used for accurately timed process control. But if you do have to time real-world or computer-based events, the timer chip can give you as much accuracy as many laboratory instruments, and it can do so with only a small investment in writing your own software. Once you've learned the tricks and techniques I've demonstrated here, you'll be able to get accurate timings that the original designers of the PC never thought we'd need. ■

Shopping at a Computer Flea Market

A fun alternative to more traditional computer products buying outlets

Shopping for a computer product? The smart money knows that you grab the latest issues of *ComputerCraft* and other computer magazines to search out your fare. You telephone one 800 number after another to compare prices and terms. Then you buy, sight unseen, and anxiously wait for the UPS truck to make the delivery. That's the way it's typically done. But Ken Gordon thinks there's a better way.

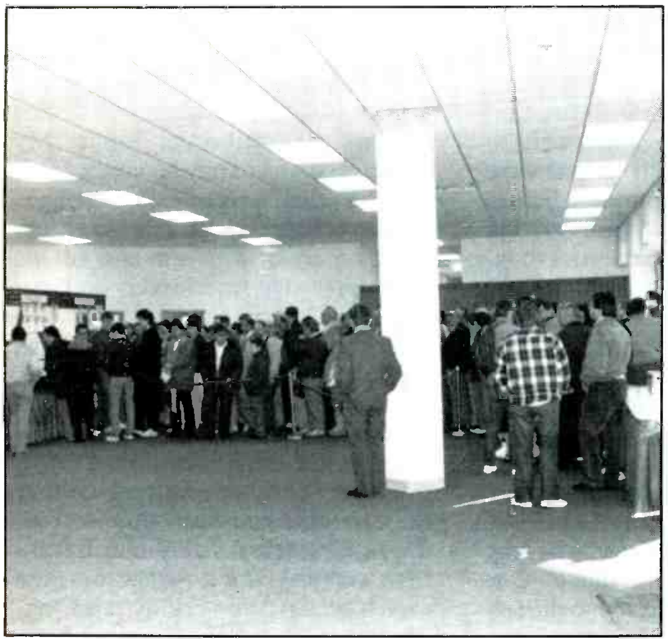
For the last 11 years, Gordon has been sponsoring local computer shows up and down the Northeast coastal area. one of a handful of such entrepreneurs to do so. From Washington to Boston, he produced 39 computer shows in 1990 and expects to do that many or more in 1991. Gordon held one of his shows (KGP Productions, Inc., 800-631-0062) in Edison, NJ last Thanksgiving weekend, which I attended.

After a 1½-hour drive and another 20 minutes in a fast-moving ticket line, my brother-in-law and I were inside the Raritan Center looking at more than 200 vendors occupying 700 tables. Forget the $800 suits, multimedia shows, carpeting and elaborate displays associated with national computer trade shows like Comdex. This is a bare-bones warehouse operation: the vendors are here to sell and the buyers are here to buy *now*, not to be impressed.

Some sellers had a few tables joined together. There were representatives from large computer stores (but not any of the national chains), too, offering a full line of computer products. Most of the sellers present were based in New Jersey, but there were representatives from New York, Connecticut, Pennsylvania, Massachusetts, Maryland and Virginia.

Other vendors mostly appeared to fit into the mail-order-only and/or "sideline" business categories. They tended to specialize in one or two types of products, memory cards, chips or shareware disks. Often, I got the impression that they had their entire inventories with them.

Although we arrived only 30 minutes or so after the show's official opening time at 10 a.m., many people had already made their purchases and were leaving with monitors, CPUs, printers and plastic bags containing unknown "goodies." Gordon said that there were 1,500 in line

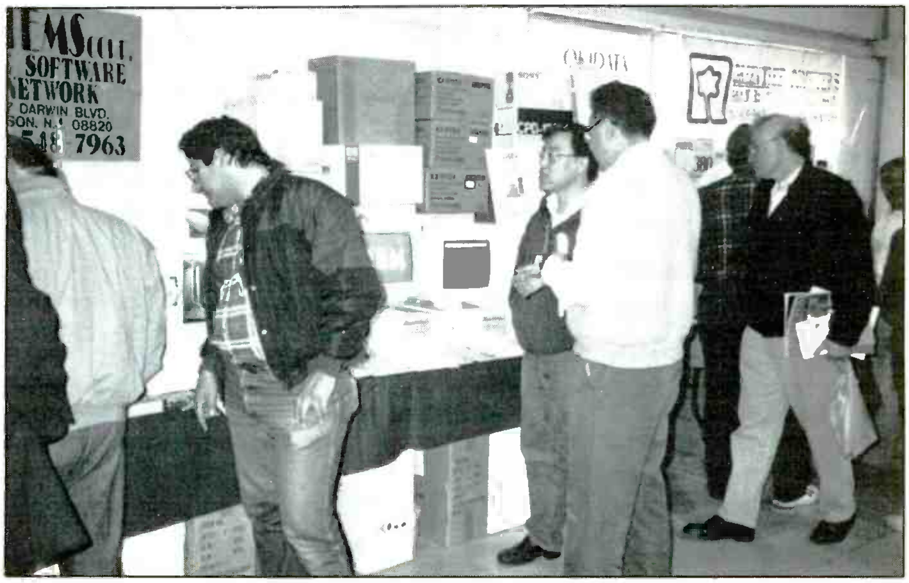


Admission line and bargain hunters.

at 9:30. Since it was a blustery morning and the vendors were set up, he opened early to let the buyers in out of the cold.

Gordon expected at least 11,000 to make their way down the aisles that day. Based on the crowds we observed, there was no reason to doubt his estimate. Unlike a typical ham radio "hamfest," which this type of show closely resembles in spirit, the aisles were wide, allowing relatively easy movement of the large crowds.

Merchandise ranged across the spectrum from 386/VGA computers to printers to parts to used equipment. I was shopping for a memory expansion card for my HP Laserjet III and an HP PostScript cartridge. My brother-in-law was looking for a hard disk for his Macintosh. As might be expected, there was relatively little in the way of Macintosh hardware and software at the show; so the trip wasn't successful for him from that perspective.



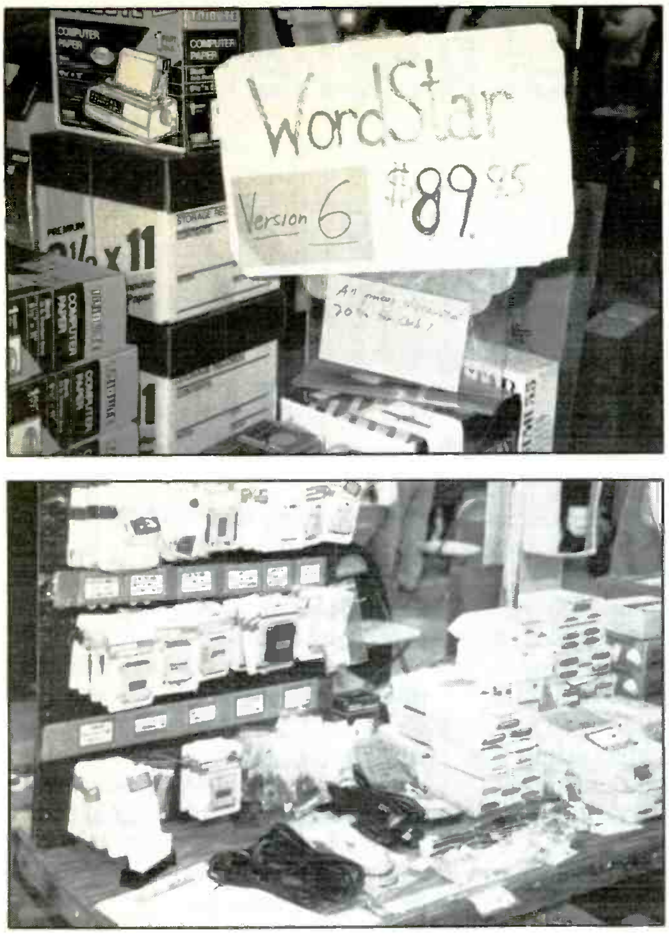
Browsing through the aisles.

On the other hand, I found five different vendors offering memory boards for the HP III. There was some variation in pricing, but in all cases the prices were below those of the typical mail-order house, which was about $170 for the board and 2M of memory at the time of the show. After surveying all prospective vendors, I settled on the one who offered a third-party board and 2M of memory at the lowest price: $132!

At these prices, you can't expect all the amenities. The board, capable of holding the maximum 4M, was bare and appeared to be of high-quality construction. I left with the bare board, memory chips (DIPs) and instructions. However, I was able to determine that the instructions were clearly written and complete before making the purchase. Upon arriving home, it took about 10 minutes to install the memory chips and set the DIP switches on the board. After installing it in the printer, a test-page printout revealed that the board and new memory were performing without a flaw with the HP III.

Finding a vendor offering the HP III PostScript cartridge was more problematical, but then it is a low-demand item that seldom finds its way into mail-order advertisements. One dealer offered to ship it to me the following Monday if I paid at the show. After some negotiation, we settled on a price of $450, which is on the low side of the mail-order range. My preference was to pay by credit card, but the seller wanted a higher-than-usual surcharge. He preferred a check. I left my check with him and got his promise to ship on Monday or Tuesday at the latest.

That meant I should have had the package by Wednesday afternoon, since my home is less than 70 miles from the store. When the package didn't show on Wednesday, I called the store. The clerk assured me that the cartridge had been shipped that day, after a delay in obtaining it from their supplier. As it turned out, the cartridge arrived Friday and appeared to have been shipped on Thursday. Looking back on it, I as-



Bargains galore!

Shopping pro makes a catch.

sume that my shipment was held until the check cleared, in spite of the salesman assuring me it would ship on Monday or Tuesday at the latest.

Computer shows like those sponsored by Ken Gordon offer the savvy shopper an excellent opportunity to save time and money making computer purchases. It's important to remain aware of some of the factors involved in such computer show dealings, however.

First, if you're searching for a hard-to-find or low-sales-volume item, your chances of finding it may not be high. Peripherals for the Macintosh and other non-IBM-type computers are few and far between at these shows. Low-demand items, such as the HP III PostScript cartridge, are also difficult to come by.

On the other hand, if you're searching for IBM-type computers and common accessories, you may very well find what you're seeking. CPUs, VGA monitors, dot-matrix printers and add-on boards abound. Software is plentiful, too, but it's less predictable which packages will show up.

Cold cash is the preferred method of payment, but many vendors take credit cards and checks. If you pay by credit card, you can expect to pay a surcharge. On the other hand, if you're paying with cash and the vendor you're dealing with has a sign stating that there's no surcharge for credit cards, ask for a discount. You may get it. If you're paying with a check, don't be surprised if the dealer wants to ship the merchandise to you after the check has cleared.

Don't expect the amenities of a high-priced dealer operating out of a store in a mall. As children's toys so often warn, "*some* assembly may be required." Also, keep in mind that you may have a bit of a walk from your parking place to the facilities. CPUs, VGA monitors and laser printers are heavy. If you're serious about buying, bring along a hand cart or wheeled baggage carrier. If you're going to buy a lot of small items, consider bringing along a backpack or large canvas bag with a shoulder strap. Dress comfortably, and that includes shoes with plenty of padding.

Is it better to arrive early or come late? There's no definitive answer to this question. If you want to walk by all the booths, it will probably take you an hour at the very least. (We spent about 2½ hours.) Arriving early should give you access to the widest selection of items. On the other hand, you may stand in line a little longer to buy your admission ticket (usually in the $5 or so range). Towards the end of the show, a dealer may be more willing to negotiate a lower price on items that haven't sold. This is particularly true of used equipment. Of course, the dealer may very well have sold out late in the day.

One final thought: bring plenty of cash, checks and credit cards. Chances are you'll find a number of offers so good you can't refuse. ■

An 80287 Socket Rocket

A simple, low-cost enhancement wrings extra performance from an an AT-class computer's floating-point processor

One way to enhance early IBM and compatible PCs and ATs was to exchange the CPU clock crystal with one of higher frequency, which yielded a noticeable improvement in processing throughput (see "PC Express," *Modern Electronics*, May 1987). Nowadays, improvements in the CPU, DRAM and PC board layout routinely produce 8088 and 80286 "hotrods" running at clock speeds up to 16 and 20 MHz, respectively. But the venerable 80286 still has a performance bottleneck: its 80287 floating-point math coprocessor.

Because the 287 runs asynchronously of the CPU clock, a math coprocessor rated at several megahertz below that of the CPU is recommended. (This is not the case with the 8087, which runs synchronously with the 8088 CPU and cannot be upgraded independently.)

If you own an AT-compatible computer that runs at, say, 12 MHz, odds are good that the socket for the 80287 runs at only 10 MHz. Each time a floating-point operation is performed, the 80286 relinquishes the task to a coprocessor operating at a slower clock rate. Although such an arrangement is still faster than if the CPU itself was forced to emulate an 80287, a significant improvement in floating-point math operations can be achieved by running the coprocessor at or well beyond the clock speed of the 80286 CPU clock.

To upgrade the performance of an AT-class computer, all you need are the fastest 80287 coprocessor you can afford, a crystal oscillator that operates at twice the frequency rating for the 80287 and an 82284 clock generator/divider. The schematic details for the required circuit are shown in Fig. 1. In this circuit, the 82284 divides the oscillator frequency by 2 and provides the 80287 math coprocessor with the 30% duty-cycle required for proper operation.

If you provide a proper heat sink for the coprocessor, you may even be able to exceed the speed rating of your particular 80287 by 2 or 3 MHz. I have run an 80287 rated at 10 MHz at a clock speed of 12 MHz using this method for several years with no problems whatsoever—without heat-sinking the chip. However, to be on the safe side, you should bond a heat sink to the chip package with thermally-conductive epoxy cement to provide added security and prolong the life of the chip.

Making the Modification

Before piecing together your Socket Rocket, examine the interior of your computer. Carefully note the space available above and around the 80287 coprocessor socket. If you do not plan installation of a heat sink, the two remaining ICs can be cemented directly to the top surface of the 80287 package using silicone adhesive. Otherwise, install the two chips on a small piece of perforated board that has holes on 0.1-inch centers and wire them together using Wire Wrap or soldering hardware.

Whichever way you choose to go, construction is simple. But exercise great care with the leads that extend

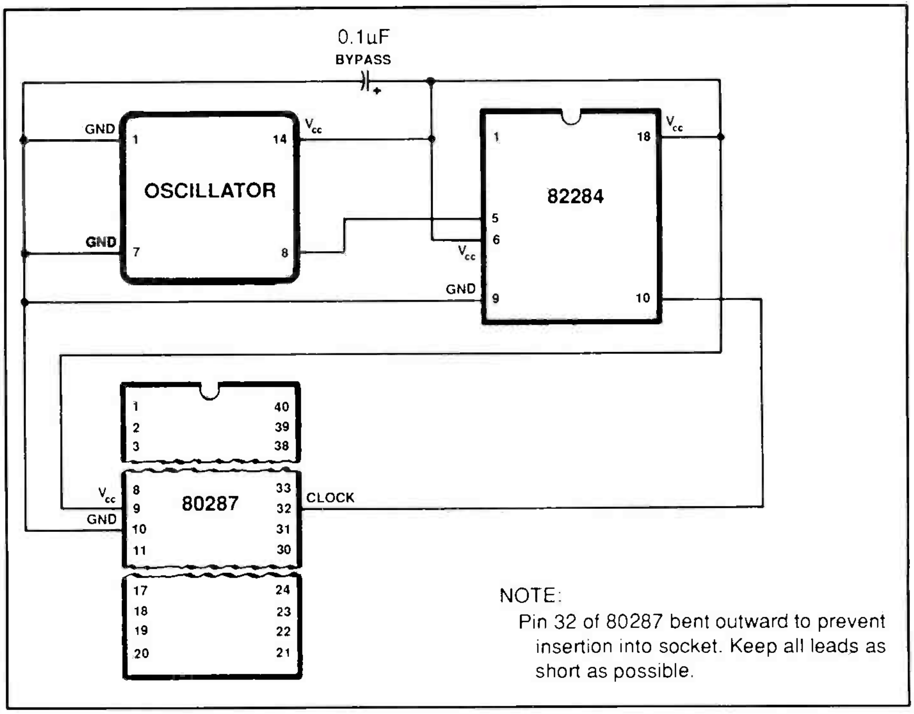


Fig. 1. Schematic diagram of simple modification circuitry.

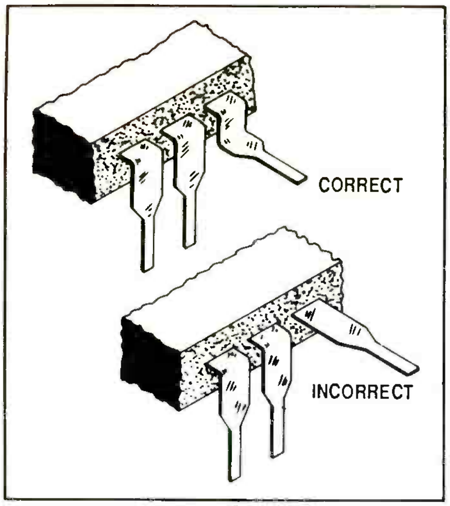


Fig. 2. Details for bending the clock-input pin of the 80287 to prevent it from plugging into its slot in the coprocessor socket on the motherboard.

from the coprocessor socket. Making sure you exercise safe handling procedures for CMOS devices throughout this modification procedure, refer to Fig. 2 and use longnose pliers to carefully bend the clock-input pin of the 80287 as shown. Note here that there is only one correct way to bend this pin to proper shape so that it does not enter the socket when the chip is installed. Do not plug the 80287 into its socket yet.

Referring back to Fig. 1, carefully solder suitable length Wire Wrap leads to the indicated pins of the coprocessor chip. Use a low-power (no more than 25- or 30-watt) *grounded* soldering iron for this and all other soldering operations. Keep the solder points as small as possible and as close as possible to the package of the IC, but make sure you obtain good electrically and mechanically secure connections. Take pains to prevent solder from "bleeding" down the pins, which will prevent insertion into the coprocessor socket later.

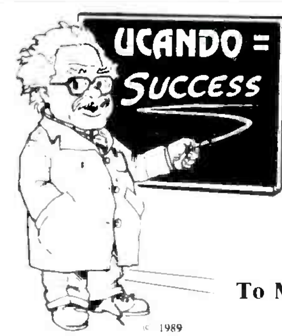
If you have decided to mount the two remaining chips on a small piece of perforated board, be sure to use sockets for them. Sockets permit you to swap oscillators until a maximum clock rate can be determined while maintaining proper operation of the 80287. For example, an 80287 may operate fine when pushed to, say, 12 MHz using a 24-MHz timebase. A little experimenting may be worth the extra time involved.

If you have not already purchased a math coprocessor for your AT-class computer, you are ahead of the game. Plan on buying the fastest rated 80287 you can afford. Using the circuit shown schematically in Fig. 1, it is possible to have a system in which the 80286 CPU is operating at a maximum clock speed of 10 MHz while the 80287 coprocessor is running at 16 MHz or higher frequency.

If you already have an 80287 installed in your computer and plan to incorporate the enhancement described here, try running a benchmark both before and after the modification. Timing regeneration of a large CAD drawing or recalculating some laborious equation within a spreadsheet are good tests to use as benchmarks if you do not have task-specific math coprocessor evaluation software. An increase of as little as 2 MHz in clock speed can shave seconds and even minutes from the time required to perform the CAD or equation operation.

Once you have the entire circuit wired together, plug the 80287 into the coprocessor socket on the motherboard of your computer. Then mount the small perforated-board assembly with the two remaining chips on it in a suitable location. Bond the heat sink onto the case of the 80287 with thermally conductive epoxy adhesive and allow the bond to cure overnight.

Although the Socket Rocket will not yield workstation performance, you should obtain noticeable improvement in the performance of your computer when number crunching, generating CAD drawings, etc. Your cost is minimal for the performance edge you gain. ■



Single-Board Computers

Designing, Building and Programming Dedicated Microprocessor-Based Devices

Welcome to a new series dedicated to the designing, building and programming of microprocessor-based devices. In particular, the focus here will be on small, single-purpose computers that are used to sense, measure or control events or conditions in the "real world" external to your computer.

Possible applications are many, including environmental monitoring and control, test equipment (IC testers, pulse and function generators, etc.), electronic music (MIDI sequencers), robotics, motor control, unit counters, ac power control, biofeedback monitors, electronic art, communications links, aids for the handicapped and more.

If you're interested in doing more with computers than simply running applications programs, a microprocessor-based project gives you the chance to design a system from the ground up. Small, single-purpose computers are ideal when a design requires more than an assortment of logic gates but less than a complete desktop computer system with keyboard, video display and disk drives. Moreover, many people don't want to tie up a computer system to perform a dedicated task.

At the heart of each design is a microprocessor, or central processing unit (CPU) on a chip. With additional circuitry and a control program, the CPU can be used to sense, measure or control outside processes, events or conditions.

This month, we'll look at what's involved in designing and building a microprocessor-based device and at what kinds of products are available to help you implement your ideas. Future columns will focus on specific products or areas of interest relating to microprocessor-based projects. In particular, I'll be reporting on kits and assembled single-board computers that are easily customized for specific applications. And since computers are useless without programs to tell them what to do, I also plan on investigating programming options and tools, including assemblers and compilers (which translate the programs you write into the machine code required by the microprocessor) and development systems (which help you test and troubleshoot your circuit and system designs).

Because input/output (I/O) interfacing also plays an important part in small-computer design, I'll be covering this as well, including techniques and hardware for interfacing microprocessors to sensors, relays, motors, displays, keypads and other real-world inputs and outputs.

If you're new to microprocessor-based design, this column will offer ideas to help you get started. If you're an experienced "computer crafter," look here for ideas, news and reviews of products you can use in your own designs.

Beginnings

Let's begin by looking back a few years to the roots of microcomputing:

In late 1974, Art Salsberg (now editor of this publication) published an article in a January 1975-dated issue by H. Edward Roberts and William Yates describing the Altair 8800 computer. The Altair made electronics history, because here, finally, was an authentic computer that *individual* hobbyists could build and program.

The basic Altair included no keyboard, video display, disk drives or other elements we now think of as basic elements of a personal computer. Its 8080 microprocessor was programmed by flipping toggle switches on the front panel. Standard RAM was 256 bytes, and a kit version of the computer cost $397 ($498 assembled), about the retail price of the 8080 CPU that came in the kit.

The computer world has changed dramatically since then. A typical personal computer now includes a keyboard, video display, disk drives and as much as several megabytes of RAM. What's more, there's no longer any need to build a personal computer from scratch, since mass production has drastically lowered prices of assembled systems. At most, building a personal computer now involves simply installing assembled boards and other components in an enclosure.

But along with these cheaper, more powerful and more versatile computers has developed a new interest in building small, customized computers. Each is dedicated to performing a specific function or a group of related functions and typically contains a single program in EPROM. To change the programmed data, you must erase and reprogram the EPROM.

In contrast, a personal computer such as an IBM PC, Macintosh or Amiga is a more general-purpose machine, since it can be used for many applications—spreadsheets, word processing, computer-aided drafting and more—just by loading appropriate software from disk. Real-world interfaces for personal computers are, for the most part, standard ones like video displays, keyboards and printers for hard copy.

(Of course, by adding appropriate hardware and software, personal computers can also be customized for monitoring and controlling real-world conditions and events. This is often a practical approach, especially when a full keyboard and video display are desired.)

Designing and building a microprocessor-based device is a complex process that requires skills in both

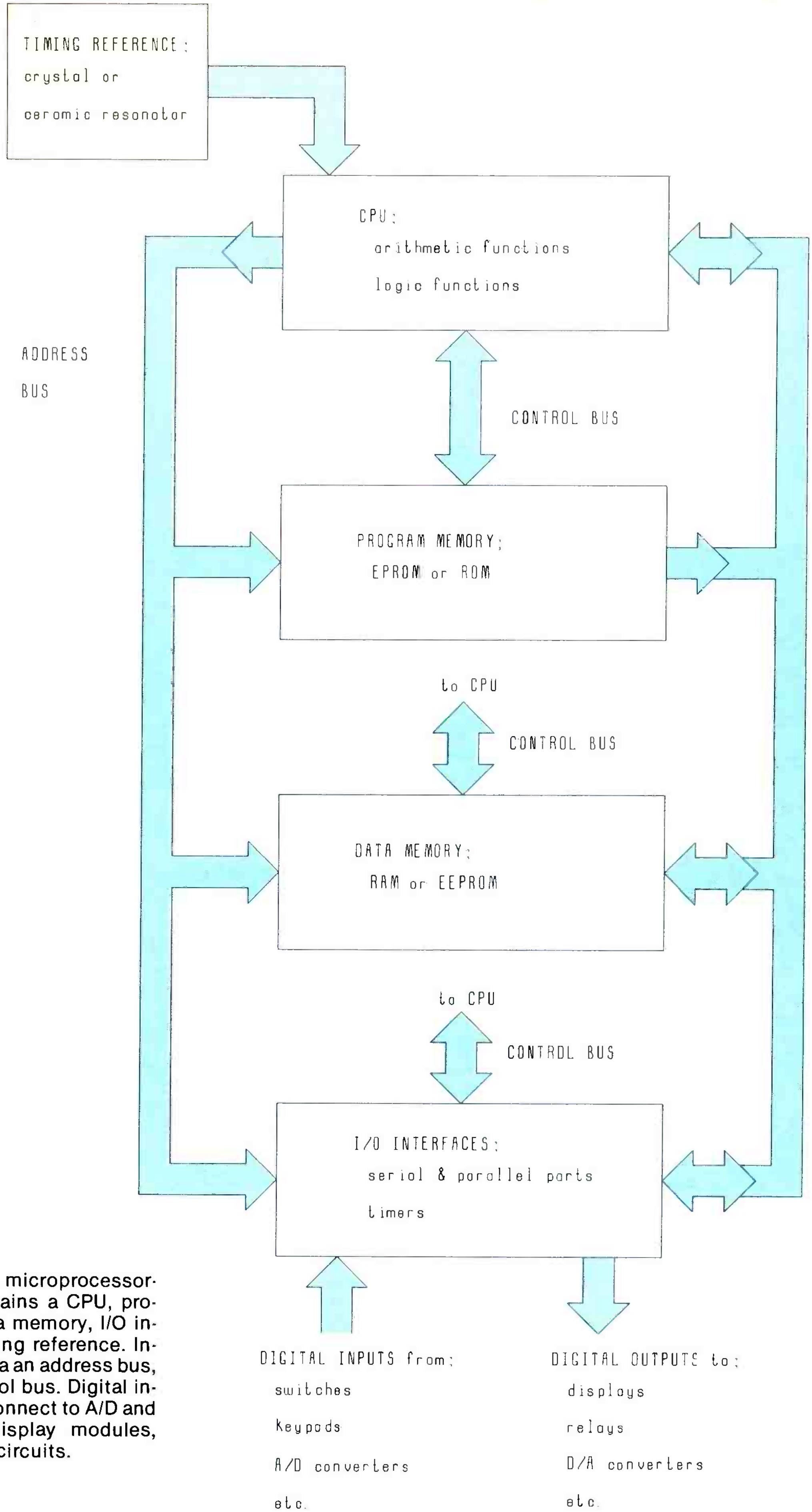


Fig. 1. A typical microprocessor-based design contains a CPU, program memory, data memory, I/O interfaces and a timing reference. Information travels via an address bus, data bus and control bus. Digital inputs and outputs connect to A/D and D/A converters, display modules, keypads and other circuits.

hardware and software design. The good news is that a couple of recent developments have simplified the tasks involved.

One is the development of highly integrated ICs that contain all the elements of a computer on a single chip, including CPU, memory and provisions for serial and parallel I/O. These ICs can reduce the number of integrated circuits and the amount of wiring or printed-circuit board "real estate" required for a project.

The other development is the ready availability of personal computers. A desktop computer, with its keyboard, video display and disk drives, can help tremendously when it's time to write and debug a program or burn a program into EPROM.

Definitions

The term single-purpose computer tells you that the computer is dedicated to a specific purpose, whether it's controlling stepper motors, detecting toxic gases or some other function. Another often-used term is single-board computer (SBC), though this can be misleading since a single-purpose computer needn't be constructed on a single circuit board, and increasing miniaturization now allows even very sophisticated systems to fit on a single board.

The microprocessor ICs themselves may be known by different names as well, depending on what the IC contains and how they're used.

Figure 1 shows the basic elements of a microprocessor-based system. All microprocessor ICs contain a CPU, the heart of any computer system, that performs the basic arithmetic and logic computations. Examples of microprocessor ICs include Intel's 8088, Zilog's Z80 and Motorola's 68000 devices. All of these can be used in personal computers as well as in single-purpose designs.

In addition to the microprocessor, other elements of a complete computer system include memory (for storing programs and data) and provisions for I/O (for interfacing to the outside world). When a single IC contains these elements as well as a CPU, it qualifies as a single-chip microcomputer. Examples include Intel's 8051, Motorola's 68HC05 and Zilog's Z8. Microcomputer ICs are a popular choice for single-purpose computers because they require fewer additional components to complete a design.

When a microcomputer is used to control outside events, it may be called a microprocessor-based controller, or microcontroller for short. Yet another term, embedded controller, tells you that the program that controls the IC is stored in a ROM, EPROM or other IC, rather than on-disk. (And a program stored in an integrated circuit is called firmware, signifying that it's less easily altered than disk-based software.)

Computer Crafting

The process of designing and building a single-purpose computer consists of several steps:

1. Define the task
2. Design and build the circuits
3. Write the control program
4. Test and debug

Sometimes the steps won't follow exactly in this order. You can begin programming before you build the circuits, or you can build and partially test the circuitry before you start writing the control program. But however you go about it, each of these steps is part of the process.

To see what's involved in each step, let's look at each in more detail.

Defining the Task

Every project begins with an idea, or a problem needing a solution. How can I monitor light intensity at different locations and times of day to find the best location for a solar collector? How can I cause my shortwave radio to automatically tune and record certain radio programs for later listening? And so forth.

Once you know what you want to accomplish, you must determine whether or not your idea is one that's best implemented with a computer-based design. In general, a computer is the way to go when the circuitry must make complex decisions or deal with complex data. For example, a simple AND gate can easily decide whether or not two inputs are both "high" and will change its output accordingly. But it would require many small-scale logic ICs to build a circuit that stores each number dialed at a telephone and the time and length of each call.

This type of application is where microprocessors come in handy. Inside, microprocessors are little more than an assortment of logic gates. But modern fabrication processes allow thousands of gates to fit in a single IC component. Since the basic functions of a microprocessor—performing arithmetic and logic computations—are common ones that are useful in many applications, it's practical to design and market a single chip that performs these functions.

On the other end of the scale, how do you know if an idea is suitable for a small, single-purpose computer or whether you should use a full desktop computer? If your design requires users to enter or view complex commands or data, or if you need large amounts of data or program storage, then a system with keyboard, video display and disk drives makes sense. Otherwise, consider a smaller system, with (as needed) switches or a keypad for user input, an LED or LCD display for visual output and RAM and EPROM for data and program storage.

Designing & Building

When you're ready to design and build the circuits for a project, there are several ways you can proceed. You can design your circuits from scratch, using manufacturers' data books as guides; you can follow a tested design (a project presented in *Modern Electronics*, for example); or you can buy an assembled single-board computer, adding only the interfaces and programming your application requires.

Does it matter which microprocessor IC you use? All microprocessors contain a CPU, and chances are that you can use any of several devices for a specific design.

Within each device family you'll usually find a selection of versions, each with different combinations of options. For example, the M68HC11 microcomputer IC is available with a choice of ROM or EPROM and with varying amounts of RAM and EEPROM. You select the version that best suits your system's requirements.

Microprocessors are also characterized by how many bits of data they can process at once. Eight-bit processors are popular for single-purpose designs, but four-bit, 16-bit and 32-bit architectures are also available.

Power consumption is another consideration, especially for battery-operated systems. CMOS devices offer lowest power consumption, and many of these also have special standby or "sleep" modes that limit current consumption to as low as a few microamperes when the circuits aren't active. Using these modes, a data logger can "sleep" between samples, powering up briefly only when it's time to take data.

All microprocessors have a defined instruction set, the binary words that cause the microprocessor to carry out specific operations. For example, the opcode 0010 0110 instructs the 8051 microprocessor to add the values in two specific locations. The binary instructions are also known as operation codes, or opcodes for short.

All microprocessors have opcodes that perform basic functions like adding, subtracting, logic operations, moving and copying data, and controlling program branching. Processors designed for use as microcontrollers also include opcodes that are especially useful in control circuits, which often require toggling or examining single bits of data.

A microcontroller circuit might use each of the eight bits of a parallel port to switch power to one of eight ac sockets. If each socket must operate independently of the others, a way is needed to change each bit without affecting the others. Many microcontrollers include bit-manipulation (also called Boolean) opcodes that permit programs to set, clear, compare, copy or perform other logic operations on single bits of data.

Another consideration in hardware design is how the program will be stored. EPROM is by far the most popular method of program storage for single-purpose computers. The procedure for saving a program in EPROM requires stepping through the program, setting the EPROM's data and address pins to the appropriate logic levels and applying special programming voltages to the IC at each step. Erasure is by exposure to ultraviolet light.

(A) Machine Code

```
1100 0011
1001 0000   1100 1000   0000 0001
1110 0000
1111 1001
1001 0000   1100 1000   0000 0000
1110 0000
1111 1000
1001 1001
0101 0000   0000 0011
1110 1001
1111 0000
```

(B) Assembly Language

```
CLR C
MOV DPTR,#0C801H
MOVX A,@DPTR
MOV R1,A
MOV DPTR,#0C800H
MOVX A,@DPTR
MOV R0,A
SUBB A,R1
JNC LABEL1
MOV A,R1
MOVX @DPTR,A
LABEL1
```

(C) High-Level Language

```
A=XBY(0C800H)
B=XBY(0C801H)
IF B>A THEN XBY(0C800H)=B
```

Fig. 2. These examples show the difference between programs written in (A) machine code, (B) assembly language and (C) a higher-level language. Each example performs the same functions, but the machine code uses binary instructions, while assembly language uses mnemonics (machine-code abbreviations) and the higher-level language (such as BASIC) uses its own keywords and conventions. (All examples are written for the 8051 microcomputer family.)

The EPROM may be part of the microcomputer IC, or it may be a separate device. Some microcomputer ICs contain one-time-programmable (or field-programmable) EPROMs. Because they have no transparent ceramic window, one-time-programmable EPROMs can't be erased. However, because they're cheaper than ceramic-windowed ICs, they're a good choice when a program has been debugged and is ready for mass production.

Many techniques are available for programming EPROMs. A manual programmer requires you to physically flip switches to toggle each bit in your program and burn the program in byte by byte. This is acceptable for short programs, but it quickly becomes tedious with longer ones.

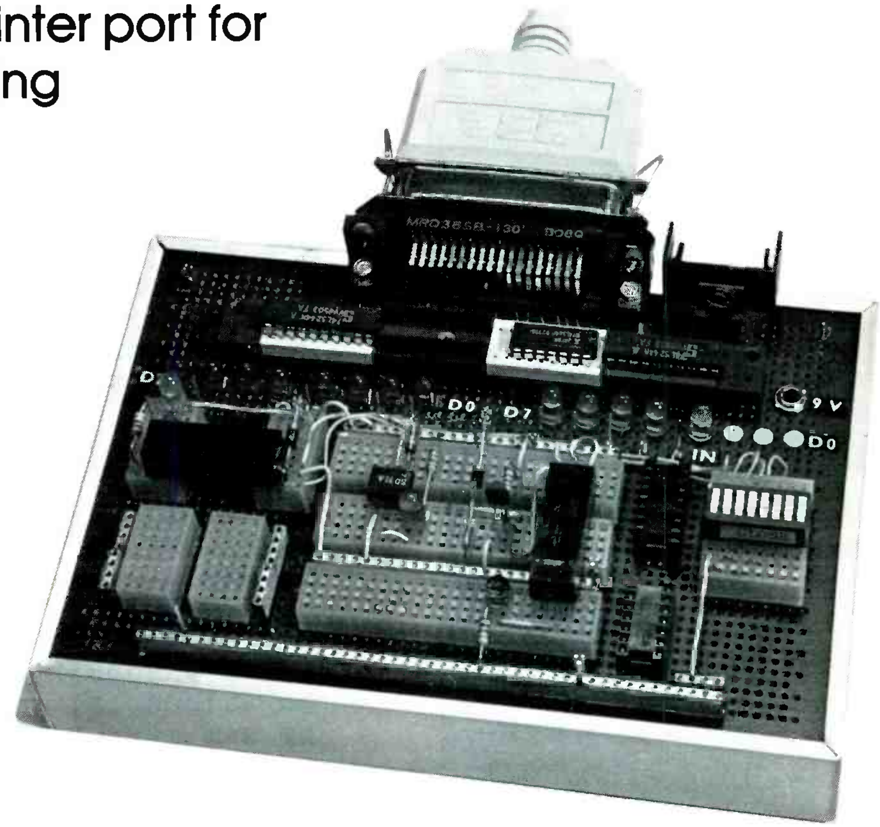
Computer control can simplify the job. With an EPROM programmer that connects to a personal computer, you can write a program at your keyboard, save it to disk if you wish and burn the program into EPROM in a few easy steps. Some single-chip microcomputers even contain their own EPROM-programming firmware; so you can program an EPROM using a personal computer and only a small amount of additional hardware.

Other options for program storage include EEPROMs and ROMs.

(Continued on page 74)

Build A Parallel Printer Port I/O Interface

Lets you use a PC printer port for more than just printing



Input/output (I/O) ports are the connecting links between your computer and peripheral equipment and control systems. Your computer has a number of I/O ports that perform various functions. The video card, for example, includes an output port that sends video and control signals to the display monitor. The keyboard is serviced by a two-way I/O port that sends initializing data bits to the keyboard and receives transmitted keystroke data in serial format from the keyboard. The multi-purpose serial ports in your computer send and receive serial data through a telephone modem. The parallel printer port and game port are other examples of ports typically found on computers.

Special I/O boards for data-acquisition and control applications may have more capabilities than you really need or are willing to pay for. In this case, your parallel printer port can serve nicely for most such applications (an I/O port to control a motor, lamp, heater, relay, solenoid and other devices in a control system). Most likely, your computer system includes a second unused printer port that obviates the need to borrow use of a sole printer port. You may even have an unused PC- or XT-class machine that can be dedicated to the control system.

In this article, we describe the characteristics of the printer port and detail how to build and use an inexpensive I/O Printer Port Interface. The arrangement offers an eight-bit latched data output port, a five-bit data input port and an optional four-bit latched data output port. Light-emitting diodes display input and output data in binary format.

The I/O Printer Port Interface also serves as a learning aid for beginners to machine-language programming. The Port is operable from DEBUG, BASIC or any language that includes I/O port IN and OUT instructions. Partially simulating a printer, the Port can be used for troubleshooting the computer printer port and cable. Additionally, the input port can be patched into a machine-code program you are debugging and used as an escape key to exit an inadvertent endless loop without having to reset your computer.

Printer-Port Characteristics

The computer printer port is an isolated I/O port that occupies three consecutive addresses in I/O space. Because it is not part of memory space, the printer port is accessed only through I/O-port instructions. Figure 1 details the computer parallel printer port address and bit map, along with corresponding pin numbers for Centronics M36 socket *SO1*.

Table 1 lists the IBM DB-25-to-Centronics M36 printer-cable connections and line assignments. The port includes an eight-bit latched data output port at base address N in Fig. 1(C), a five-bit status input port at address N+1 in Fig. 1(B) and a four-bit latched data control output port at address N+2 in Fig. 1(A). Base address N depends on computer configuration and DIP-switch settings on the computer printer card. Because they differ from conventional output ports, both output ports permit a "read" of data last sent to the port.

The eight-bit data port is a conventional follower port that duplicates the data sent to the port. The five-bit status input port spans bits D3 through

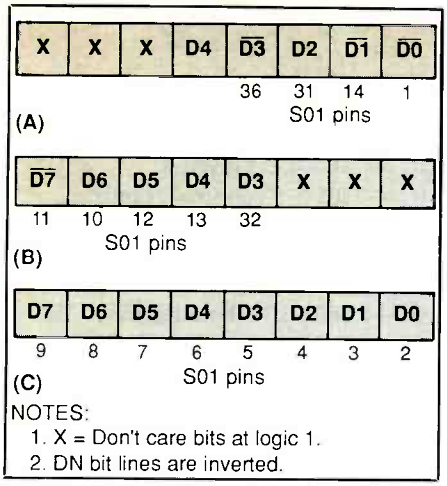


Fig. 1. Computer printer port map.

Table 1. IBM DB-25-to-Centronics No. M36 Connections

DB-25	M36	Signal	DB-25	M36	Signal
1	1	/STROBE	14	14	/AUTO FEED
2	2	D0	15	32	/FAULT
3	3	D1	16	31	/INIT PTR
4	4	D2	17	36	/SEL PTR
5	5	D3	18	33	GND
6	6	D4	19	19	GND
7	7	D5	20	21	GND
8	8	D6	21	23	GND
9	9	D7	22	25	GND
10	10	/ACK	23	27	GND
11	11	BUSY	24	29	GND
12	12	PAPER END	25	30	GND
13	13	PTR SLTD			

D7, with bit line D7 inverted. This is corrected with an inverter gate in the port interface.

Unconventional in several respects, the control output port spans bits D0 through D3. Bit D4 exists in the port data latch but was not connected to the printer cable. Data bits D0, D1 and D3 are inverted and output logic 0 when a logic 1 is sent to these bit positions. All non-existent "don't-care" bits return a logic 1 on port read.

Shown in Fig. 2 are partial circuits of the IC gates directly interfacing with the computer printer cable signal lines. The ICs on your printer card are either the same as those shown or equivalents. Figure 1(C) shows bit line D0 of the eight-bit data output port line driver consisting of a 74LS374 eight-bit data latch and buffer. The data latches store the data last sent to the port until later updated. Commonly used as a line driver, the 74LS374 can sink 16-milliamperes.

Figure 1(B) shows bit line D3 of the five-bit status input port that uses a portion of a 74LS244 eight-bit follower gate as a line receiver. The status port does not include a data latch.

Shown in Fig. 2(A) is bit line D0 of the control output port, which uses an open-collector 74LS05 hex inverter. The open-collector gate requires use of external pull-up resistor *R* connected to +5 volts. The resistor was located in the printer and measured 4,700-ohms. Possibly, the computer printer circuit card may additionally include pull-up resistors. The 74LS05 is capable of sinking a maximum of 8 milliamperes. The data latch for this port appears to be a 74LS174 hex D-type flip-flop on the printer card. The ports are controlled by port address decoders and control circuits that are part of a custom-designed PAL integrated circuit.

About the Circuit

Shown in Fig. 3 is the complete schematic diagram for the PC Parallel Printer Port I/O Interface circuitry. This interface circuit includes the eight-bit data output port and the five-bit status input port. The eight-bit data output port connects to 74LS244 buffer/line driver *IC1*. The buffer gates are capable of sinking 24 milliamperes at logic 0 and sourcing 15 milliamperes at logic 1.

Pull-up resistors *R1* through *R8* terminate the printer cable lines to reduce noise and improve signal transfer. Light-emitting diodes *LED1* through *LED8* provide visual indication of the status of the data bits. On logic 0, the LED lights and the gate sinks about 10 milliamperes, leaving about 15 milliamperes of sink current available for port circuits.

Five-bit data input port buffer gate *IC2* is a 74LS244. Pull-up resistors *R9* through *R13* apply a logic 1 to the inputs of the gates. Positions 1 through 5 in DIP switch *S1* apply logic 0 to the inputs when closed. LED data indicators *LED9* through *LED13* light when logic 0 is applied to gate inputs. Gate *IC3*, inverts bit line D7 to alter it to read as a follower bit. Not wired to buffer gates, the control port data bit lines on socket *SO1* as listed in Fig. 1(A) were connected to board terminals for later wiring when needed.

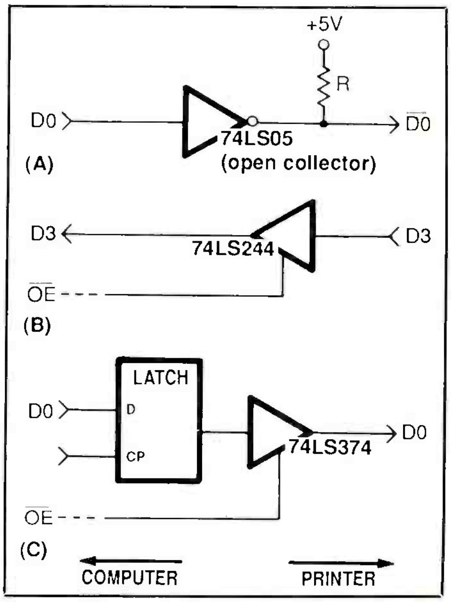


Fig. 2. Computer printer port I/O gates.

An ac wall adapter power unit that supplies 9 volts filtered dc at 500 milliamperes plugs into jack *J1* to provide power for the project. Regulator *IC4* supplies regulated +5 volts dc to the Interface circuit. Rectifier diode *D1* protects the circuit from damage that would otherwise occur if reverse voltage were applied to the input. Capacitors *C1* and *C2* stabilize the regulator. Capacitors *C3* and *C4* affect noise reduction. DIP switch *S1* is temporarily installed in the breadboard portion of the port interface.

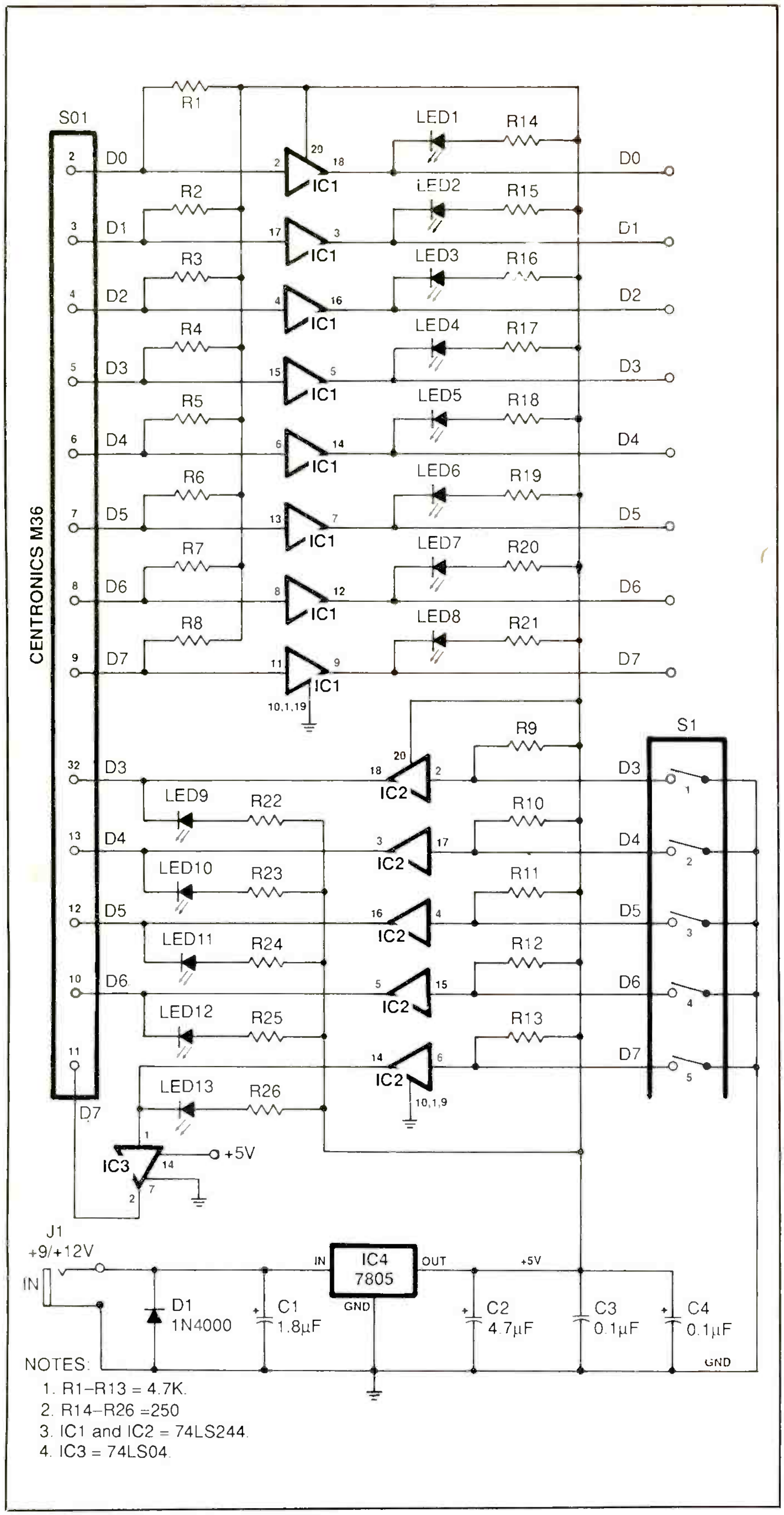


Fig. 3. Complete schematic diagram (minus its plug-in wall-type power supply) of Parallel Printer Port I/O Interface circuitry.

PARTS LIST

Semiconductors

D1—1N4000 silicon rectifier diode
IC1,IC2—74LS244 eight-bit line driver
IC3—74LS04 hex inverter
IC4—7805 +5-volt fixed regulator
LED1 thru LED13—Light emitting diode

Capacitors

C1—1.8-μF, 35-volt tantalum
C2—4.7-μF, 15-volt electrolytic
C3,C4—0.1-μF, 15-volt disc

Resistors (¼-watt, 5% tolerance)

R1 thru R13—4,700 ohms (SIPs, see text)
R14 thru R26—270 ohms

Miscellaneous

J1—miniature phone jack
SO1—Centronics No. M36 male connector
S1—Eight-section DIP switch
Printed-circuit board or perforated board with holes on 0.1″ centers and suitable Wire Wrap or soldering hardware (see text) and suitable enclosure or solderless breadboarding system; solderless breadboarding components; filtered 9-volt dc, 500-mA plug-in power supply; small heat sink; machine hardware; hookup wire; solder; etc.

Note: Resistive SIPs are available from Digi-Key, P.O. Box 677, Thief River Falls, MN 56701-0677 (tel.: 1-800-344-4539). An adjustable 6-to-12-volt dc, 500-mA plug-in power supply is available from Consolidated Electronics, Inc., 705 Watervliet Ave., Dayton OH 45420-2599 (tel.: 1-800-543-3568).

Construction

Shown in the lead photo and Fig. 4, the Interface is permanently wired at the rear of a solderless breadboarding chassis, using both Wire Wrap and soldering techniques. The assembly shown is a Vector Electronics aluminum rail chassis supporting a 4½ × 6½-inch perforated board with holes on 0.1-inch centers and bus traces on one side (a board without traces would be the better choice, but I had this one on hand and, so, used it for the prototype of the project). The solderless breadboard tie blocks shown are Vector Klip-Bloks, Klip-Strips and Klip-Buses, which plug into board holes in any arrangement.

Because conductor routing and component placement are not criti-

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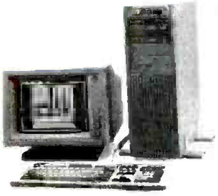

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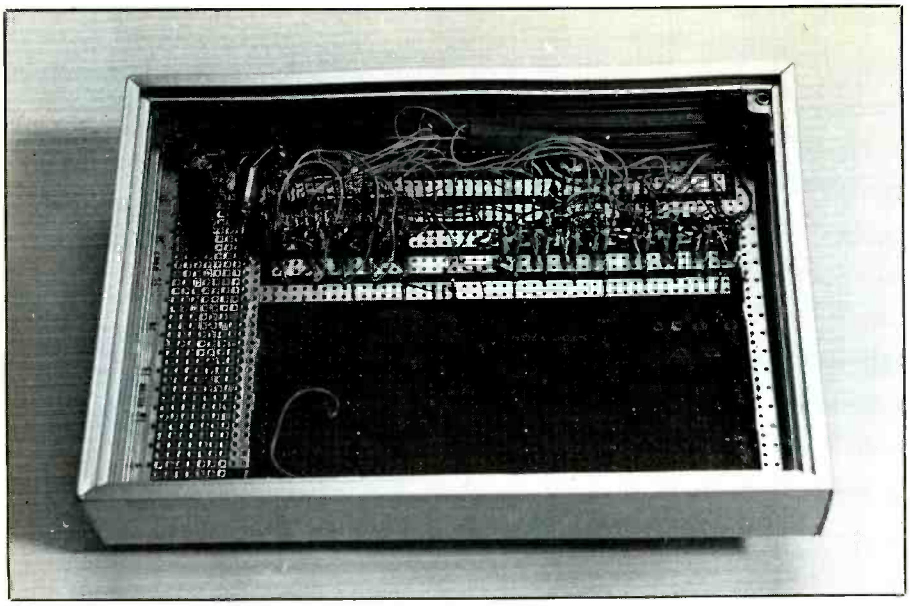

Fig. 4. This interior underside view of author's prototype shows Port Interface permanently wired at rear of enclosure.

cal, you can a use any wiring method or breadboarding approach you wish. In fact, if you are ambitious, you can design and fabricate a printed-circuit board on which to wire together the components. You can install a Centronics M36 connector on almost any solderless breadboarding system, such as the Ace and Power-Ace systems (the latter has a built-in power supply).

The Centronics 36M connector shown is a right-angle solder-tail type designed for mounting directly on a pc board. Connector pin spacing precludes passing of the solder tails through board holes, though. Install the connector on two ⅜-inch-long spacers to raise the solder tails slightly above the surface of the board. Otherwise, cut a rectangular hole in the board to pass the solder tails below the board.

Table 1 shows the IBM DB-25 connector pin assignments and corresponding Centronics M36 (*SO1*) pin numbers. The M36 pin numbers are labeled on the connector. Before installing *SO1*, cut 5-inch lengths of 30-gauge insulated Wrap wire and strip 1 inch of insulation from both ends. Wrap one end of these wires to the pins on *SO1* using a Wire Wrap tool and follow with solder.

Pass the free ends of the wires through board holes in the exact same order as connected. Pass mounting bolts through the connector and spacers and secure the assembly in place. The eight-bit output port and *IC1* are at the left in Fig. 4. A 20-pin Wire Wrap socket to the right of *IC1* holds two nine-position 4,700-ohm resistive networks in single-in-line packages that are used for resistors *R1* through *R13*.

The five-bit input port is at the right, *IC2* is at the extreme right, and *IC3* is to the left of *IC2*. Install sockets for the ICs and SIPs. Install *LED1* through *LED8* in a row just forward of IC1. Allow additional spacing between the fourth and fifth LED to divide the group into two four-bit nibbles. Install all LEDs with anode lead or arrow tail to the right. Label the right-most LED as D0 and left-most LED as D7. Install eight Wire Wrap post pins forward of each LED for connection to the output of corresponding data bit of buffer gate *IC1*.

Proceed similarly to install *LED9* through *LED13* and Wire Wrap post pins forward of the five LEDs. Bit positions D0, D1 and D2 are blank and are represented by white vinyl tape dots. Label the right-most dot as D0 and left-most dot as D7.

Install and wire LED resistors *R14* through *R26*. Discrete resistors were used in the prototype, but these can be in the form of SIPs installed in a Wire Wrap socket if you wish. Wire *IC4* into the circuit, shown mounted vertically to right of the Centronics connector, with *J1* nearby. Install a small bat-wing heat sink on *IC4*. Install the DIP switch in solderless tie blocks and wire it to the input terminals of the input port. Assign the left-most switch as bit D7.

Terminate the control port wires of pins 1, 14, 31 and 36 of *SO1* on Wire Wrap post pins. If you wire the control port to buffer gates, make it an inverting port. Use the three remaining *IC2* gates on bit lines D0, D1 and D3 wired similarly to the bit lines of *IC1*. Use a spare *IC3* gate to invert bit line D2 to make it an inverting four-bit output port. Check your wiring for errors and omissions.

Checkout & Use

Perform the following tests to locate short circuits and wiring errors that can damage the computer printer port or Interface Port. Perform resistance checks with *IC1*, *IC2* and *IC3* not plugged into their sockets, with no connection made to your computer and with no power applied to the project. Determine the polarity of the voltage at your ohmmeter probes with the aid of a dc voltmeter or multimeter set to the dc-volts function before making your in-circuit tests. Resistances cited below are nominal, with some varying considerably, depending on leakage currents and ohmmeter probe polarity.

Pins 1 through 18 of *SO1* are readily accessible at the topside rear of the connector. For *SO1* pins 2 through 9, the resistance measured from each pin to the port +5-volt bus should measure about 4,700 ohms. The resistance from each pin to port ground should be greater than 4,700 ohms.

For the unused control lines on *SO1* pins 1, 14, 31 and 36, the resistance from each pin to the +5-volt bus or to ground should be infinity. For pins 10, 12, 13 and 32 of *SO1* and for pin 14 of *IC2*, the resistance from each pin to +5 volts should be near infinity, with the ohmmeter + lead connected to the pins so that reverse-bias is applied the LEDs. Reversing the ohmmeter leads should register a resistance normally greater than 100,000 ohms because the LEDs are now forward biased. For pin 11 of *SO1*, the resistance to +5 volts or to ground should be infinity.

(Continued on page 76)

Free as a Mouse

Testing a new cordless pointing device

There's a certain movement people make when working with a mouse for extended periods of time. It's a tug to generate some slack in the cord that attaches the mouse to the computer. You may not have thought you could ever eliminate this annoyance, but with a new product from Lightwave Technologies, you can. It's called "Lester, The Cordless Mouse," the "Lester" being an acronym for Light Emitting Static Tracking Extended Range technology.

The Cordless Mouse, for IBM and true compatible PC, XT, AT and PS/2 computers, comes in a package that includes the mouse, an infrared receiver unit that attaches to the computer's RS-232 serial port via a nine-pin DIN plug with 4-foot, 9-inch cable; (a 9-to-25-pin adapter and an adapter for PS/1 and PS/2 computers are also provided); two AAA cells; and software drivers (both COM1 and COM2). Also included are a mouse pad and a paint program called *Visualizer*. A mouse holder that attaches to the side of a monitor or in any other convenient location is optional. The Cordless Mouse has a suggested retail price of $149.95.

PC/MS-DOS 2.0 or later and 128K minimum RAM are required for operation. The mouse comes with a five-year limited warranty.

Fig. 1. The Cordless Mouse operates over a range of up to 5 feet between mouse transmitter and receiver and up to 90° off-axis over an infrared link.

About the Cordless Mouse

The Cordless Mouse is a three-button opto-mechanical device that measures 4.375 × 2.5 × 1 inches. At the bottom of the mouse is a tracking ball with an anti-static silicon rubber coating. The ball is removable for cleaning and maintenance. Also along the bottom of the mouse are four Teflon® feet that reduce resistance to sliding and a battery compartment that holds two AAA cells. The Cordless Mouse has a power consumption of approximately 9 milliamperes.

Lester contains a 12-MHz, eight-bit CMOS CPU that enables the mouse system to provide unusual functions that include sensing and switching of the serial port used (COM1 or COM2), among other features.

On the left side of the mouse is a wedge-shaped button that's used for several purposes. It's used to activate the mouse when you first start working. If you leave the mouse idle for more than 10 minutes, it shuts off to conserve power. The button is then used to turn it on again.

Finally, the button can be used to vary the tracking ability of the mouse. If you move the mouse slowly while holding the button pressed, its variable tracking feature causes the cursor to move across the screen in very slow steps. The slower you move the mouse, the greater the resolution, automatically up to 1,200 dpi. If you move the mouse quickly with the button pressed, the variable tracking feature causes the cursor to bolt across the screen in large increments.

At the front of the mouse is an infrared light-emitting diode. You can move the mouse in a 90° cone in relation to the receiver (see Fig. 1) and still have the system work correctly. You can also position the receiver well above the mouse transmitter, as long as there's sufficient distance and a clear line of sight between transmitter and receiver.

Standard default resolution of The Cordless Mouse is 300 dpi. This is continuously variable between 10 and 1,200 dpi, as previously cited. You can bring up a menu at any time to change the default resolution, too. Tracking speed of the Cordless Mouse is up to 24 inches/second.

Setting Up

Setting up The Cordless Mouse is a snap. You don't even have to open your computer. The biggest task you have is finding a place to set up the infrared receiver, a device that's about half the size of a typical mouse. The receiver's cord connects to the computer via either the COM1 or COM2 serial-port connector on your computer. When you mount the receiver, which measures about 2½ × 2 × 1 inches, it has to be in line of sight of the mouse but not necessarily at the same level. The manual suggests that the receiver be mounted about 12 to 15 inches from the mouse. The system is said to operate at a distance of up to 5 feet away. Working with The Cordless Mouse confirmed that it operates even beyond this rated distance.

If you set up your PC in a typical manner, with the monitor mounted on the system unit and the keyboard immediately in front, the best place for the receiver is on the desk, alongside the right side of the system unit (for right-handed people, of course). Curiously enough, the packaging shows a picture of the receiver placed on top of the system unit and the mouse on the desk next to the keyboard. This arrangement doesn't work, since the signal from the mouse can't "leap up" to the receiver above it.

Once you connect the receiver's cord to one of the serial ports on the system unit, you're ready to go. Lightwave Technologies has accounted for all possible connectors by including the nine-pin DIN connector at the end of the receiver cord, a 9-to-25-pin adapter and a 9-pin-to-PS/1 or -PS/2 adapter.

If you're running a program like *Windows* 3.0 that includes mouse drivers, The Cordless Mouse will work if you install *Windows* for either the Microsoft Mouse (two buttons, right and left work, center is inactive) or the Mouse Systems Mouse (three buttons). If you have a program like *PC Paintbrush IV Plus* that asks you to load a mouse driver from disk, you must insert the disk included with The Cordless Mouse and choose the driver you want (either the Microsoft or the Mouse Systems Mouse driver). The drivers come on both 5¼- and 3½-inch disks. The Cordless Mouse automatically recognizes which driver is present. Also included on-disk is a test program that you can use to make sure The Cordless Mouse is working properly.

Using It

I tested The Cordless Mouse with several programs, including *Windows* 3.0, Microsoft *Excel* and *PC Paintbrush IV Plus*. It worked fine with all programs. It rolls easily, and the buttons have a nice feel and click. There were no perceptible problems with on-screen cursor movement as the mouse was moved from side to side and the receiver was moved to different heights. The Cordless Mouse didn't feel as comfortable as the Microsoft Mouse that I normally use, though.

Included in The Cordless Mouse package are some memory-resident pop-up menus for popular programs like Lotus *1-2-3* (versions 1A through 2.xx) and *dBASE III*. Although these pop-up menus work fine, and in Lotus *1-2-3* give you the ability to move the cursor with the mouse, they're limited to a few simple commands and, in my opinion, aren't worth installing.

Another item included with the package is a *Visualizer* paint program, which works in all IBM graphics modes, including 16-color VGA. Although the program worked fine on a PC with a Paradise-compatible VGA board, it exhibited some bugs when run on a PC with a Tseng Labs-compatible VGA board. The main feature of the program is that every part of it can be accessed with the mouse, including loading and saving files. The only time you have to use the keyboard is to type text. *Visualizer* also comes on both 5¼- and 3½-inch floppy disks.

Conclusions

The Cordless Mouse package includes everything you might ever want with a mouse, including a mouse pad and a paint program. The Cordless Mouse is also completely compatible with both the Microsoft mouse and the Mouse Systems Mouse. At $149.95 suggested retail, undoubtedly to be discounted, the price isn't great, but it is fair. We used the mouse with different kinds of software and it worked the same as any other mouse that attaches to a PC via an umbilical cord. The question, therefore, is: Should you buy The Cordless Mouse?

As far as I can determine, you might consider The Cordless Mouse for one of several reasons. First and foremost is that you really hate the cable attached to competing products. Second is that you need a mouse that has three active buttons; if so, this is about as good a choice as any. Third is that you like the variable tracking feature. Fourth is that you want the extras included with the package, such as the mouse pad, menus and paint program. All are valid reasons for buying The Cordless Mouse.

However, there are also a few reasons why you may not want to consider The Cordless Mouse. First is that its ergonomic design isn't, in my opinion, the match of the Microsoft Mouse. Second, it needs a power source of its own (the AAA cells mentioned above). The supplied alkaline cells have a rating of 100 hours normal use, but the manual mentions that if you use rechargeable nickel-cadmium cells, they'll pay for themselves in "a very short time." Finally, there are no provisions for switching keys for left-handed users

In conclusion, then, the prime reason to buy The Cordless Mouse is the freedom you can experience by eliminating the direct connection by cable to your PC. If you don't care about this innovative feature, the reasons for buying The Cordless Mouse aren't so compelling. ■

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A Laser Update

When Theodore Maiman announced the development of the first laser in 1960, who would have thought that lasers would someday be used in light shows and to read music encoded on plastic disks, print text and graphics, carry conversations through optical fibers and scan bar-coded labels on groceries?

Thanks to a swarm of important advances in semiconductor devices, lasers will become even more important in coming years. Therefore, electronics enthusiasts would do well to stay abreast of the latest developments in the field, especially since many kinds of lasers have become available at prices that are considerably lower than they were just a few years ago.

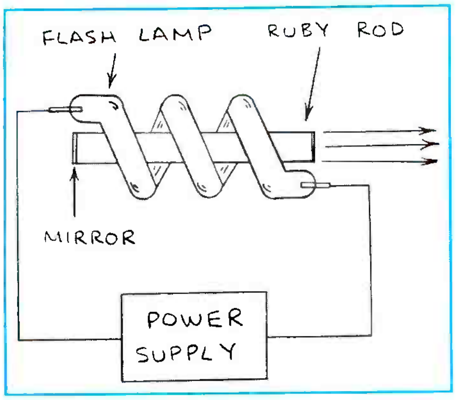

Fig. 1. Illustrated are the basic components of a ruby laser.

The First Laser

The first laser was demonstrated in 1960 by Theodore Maiman of Hughes Aircraft. Although the specific kind of laser Maiman developed is no longer very important, its operation is so straightforward that it is worthwhile to examine it in some detail.

Maiman's laser consisted of a small ruby rod encircled by a helical xenon flash lamp, as shown in Fig. 1. One end of the ruby rod was coated with a metallic film that reflected essentially all the light that struck it. The other end of the rod was coated with a metallic film that reflected most, but not all, of the light that struck it.

When a large capacitor is discharged through a xenon flashlamp, the xenon gas emits a brief but intense burst of white light. Ruby is aluminum oxide (sapphire) containing a tiny fraction of chromium atoms. Some of the green and blue wavelengths emitted by the flashlamp in a ruby laser stimulate the chromium atoms in the ruby crystal to greater-than-normal energy levels.

Figure 2 is a highly simplified energy level diagram that summarizes what happens when a chromium atom is excited. Ordinarily, the outermost electrons of a chromium electron at rest occupy what is known as the ground state or level. When excited by blue or green wavelengths from a flashlamp, an outermost electron immediately jumps to an excited level. Since blue light has more energy than green light, it raises the electrons to higher energy levels than does green light. Almost as soon as the excited electron reaches an excited level, it falls to an intermediate energy level known as the metastable level, in the process emitting as heat some of the energy it absorbed from the flashlamp.

Ordinarily, the excited electron remains at the metastable level for an interval known as the fluorescent lifetime before it spontaneously falls back to the ground level. When this occurs, the electron gives off a photon of light whose wavelength is determined by the energy separation between the metastable and ground levels. The excited electron can also be stimulated by a passing photon to return to ground level and give off a photon before its fluorescent lifetime expires. This process, known as stimulated emission of radiation, is an essential feature of laser operation. Indeed, the very name laser is an acronym for light amplification by stimulated emission of radiation.

As the powerful flash of light from the xenon lamp continues to pump more photons to an excited state, a point is reached where the majority of chromium atoms are in an excited state. This state is known as a population inversion since the population of excited electrons exceeds that of electrons at rest.

When some of the excited electrons at the metastable level spontaneously fall back to their ground levels, they give up the energy they previously absorbed in the form of photons of deep red light with a wavelength of 694.3 nanometers. Some of these photons strike one of the two mirrors evaporated onto the two facing ends of the rod and are reflected back through the rod, where they stimulate additional excited electrons to fall back to their normal levels. These photons are in-phase with those that stimulated their emission.

Soon a cascade of photons is reflecting back and forth through the rod, stimulating still more in-phase photon emissions from excited electrons. A powerful pulse of red light then emerges through the partially transparent end mirror, as illustrated in Fig. 3. Since the pulse of light results from the collapse to ground level of many excited electrons, the pulse is very brief. But because the flash from the flashlamp has a duration measured in milliseconds, the chromium atoms in the ruby rod continue to be excited until a majority are again excited, a population inversion again occurs and another brief pulse of laser light is emitted. The end result is that the burst of red light emitted by a ruby laser resembles the output of a relaxation oscillator in that it consists of an envelope of many brief but powerful spikes.

Scientists and engineers were intrigued both by the concentrated power of the light emitted by Maiman's first ruby laser and the coherence of its beam. Many previously impossible applications were made possible by the coherent nature of the beams from lasers. This characteristic of laser light is so important that it needs a good deal more explanation.

Coherent Light

A precise definition of coherent light is well beyond the level of this column. One important characteristic of a coherent beam of light is spectral purity. The light from most lasers possesses a very narrow bandwidth and is, therefore, considered to be highly monochromatic (one color).

The waves within a coherent beam are highly ordered and in-phase with each other. While the light from an incandescent lamp resembles the confused scramble that results when raindrops splash into a puddle, coherent waves from a laser

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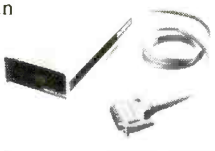

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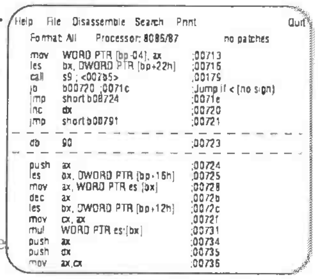

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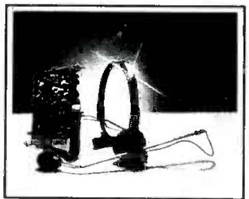

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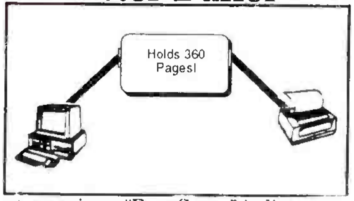

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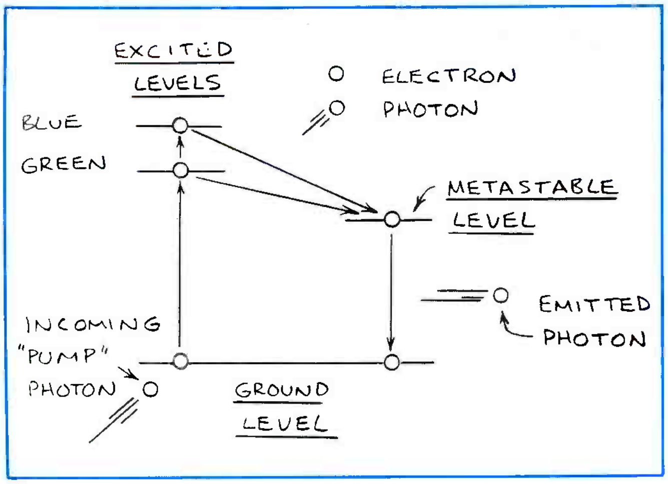


Fig. 2. Energy states in a ruby laser.

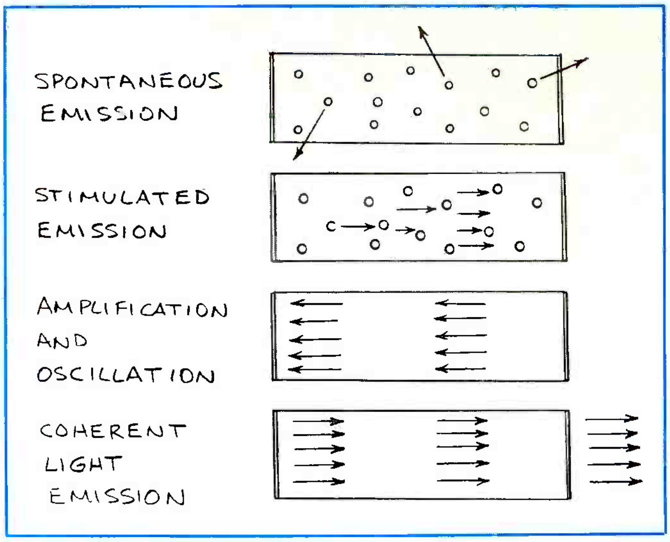


Fig. 3. Production of coherent light by a ruby laser.

resemble a thin pie-section of the orderly waves produced when a single stone is dropped into a quiet pool.

Another characteristic of the light beam emitted by most lasers is its highly parallel or collimated nature. Even when no external lens or telescope is used, the beam from a low-cost helium-neon laser may have a divergence (spread) of only one milliradian (0.001 radian, with a radian being 57.3°). A beam with a divergence of 1 milliradian spreads to a diameter of 1 meter at a distance of 1 kilometer.

How a tiny bit of coherent light can be squeezed out of the light emitted by an ordinary incandescent lamp with the help of a filter, collimating lens and a pinhole is illustrated in Fig. 4. The trouble with this approach is that the coherent beam is so weak that it is virtually unusable. A low-cost helium-neon laser can produce several milliwatts of highly coherent light suitable for many kinds of experiments and demonstrations only contemplated but never observed before the laser era.

Now that you know something about the practical aspects of coherent light, you may be wondering why coherence is so important. Highly monochromatic light has many important applications in various kinds of spectroscopy, which is an important method of analyzing substances by measuring the optical wavelengths they either reflect or transmit. Since the speed of light through a glass fiber is affected by its wavelength, monochromatic light is very important for the passage of very-high frequency communication signals through optical fibers.

Light that arrives with its wavefronts all in-phase with each other has important applications in making holograms and in interferometry. A common application of interferometry is to divide a laser beam into two separate beams and recombine the beams at some point. The recombined beams form a predictable pattern of concentric rings or parallel bars. If one beam is subjected to outside interference, such as absorption by a gas or a slight change in path length, the interference pattern will be altered.

Another important benefit of the in-phase nature of coherent light is that it can be focused to a spot not much larger in diameter than the wavelength of the light itself. This is how lasers can deliver exceptionally high levels of optical power to microscopic points. It is also how the laser in a compact disc player can easily track the microscopic pits etched into the surface of a CD ROM.

The fact that many lasers emit highly parallel beams is especially important. When external optical devices, such as lenses and mirrors, are used to focus or steer the laser's beam, the tightly collimated beam produced by many (but not all) lasers means the entire beam can be captured and manipulated without any of it being lost.

An aspect of coherent light that is especially important when applied to most lasers is the exceptionally high intensity of the beam from a laser. Indeed, the light from most lasers is incredibly more intense than that from any natural or artificial light source.

Consider that a 100-watt incandescent lamp emits around 5 watts of visible light in all directions. If this light could be collected with a reflector or lens and focused onto a tiny spot, it would have enough intensity to ignite paper or wood. Since the light is not concentrated, you can safely hold your hand fairly close to such a lamp. A laser that emits a continuous 5-watt beam, however, commands considerable respect since its beam might cause accidental ignition of various materials and permanent eye damage.

Another comparison concerns the spectral purity of laser light. The filament of an incandescent lamp would have to be heated to the impossible temperature of 10,000,000,000,000,000° Celsius, filtered to a single wavelength and concentrated with a lens to produce a beam with the intensity of a small helium-neon laser only a tenth as powerful as the tiny flashlight on my key chain.

Perhaps some personal experiences will help you better appreciate the amazing intensity of a laser. Once I was aligning a homemade infrared laser diode voice communicator on a desert mesa with the help of an infrared viewing device. The laser transmitter was a kilometer away, and I was trying to find where the beam was so the receiver could be properly positioned. Since it was high noon, the brilliant sunlight swamped out the image converter tube in the viewer and the laser beam was not visible. Everything changed when I placed a narrow bandpass interference filter over the input lens of the viewer. The filter's transmission peaked at the 905-nanometer wavelength of the laser, and the laser appeared as a brilliant greenish-yellow glow against a dark landscape. Now, when viewed at its wavelength, the straight-on beam from the laser diode, which was smaller than a grain of sand, was incredibly brighter than the noon sun.

On another occasion, several students and I placed a 6-milliwatt helium-neon laser atop a high building at night and

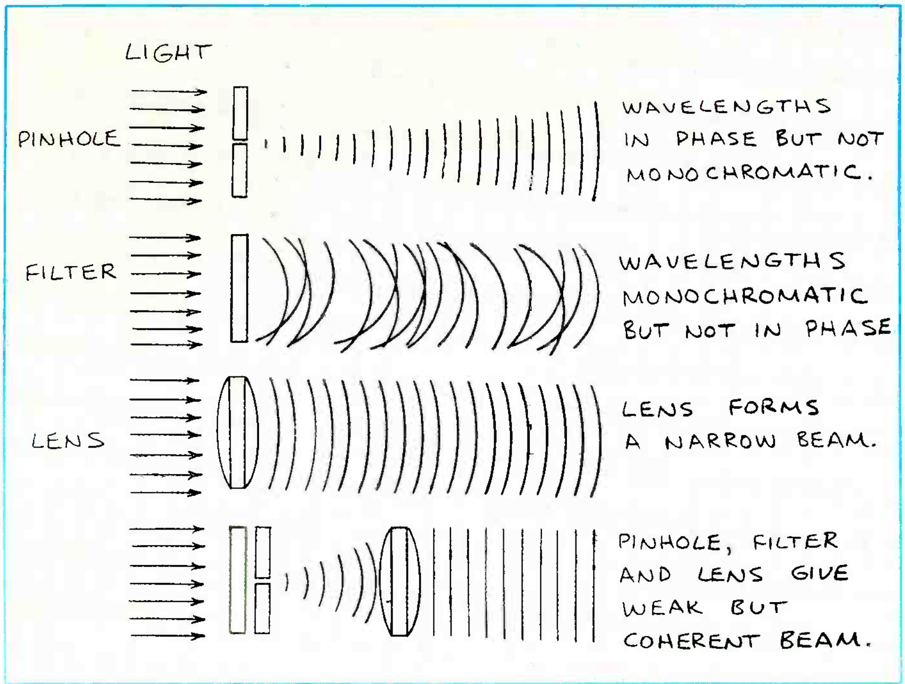


Fig. 4. Process of transforming ordinary light into coherent light.

pointed it at an optical retroreflector we had previously placed on the side of a mountain 20 kilometers (12.5 miles) away. A retroreflector is an optical corner reflector that returns an incoming beam directly back to its source. The Apollo astronauts placed several arrays of retroreflectors on the moon, where they are still used to make accurate measurements of the distance between Earth and the moon.

Our laser was aligned when a speckle of light from the retroreflector could be seen in the distance. On driving out to the corner reflector and looking back toward the laser, we were at first disappointed when the expected red glow from the laser was not visible against the lights of the city. Suddenly one of the students, who had walked down the slope, shouted for the rest of us to join him. When we did, we were dazzled by a brilliant red star that was far brighter than any of the city lights, including the circling beacon at the airport. Walking only 10 or 15 paces in any direction caused the brilliant red starburst to disappear completely from the city skyline. As our eyes became adapted to the darkness, we eventually noticed that the shimmering glow from the beam was actually visible on light colored gravel and boulders.

Other Kinds of Lasers

Maiman's demonstration of the ruby laser was quickly followed by development of many other kinds of lasers that used as an active medium materials other than ruby. Indeed, today ruby lasers are very rare and are vastly outnumbered by other kinds of lasers. While some of these lasers are activated by flashlamps, others are activated by r-f energy, electrical discharge, chemical reactions, electron beams and direct flow of electricity. Their active materials include such solids as glass and various crystals, semiconductors, liquid dyes, hot metal vapors, many different gases and a variety of chemical compounds.

Solid-State Lasers

Lasers that have as an active medium a solid material activated by an external light source are known as solid-state lasers. The ruby laser is, of course, a solid-state laser. Far more common today are solid-state lasers in which the active material is the rare earth neodymium contained within glass or a crystal such as yttrium-aluminum-garnet (YAG).

When neodymium ions are stimulated to a greater-than-normal energy level, they emit photons with a wavelength of 1.06 micrometers in the near-infrared portion of the spectrum. Neodymium-doped lasers are considerably more efficient than ruby lasers. Therefore, far less energy is required to pump them to a state where laser action can begin.

I have spent a good deal of time working with neodymium-doped glass and YAG lasers. The most sensitive requirement of these lasers is the orientation of the mirrors when they are mounted external to the laser rod. Often several hours are required to align the mirrors.

The alignment system can be as simple as an inexpensive helium-neon gas laser whose beam passes straight through the laser rod. When first set up, reflections from the pencil-lead-thin beam from the red laser form tiny dots of light on a target. Each dot represents a reflection from the ends of the laser rod and the reflective surfaces of the mirrors. Alignment consists of carefully adjusting the positions of the mirrors so that all dots of reflected light are superimposed atop each other. When this occurs, the surfaces of the mirrors and the ends of the laser rod are all parallel with respect to one another.

After the mirrors are aligned, the laser is tested by firing it and examining the pattern of its beam. Various kinds of computer-augmented video systems are available for this purpose, but they are expensive. Therefore, test shots are often accomplished by firing the laser at a piece of exposed Polaroid film or a special sheet of test paper. The laser beam forms a pattern on the film or paper that clearly discloses any non-uniformities. With experience, one learns how to make tiny mirror adjustments to eliminate them.

If the laser rod and its mirrors are perfectly aligned using an alignment laser, why does the resultant beam sometimes include a non-homogeneous structure? One important reason is that the heat from the powerful lamp used to excite the laser rod causes thermal expansion in the rod, its mounting assembly and the mounts holding the mirrors. These thermal distortions can cause slight misalignments that cause beam imperfections.

Neodymium-doped lasers were pumped solely by flashlamps until the discovery that various kinds of high-intensity continuous lamps could be used to pump them. This made possible neodymium lasers that operated continuously. In the late 1960s, it was discovered that high-power light-emitting diodes that emit energy at around 850 nanometers, the principle absorption band for neodymium, could be used to pump a small neodymium laser. Today, many such continuous lasers are available, some pumped by high-power near-infrared emitting diodes and others that are pumped by near-infrared-emitting laser diodes.

When placed in the beam from a Nd-YAG or glass laser, certain so-called nonlinear crystals can double the frequency of the beam, thereby halving the wavelength. In the case of neodymium, such a crystal changes the invisible 1.06-micrometer beam into a brilliant green beam with a wavelength of 532 nanometers.

Many nonlinear crystals are available, among the most common being potassium-dihydrogen-phosphate (KDP) and lithium-niobate.

Some diode-pumped neodymium lasers incorporate a frequency-doubling crystal to provide a continuous beam of brilliant green light. For now, these lasers are very expensive, but less-costly alternatives may eventually become available for important commercial applications that await the development of inexpensive lasers with a blue or green output. The density of data stored on an optical compact disk, for example, is determined by the wavelength of the light used to create and read the stored data. A green laser with a 532-nanometer beam can be focused to a spot half the size of the beam from a near-infrared laser with a wavelength of 1.06 micrometers.

Gas Lasers

The best known gas lasers are those that use carbon-dioxide or a mixture of helium and neon. Most carbon-dioxide lasers are highly efficient and emit infrared radiation at 10.6 micrometers. Powerful continuous carbon-dioxide lasers are used for many kinds of industrial purposes, including cutting and drilling such materials as fabric, wood and metal.

Helium-neon (HeNe) lasers are especially common, now that they have been incorporated into the scanning mechanisms of many supermarket checkout counters. A rapidly rotating, multi-faceted mirror scans the beam across bar-code labels on products. You can easily see the pattern the beam forms the next time you are at a checkout counter equipped with a bar-code scanner. Just place a white card over the counter to observe the pattern the laser makes.

Since HeNe lasers are used by the tens of thousands in bar-code scanners and surveying instruments and for countless optical-alignment applications, their cost has fallen considerably over the years. There is now a surplus market for these lasers, and new or nearly new HeNe laser tubes can be purchased for less than $50. The tube must be powered from a high-voltage source, many kinds of which are available. Most are modular devices requiring only connection to the 117-volt line or a battery.

The coherent nature of the beam emitted by most HeNe lasers is exceptionally good when compared to that emitted by most solid-state and, especially, semiconductor lasers. Therefore, HeNe lasers are well suited for interferometry, holography and other applications in which a highly monochromatic and coherent beam is important. Another important feature of the HeNe laser is that its beam is exceedingly narrow, only about 1 milliradian from a typical inexpensive HeNe laser.

Semiconductor Lasers

Efficient near-infrared emitting diodes were invented around the same time Maiman developed the first ruby laser. Some of these devices transformed into near-infrared radiation an amazing 80% of the electrons passing through them.

In the fall of 1962, three laboratories almost simultaneously announced the development of gallium-arsenide (GaAs) diodes that functioned as lasers when cooled to the temperature of liquid nitrogen and driven by very brief current pulses. These early lasers had to be driven by current levels equivalent to 10,000 amperes per square centimeter of diode junction area to arrive at the onset of laser action. Though a single laser had a surface area considerably smaller than a square centimeter, the current required to achieve laser action, the so-called threshold current, ranged up to 100 amperes and more for these early diodes. This explains why these early laser diodes had to be cooled with liquid nitrogen and why they did not last very long; some failed after emitting only a single pulse.

The most significant difference between these early laser diodes and ordinary infrared-emitting diodes was that a pair of facing mirrors was provided on opposite sides of the semiconductor chip. Some diodes were formed by polishing mirror-like surfaces onto the edge of the chip. A much simpler way to form the mirrors is to simply cleave the GaAs crystal along parallel crystalline planes. This procedure produces perfectly flat and parallel facets that function as mirrors.

Whether cleaved or polished, a flat GaAs surface has a reflectance of around 35%. While this is substantially less than the nearly 100% reflectance of the reflective films evaporated onto the ends of ruby laser crystals, GaAs diodes are so efficient as photon generators that they will function as lasers without the need to enhance the natural reflectance of the crystal. In fact, a laser beam emerges from both ends of GaAs and similar laser diodes unless one end is coated with reflective film. When this is done, the threshold current at which laser action begins can be substantially reduced.

Laser diodes became considerably more practical when new crystal-growing methods made possible the fabrication of diodes with perfectly flat and ultra-thin junction regions sandwiched between layers of semiconductor that have a higher index of refraction than the junction itself. The thin junction caused the density of photons to be very high where electrons crossed the junction.

The dip in index of refraction at the junction caused many photons that would otherwise have escaped through the top and bottom of the laser to be refracted back into the junction region. The result was lasers with a threshold current of a few hundred milliamperes or less. Lasers like these were the first to operate continuously at room temperature.

Figure 5 illustrates the threshold of one

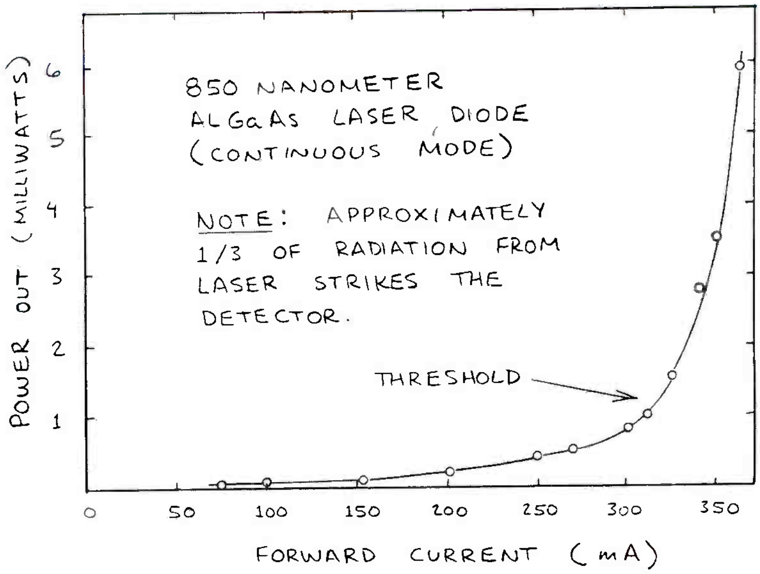


Fig. 5. Graphic depiction of optical power from a typical laser diode.

of these kinds of laser diodes measured in my shop. The laser is a GaAlAs device that operates continuously at room temperature and emits an 850-nanometer beam. Since the beam is fan shaped, only around a third of it was collected by a focusing lens used to project the laser emission onto a calibrated detector.

Note in Fig. 5 that at less than about 300 milliamperes, the optical output from the laser is relatively linear and the laser operates much like a light-emitting diode. However, beyond 300 milliamperes, the power output increases dramatically as stimulated emission of radiation takes over. The point at which laser operation begins is the threshold.

The 780-nanometer near-visible laser diodes used in CD players and the 670-nanometer visible-light laser diodes that have recently become so popular among experimenters are all made using variations of the junction configuration described above. Usually, these new lasers incorporate internal barriers to confine the active portion of the junction (the light-emitting region) to a thin thread-like structure buried inside the laser chip. These lasers have a typical threshold of around 50 or 60 mA.

Already these highly efficient visible lasers are replacing considerably larger and more fragile helium-neon lasers in some applications. Their beam quality, however, is not nearly as good as that from a HeNe laser, and beam divergence is typically measured in tens of degrees, rather than the fraction of a degree provided by HeNe lasers. Fortunately, the very tiny emission region of these lasers means their beams can be collimated by a simple lens.

Dozens of different kinds of laser diodes have been developed over the past three decades. Among the most important are tunable infrared laser diodes, visible-wavelength laser diodes and those designed specifically for lightwave communications via optical fibers. Although most of the initial research was accomplished in the U.S., the long-sought goal of visible-light laser diodes was first achieved by Japanese companies.

Another important category consists of various kinds of experimental low-power laser diodes that have thresholds of only a few milliamperes. At the opposite end of the power spectrum are high-power laser diodes suitable for use in medical procedures and optical pumping of solid-state lasers, such as neodymium-doped YAG. Pumping a neodymium-doped YAG laser with a diode laser is much more efficient than using a flashlamp because of the use of lasers that emit a wavelength at the peak of the neodymium spectral absorption region. Much of the energy emitted by a flashlamp is wasted, since it is not absorbed by neodymium.

Q-Switching and Damage

The pulse of light emitted by Maiman's first ruby laser was exceedingly powerful. Nevertheless, it soon became evident that ruby lasers could emit substantially more power, but in a burst measured in nanoseconds, rather than microseconds or milliseconds, by temporarily spoiling the reflective cavity formed by the two end mirrors. This method is known as Q-switching or Q-spoiling.

The two simplest ways to Q-switch a ruby laser require that the totally reflecting mirror evaporated onto one end of the ruby rod be replaced by an external mirror. In one method, an electro-optical switch is inserted between the crystal and the totally reflecting external mirror. In a second method, the totally reflecting external mirror is mounted on the armature of a rapidly rotating motor. In both cases, the flashlamp is fired while the totally reflecting mirror is either blocked or out of position, disabling the laser.

By the time the mirror is unblocked or in the correct position, the light from the flashlamp has pumped nearly all the chromium atoms to an excited state. Therefore, the resultant burst of light is considerably more intense than the longer-duration pulse emitted by the same laser without a temporarily spoiled cavity.

While I was assigned to a military laser laboratory, I learned first-hand about the substantial increase in power made possible by Q-switching a neodymium-doped glass laser. This laser used a glass rod about the size of a large cigar. I had spent most of a day aligning the laser's mirrors to a point where the laser was producing a beam with a very uniform cross-section.

Between test firings, I began increasing the power of the flash delivered to the laser rod by increasing the voltage applied to the flashlamp's capacitor bank while measuring the laser energy with a calorimeter placed in its beam. As I completed the countdown for a shot and pressed the fire button, there was a loud popping sound. The exposed end of the glass laser rod flew out of the laser assembly like a bullet and struck a wall several paces away! The energy from the flashlamp concentrated in the glass rod caused more thermal stress than the cooling water flowing around the rod could remove, fracturing it with considerable force.

This experience was nothing new. In fact, the traditional going-away present for those of us who completed our assignments at the laboratory was a plaque on which was mounted part of a large ruby laser rod that was destroyed in much the same manner as the glass rod I just described. The polished face of the broken ruby rod on my plaque bears several chips that were caused when hot spots in the laser beam literally blew away small pieces from the end of the rod.

It is important to note that the chips on the face of my ruby rod were caused by excessive power in the laser beam itself and not by the flashlamp. This same mechanism also causes damage to the end mirrors and various optical surfaces of other kinds of lasers. For example, I have used a microscope to examine the end facets of several semiconductor diode lasers that still functioned as infrared-emitting diodes but not as lasers. Some of these lasers had clearly visible chips along the junction where tiny bits of semiconductor had been literally blown away by excessive optical power. Since the facets no longer functioned as mirrors, these laser diodes had been reduced in status to ordinary infrared-emitting diodes. At least they still functioned; often a zapped laser diode chip is partially melted by excessive current.

A Q-switched solid-state laser can deliver a very brief pulse with an amplitude of many millions of watts. It is interesting to note that the military has developed various kinds of continuously operating lasers that have produced hundreds of thousands and even a few million watts of power in bursts of several seconds or so. Some of these lasers are the size of small buildings and are pumped by chemical means or by powerful blasts of gas forced through a special nozzle.

Going Further

In a subsequent column, I will describe some fairly inexpensive ways to begin experimenting with both gas and semiconductor lasers. Some sources for both assembled lasers and laser components will be listed. I will also describe some interesting experiments.

Meanwhile, you may wish to learn more about lasers by looking at some of the many publications on the subject. Keep in mind that this column has barely begun to explore the enormous world of lasers. Libraries are bulging with books, technical papers and articles on this subject. Jeff Hecht's *The Laser Guidebook* (McGraw-Hill, 1986) is a good general introduction to virtually all classes of lasers. I highly recommend it. Jeff also wrote *Understanding Lasers* (Radio Shack, 1988), another excellent general introduction. Both books include a glossary, detailed discussions of laser operating principles and explanations material about the many kinds of lasers. ■

Ted Needleman

A Fun Game Sequel and a Computer Sound Upgrade

The Software Toolworks has been busy developing new products. Perhaps you missed my look at this company's *Life & Death* medical simulation game five months ago, which I felt was an exceptionally good game. It places you in the role of a surgical resident in the abdominal surgery wing of Toolworks General Hospital and presents you with patients whose problems you diagnose and, where necessary, lets you operate on them to bring them back to health.

Life & Death 2 is the company's sequel to this program, though you don't need to have played *L&D* to enjoy it. Software Toolworks' advertising slogan pretty much sums it up—"Go for the brain!" In this sequel, you become a resident in the new microsurgery wing of Toolworks General. And as educational and enjoyable as the original *Life & Death* was, this new game program is even more fun and challenging to play.

As with the original *Life & Death*, the first thing you must do when the software is booted is sign in. Then you're directed to various patient rooms, or you can go to the classroom and browse through the on-line neurology reference. In this version of *L&D*, you even have your own office, where you select members of your surgical team (when you need to operate) or read through a condensed course of neurological syndromes.

The hospital is presented in a bird's-eye view, and you move to a particular room or place by mousing the cursor over to the desire area and clicking the left mouse button. Once in a patient's room, you examine the clipboard hanging on the wall to determine the patient's condition and to see if he has any allergies or a pacemaker. Then you conduct a physical exam.

This is done by clicking on the appropriate part of the patient. There are three areas you must check—legs, arms and face. On the legs and arms, you check knee and elbow reflexes with a rubber hammer, check for sensation by sticking the patient with a pin and determine muscle weakness by lifting the limbs and seeing how slowly they fall.

You also check the face with a pin, and you check the patient's pupil reactions with a small penlight. There's also a little stick that you use to see how well the patient can track and a card that reads "say ALICE" to check for slurred speech. If you're not certain as to your ability to make these determinations, there's even a small clipboard you can examine that has the results of your exam spelled out.

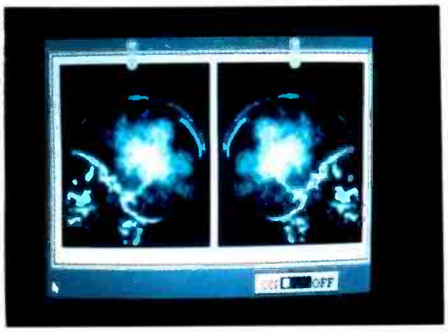
Then, depending on your preliminary diagnosis, you can order an x-ray, MRI or CAT scan, or angiogram, prescribe a painkiller (for migraine sufferers), or you can refer a patient for physical therapy or to a psychiatrist. With certain conditions, such as a tumor or aneurysm, you must operate.

This sequel has some significant differences from the original program. For one thing, the graphics are much better. The Software Toolworks recommends a minimum of EGA resolution, but it's much more enjoyable if you're in VGA mode. You'll also need a fairly hefty PC to run *L&D2*. While the specifications state it will run on an XT, a fast 286 is a more realistic minimum, and a 386 is an even better choice. You'll also need at least 640K of RAM and a hard disk.

Life & Death 2 came on three 5¼-inch diskettes (3½-inch disks are available) and has to be installed using the installation routine supplied, as the software is in a special condensed format. The Software Toolworks states that the disks are not copy-protected but that due to the use of this special format, DOS' DISKCOPY command won't work to make backup disks. The company recommends (and I concur) that you back up the subdirectory where the software is installed with any hard-disk backup programs.

One other major improvement is the use of sound. When installing the software, you specify whether it's to use the PC's internal speaker, an AdLib board or a Sound Blaster board (reviewed a bit further on). At various times, including start-up, music plays through the specified medium. Other sounds, such as a hearty "ouch!" from the patient, occur when you're sticking the patient, and operating-room sounds, such as the EKG and bone drill, add quite a bit of spice.

I really liked the original *Life & Death* program, and I like the sequel even more. It's the closest thing you can find to a medical school in a box, and aside from being engrossing, you also learn something by playing it. There are two things, though that I'd love to see The Software Toolworks do with *L&D2*. The first is to offer add-on "illness packs." There are only about 10 problems that crop up over and over. And, for a klutz like me, who loses 29 out of 30 patients once they get to the operating room, the diagnosis is more fun than surgery. A second add-on I'd like to see for those people who have lots of disk space might be a few additional


(A)


(B)


(C)

The Software Toolworks' Life & Death 2 program has great graphics: (A) the x-ray screen; (B) CAT-scan scene; (C) operating-room scene patient images. The four supplied get recycled over and over.

I can't really complain, though. For $49.95, *Life & Death 2* is a bargain. It's educational, fun and less than a third of what a real neurologist charges for an initial consultation. One thing I should point out is that while the software was developed in conjunction with a real physician, and the symptoms are consistent with real illnesses, this is a *game*! And while you can learn a lot from The Software Toolworks' medical simulations, if you think you might have a medical problem, please see a *real* doctor! This seems like a rather obvious thing to do, but when I was telling someone about the original *L&D*, he asked me if I thought it would help him figure out why he has stomach aches.

CMS Sound Blaster Card

About a year and a half ago, I did a series of columns on computer and MIDI (Musical Instrument Digital Interface). Among the products I reviewed was CMS' Sound Blaster board. I liked it, but at the time felt it was somewhat limited in what it could do. I recently received the new Sound Blaster, still manufactured by Creative Music Labs but now being distributed by Brown-Wagh Publishing, and it really blew me away!

The Sound Blaster isn't only an 11-voice FM music synthesizer that's completely compatible with the AdLib sound board, but a great deal more. The AdLib compatibility lets the Sound Blaster add sound and music to more than 100 game, educational and presentation software packages. In fact, even IBM's own Storyboard Live, a new multimedia package, now supports the Sound Blaster card. To support music capabilities of the card, CMS supplies a software package called *FM Intelligent Organ*. I reviewed this in depth a while back, but it has capabilities similar to a Casio keyboard. It provides rhythm and chord accompaniment while you play the melody with the PC's keyboard, which is mapped to a piano keyboard. The board has a 4-watt/channel stereo amplifier built in, and the sound quality with the less-than-$30-a-pair Radio Shack mini-speakers I used was terrific.

Next, CMS has provided a digitized voice channel. Plug a microphone into the variable jack, and you can easily perform digital sampling and recording of voice or any other audio source. CMS provides several software utilities that let you make good use of these capabilities. VOXKIT lets you record, store, play back and even edit your voice or sound input. It's easy to use and very powerful.

Then there's SBTALKER, which takes an ASCII text file like those produced by most word processors and vocalizes it in a quite understandable English. I do a lot of speeches and presentations, and for an upcoming one, I'm working on having a conversation with a Sound Blaster-equipped PC.

Along with SBTALKER comes DR SBAITSO, a "psychiatrist"-type of program that's very similar to the ELISA software popular from the early days of computing. You type in a statement, and the program asks how you feel about that or mumbles a distracted "uh-huh." The Doc's accent is kind of thick, but it's a fun program to play with for a while.

The last bit of included software is the one my kids love the most—the Talking Parrot. This puts a colorful image of a parrot on the screen. The parrot makes snide comments and accepts voice input from the microphone, feeding it back in a speeded-up "parrot" voice. The thing they love most, though, is that when you hit a key on the keyboard, the parrot giggles, yells a loud "ouch!" or tells you to go away and leave it alone. I'm amazed at how my four kids can spend an hour tutoring this poor animal, trading insults with it and laughing uproariously all the while. It's educational, too—I've learned

(Continued on page 86)

Joseph Desposito

Flash Memory Cards; Microprocessor Supervisory Circuits; High-Speed Low-Power DRAMs; and a 16-Bit SCSI Adapter

In step with the new focus of this magazine, this column highlights computer or microprocessor products exclusively. The products I describe here are especially useful for increasing the storage capacity and overall speed of microcomputer systems.

Flash Memory Cards

Fujitsu Microelectronics (Integrated Circuits Div., 3545 N. First St., San Jose, CA 95134), a major memory card supplier, has added two new flash EPROM memory cards to its family of industry-standard cards.

The MB98A8101 and the MB98A8122 68-pin flash memory cards are available in 1M and 4M densities, respectively. These densities can accommodate on a single card 98% of all PC programs available. Flash cards are cost-effective, non-volatile and re-writable storage media. They have the advantages of retaining data stored in them when power is disconnected and have the ability of being erased and re-programmed with data.

Fujitsu and Intel have agreed to jointly define and develop flash memory cards. As a result, Intel has also introduced 1M and 4M flash memory cards. The series of cards comply with the JEIDA 4.0 and newly defined PCMCIA 1.0 industry standards. Both companies are members of PCMCIA (Personal Computer Memory Card International Association), which published the standard for 68-pin cards in August 1990.

Fujitsu's flash cards measure 85.6 × 54.0 × 3.3 mm, closely matching the size of three stacked credit cards. Access times are 250 ns, and typical byte erase time is 10 ns for random write to erase zones. Power consumption for the cards in standby mode is 400 mA for the 1M and 80 ns for the 4M cards. Fujitsu's flash cards utilize Intel's ETOX II single cell EPROM tunnel-oxide technology.

Flash cards can replace traditional hard- and floppy-disk drives found in many applications, particularly in portable PCs. This is where memory cards offer the versatility of floppy drives and reliability of semiconductor technology.

Flash memory cards can be utilized in a wide range of applications, including notebook and pocket PCs, medical instrumentation, industrial equipment and telecommunication systems.

Prices of flash cards are $295 for the 1M and $1,195 for the 4M units in 1,000-piece quantities.

In its continuing efforts to introduce designers to memory card technology, Fujitsu also announced a memory card kit that comes complete with the tools needed to examine memory-card capabilities. Elements of the kit include Fujitsu's memory-card data book; 68-pin memory-card connector; an SRAM, OTPROM, EPROM and Flash EPROM memory card; and a ThinCard Drive from Databook Inc. (with software, cables and manual).

All memory cards in the introduction kit comply with JEIDA 4.0 and PCMCIA 1.0 industry standards. The wide variety of memory cards included in the kit give designers the opportunity to evaluate each specialized card technology. The ThinCard Drive easily connects to any PC, XT or AT computer to read from and write to 68-pin cards.

The memory-card introductory kit can be used to evaluate cards in a variety of applications—for example, in the medical instrumentation field for patient record keeping, in network terminals that require system configuration and in notebook computers for application software and file storage.

Fujitsu's memory-card introduction kits are priced at $999 each.

Simple Microprocessor Supervisory Circuits

From Maxim Integrated Products (120 San Gabriel Dr., Sunnyvale, CA 94086) come the MAX700-702 power-on reset controllers with manual reset inputs. Requiring no external components, these integrated circuits provide a simple, low-cost method of increasing microprocessor circuit reliability.

The MAX700-702 supply a RESET/(RESET) pulse of at least 200 ms duration on power-up, power down and during low-voltage brownout conditions ((RESET) only MAX702). They also feature a debounced manual reset input that forces the reset outputs to their active states for a minimum of 200 ms.

Additionally, the MAX700 features adjustable hysteresis and preset, or adjustable voltage detection, allowing different voltage thresholds to be monitored (Fig. 1). The supervisors are designed to be used in portable instruments, where supply current is limited to 200 μA, and all parts are available in space-saving eight-pin DIP and SO packages.

Other applications include portable computers, low-power controllers, intelligent instruments, automobile systems and any microprocessor system that requires accurate power supply monitoring.

Prices for quantities of 1,000 and more start at $1.91 for the MAX702.

High-Speed, Low-Power DRAMS

A family of new generation 1M-bit dynamic RAMs (DRAMS) that offer a combination of high speed and low power consumption is available from Panasonic Industrial Co. (Semiconductor Sales Div., Two Panasonic Way, Secaucus, NJ 07094). Designated the MN42C4256A/SJ/L-06/07/08 and the MN42C1000A/SJ/L-06/07/08, (262,144 × 4-bit words and 1,048,576 × 1-bit words respectively), the devices feature a self-refresh current of just 80 μA maximum and maximum access times of 60 to 80 ns.

In addition to the three conventional types of refresh modes (RAS-only refresh, CBR auto-refresh and Hidden refresh), Panasonic is offering these devices with a new refresh mode called CBR self-refresh. CBR self-refresh current is so low that it can extend average battery life to more than 1,000 hours.

The devices are suitable for a variety of applications—such as mainframe memories, RAM disks and the new high-speed processors—that require high reliability, high speed and low power.

Major specifications include: typical cycle times (t_{RC}) ranging from 120 to 160 ns maximum; standby power of 0.28 at CMOS levels and 2.75 mW at TTL levels; operating current of 70 to 80 mA maximum; standby current of 50 μA; maximum self-refresh power of 0.44 mW; plug-to-plug compatibility with standard existing 1M-bit DRAMs; and TTL com-

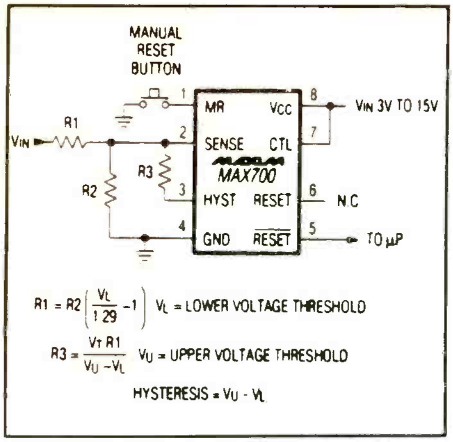


Fig. 1. Maxim Integrated Circuits' MAX-700 power-on reset controller permits different voltage thresholds to be monitored.

patible I/O. The units operate on 5 volts dc, offer fast page-mode capability and are available in 26/20-pin SOJ, 20-pin ZIP, 18-pin DIP (1M × 1) and 20-pin DIP (256K × 4).

16-Bit SCSI Adapter

ALWAYS Technology (31336 Via Colinas, Suite 101, Westlake Village, CA 91362) a leading supplier of Small Computer Systems Interface (SCSI) adapters, has a new half-card 16-bit SCSI host adapter. Unlike the EISA SCSI adapter described last month, this one targets ISA 286, 386, and 486 PC/AT-compatible computers. Called IN-2000, it features a proprietary architecture that enables "programmed I/O" via a fast dual-port RAM buffer. This approach does not use the Direct Memory Access channel.

The IN-2000 adapter bridges the performance gap typically associated with the DMA channel of the PC/AT. Long recognized as a chronic source of I/O bottleneck problems, DMA restricts the rate of data flow, which causes performance compromises in the new high-speed PC systems available today. By avoiding the DMA transfer approach, the ALWAYS SCSI adapter offers significant I/O improvement, particularly for programs requiring extended and expanded memory such as *Windows* 3.0 and *DESQview*.

The ALLWAYS IN-2000 adapter, designed as a half card to accommodate shrinking PC enclosures, measures 6⅔ inches × long and 4⅓ inches high. It dissipates only 3 watts of power.

The product's use of programmed I/O instead of DMA transfer eradicates the frequent problems associated with DMA conflicts: since there are only eight DMA channels in the PC/AT architecture, DMA devices—such as disk controllers, video cards, scanners and others—can often conflict in assignment.

Because of the company's use of programmed I/O over DMA, the IN-2000 makes obsolete the installation headaches associated with DMA-transfer SCSI adapters, whose myriad of jumpers can be difficult to install.

With the IN-2000, I/O address changes are handled on the board using switches, rather than jumpers. These switches make it easy to change to other values of I/O, base addresses and interrupts. Nine switches are in one switch block close to the card edge, and no special EPROM change is needed for making interrupt or address changes. A software utility that displays the switch settings and alternate choices on the PC video monitor simplifies making I/O changes.

Another feature of the IN-2000 is that the DOS driver and format software are incorporated into the adapter's on-board EPROM, allowing for easy installation of DOS. Other operating systems and devices, such as SCO UNIX, SCO XENIX, Novell NetWare 286 and Sytos Plus drivers, are included at no additional cost. A Novell NetWare 386 driver is also available as an option.

The IN-2000 also contains an on-board, AT-style, switch-operated floppy controller that supports high- and low-density 3.5- and 5.25-inch drives. Both internal and external SCSI connectors are provided, and up to seven disk drives, each up to 1,200M in capacity, are supported internally and/or externally to the PC. The IN-2000 can co-reside with IDE, ST506 (MFM or RLL) and ESDI drives and controllers.

The IN-2000 has been extensively tested and works with *Windows* 3.0, *DESQview* and other programs that use extended and expanded memory. For Novell NetWare file-serving applications, up to four adapters, each with up to seven disk drives or other peripherals, can be used. ALWAYS ships a Novell-certified NetWare 286 driver (VAD) with the standard product kit. Certified drivers (NLM's) are also available for NetWare 386 and for new NetWare Ready drives. SCSI has recently gained popularity in the Novell market because it supports duplexing (one drive and adapter on each of two server channels) and a wide range of peripherals, including CD-ROMs, optical drives, various tape formats and other peripheral devices.

The IN-2000, which carries a lifetime warranty, is available at the suggested single-unit retail price of $249, including DOS, SCO UNIX, SCO XENIX, Sytos-Plus and Novell 2.7 drivers. ■

EEPROMs are much like EPROMs except that they're electrically erasable—no ultraviolet source is required. Limitations of EEPROMs include their slower speeds and higher cost. ROMs are cost-effective when you need thousands of copies of a single program. ROMs must be factory-programmed and once programmed, can't be changed.

Some microcomputer ICs use ROM to store special programs, such as test and debugging aids. For example, Intel's 8052AH-BASIC microcomputer IC stores an entire BASIC-language interpreter in ROM, for use in programming the microcomputer.

Most systems also require a form of temporary data storage. Typically, this is RAM, which can be erased and written to again and again. The RAM may be located in the same IC as the microprocessor, or external to it, or both. Some single-chip microcomputers also contain a small area of EEPROM in which can be stored identification, security, or boot-up information that will be changed only occasionally.

Finally, input/output also requires decisions. Interfaces to sensors, keypads, switches, relays, displays and other I/O devices must be designed. Most microcomputer ICs include serial and parallel interfaces, and if expansion is required, special interface ICs may be added.

The Control Program

When it's time to write the program that controls your computer, you have options, including using machine code, assembly language and higher-level languages. Figure 2 shows a portion of a program coded in examples of each of these. Which programming language you use depends on what's available for your microprocessor, as well as factors like desired execution speed, program length and convenience.

The most fundamental program form is machine code. This is the binary instructions that cause the microprocessor to perform the operations you desire.

One step removed from machine code is assembly language, where abbreviations called mnemonics (memory aids) are substituted for the machine codes. The mnemonics are easier to remember than the machine codes they stand for. Since machine code is ultimately the only language that a microprocessor understands, you also need some way of translating assembly-language programs into machine code.

For short programs, you can "hand assemble"—translate the mnemonics yourself manually by looking up the machine codes for each abbreviation.

Another option is to use an assembler, which is software that runs on a desktop computer and translates the mnemonics into machine code. Most assemblers provide other features, such as formatting the program code, converting between number systems and creating a listing that shows both the machine-code and assembly-language versions of a program. A disadvantage to assembly language is that each device family has its own set of mnemonics; so you have to learn a new vocabulary for each family you work with.

To get around this problem, higher-level languages like C, Pascal, Fortran, Forth and BASIC are standardized and, thus, "portable." With minor differences, you can use a language like C to program many different devices.

Higher-level languages also simplify programming by including powerful statements and operations that allow you to do in one or a few lines what would require many machine codes to accomplish.

Two forms of higher-level languages are available: interpreters and compilers. An interpreter translates a program into machine code each time the program runs, while a compiler translates only once, creating a new file that can be run directly, without translating.

Generally, interpreters are convenient for short, uncomplicated programs, while compilers become necessary when the program is long or must execute quickly. A single language, such as BASIC, may be available in both interpreted and compiled versions.

Each device family requires its own interpreter or compiler to translate the higher-level code into the machine code for that device. In other words, you can't use BASICA (for IBM PCs) to program an 8051 or 68HC11 microcontroller—you need versions developed specifically for these devices.

Also, when such a program is translated to machine code, it's usually larger and slower than an equivalent program written in assembly language. In addition, the higher-level language may not offer all the capabilities of assembly code, though you can get around this by calling subroutines in assembly language when necessary. So in spite of their advantages, higher-level languages aren't always the answer.

For More Information

These manufacturer's data books have more—including applications notes—on microprocessor-based designs:

M68HC05 Microcontroller Applications Guide
(Motorola No. M68HC05AG/AD)
Focuses on the MC68HC05 microcontroller IC, but is also a good basic guide to microcontrollers. Includes step-by-step development of the hardware and software for a programmable thermostat.

M68HC11 Reference Manual
(Motorola No. M68HC11RM/AD)
Includes detailed descriptions of internal subsystems and functions of M68HC11 microcomputer IC.

From:
Motorola Literature Distribution Center
P.O. Box 20912
Phoenix, AZ 85036

Eight-Bit Embedded Controllers Handbook
(Intel No. 270645)
Embedded Applications
(Intel No. 270648)

From:
Intel Literature Sales
P.O. Box 7641
Mt. Prospect, IL 60056-7641
1-800-548-4725

Z80 Family Data Book

Z8 Family Design Handbook

From:
Zilog, Inc.
210 Hacienda Ave.
Campbell, CA 95008-6609
(408) 370-8000

Testing & Debugging

Once you've written your program, it's time to test it and, if necessary, debug it so that it works properly. You have several choices here as well. One option is to burn your program into EPROM, install the EPROM in your system, run the program and observe the results. If problems occur (and they usually do) you modify the program, erase and reburn the EPROM and try again, repeating as many times as necessary until the system is operating properly.

Another option is to use a development system. A typical development system allows you to load your program into RAM (instead of more permanent EPROM) and try it out, modify it and retry as often as needed until the program is working properly. Most systems also allow you to single-step (run the program one step at time, pausing after each step) for easier troubleshooting.

Other development tools include simulators and in-circuit emulators (ICEs). A simulator is software that runs on a desktop computer and demonstrates what would happen if a specific microprocessor were to run a particular program. You can look "inside" the simulated microprocessor, observe its internal memory and single-step or set breakpoints to stop program execution at a desired program step or condition. In this way, you can get a program working properly before committing it to EPROM.

An in-circuit emulator is hardware that replaces the microprocessor in question by plugging into the CPU's socket on the device you want to test. Like a simulator, an emulator lets you control program execution and monitor what happens at each program step.

Easy debugging and troubleshooting can make a big difference in how long it takes to get a system up and running. Availability of low-cost, full-featured development tools may be reason enough to choose a particular microprocessor for your designs.

Your Feedback Is Welcome

This series was prompted by reader requests for more on designing, building and programming microprocessor-based devices. I welcome your comments, suggestions and questions, and I'll try to cover requested topics in future installments.

Send your correspondence to me at *Modern Electronics*, 76 North Broadway, Hicksville, NY 11801. If you wish a personal reply, please include a SASE.

Next month: a review of two microcontroller boards that can be programmed in BASIC: Micromint's BCC52 BASIC-52 computer/controller board and RTC52 processor board with economical development system. ■

Jan Axelson

The resistance from output pins 3, 5, 7, 9, 12, 14, 16 and 18 of *IC1* to either +5 volts or to ground should be near infinity with the + lead of the ohmmeter connected to the pin. Reversing the ohmmeter leads should cause the resistance reading to be 100,000 ohms or greater, depending on reverse-leakage current of the LEDs. Verify the absence of a short circuit from the +5-volt bus to ground and from the IN pin of *IC4* to ground.

Plug the power pack into an ac outlet and verify that the tip of the miniature plug at the end of its cord is at +9 to +12 volts. Insert the plug into *J1* and check to see if +9 to +12 volts appears at the IN pin of *IC4*. Verify +5 volts at pin 20 of *IC1* and *IC2* and pin 14 of *IC3*.

With no power applied to the project, plug the ICs into their respective sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets. Set all positions of the DIP switch to "off" and apply power to the Interface. All LEDs should be off. In succession, close positions 1 through 5 of the DIP switch and observe that each corresponding LED lights. With a test lead connected to board ground, touch the other end in succession to pins 2 through 9 of *SO1* and observe that the corresponding LED bit-line indicator lights. Measure the potential at pin 2 of *IC3*, which should be about +5 volts with position 5 of the DIP switch set to "on" and near 0 volt with this switch position "off."

Check your computer manual for base address N of the parallel printer port(s). With a monochrome system, primary port LPT1 was listed at address 03BCH (956 decimal) and secondary port LPT2 was listed at address 0378H (888 decimal). You can use a utility that lists the addresses of serial and parallel ports installed in your computer.

With your computer turned off, disconnect the printer cable from the printer and connect it to the Interface Port. Apply power to the Port and turn on your computer. The following assumes use of the Port at address 03BCH. After power-up, the data-out LEDs indicate binary 0000 1011 (hex 0B), as initialized by DOS. With the DEBUG utility in the current directory or in a path, type DEBUG at the DOS prompt. You will see a dash prompt and a blinking cursor. Type the port input instruction -i 03BC and press ENTER. You should see a return of 0B on your video screen.

Next, type port output instruction -o 03BC FF to send hex FF (binary 1111 1111) to the port. All LEDs of the output port should be off. Send byte 00 to the port to cause all output port LEDs to light. Use the OUT instruction to send 01, 02, 04, 08, 10, 20, 40 and 80 hex to the port in succession. This should turn off one LED at a time in succession from D0 through D7, with the other LEDs turned on.

Five-bit input port address N+1 is 03BC+1 or 03BD. Open all positions of the DIP switch to set input bits D4 through D7 to logic 1. Type input instruction -i 03BD and press ENTER. You should see FF appear on the screen. Bits D0, D1 and D2 always return a binary 1.

Close positions 1 through 5 of the DIP switch and repeat the read on the port. You should observe a return of 07 hex (binary 0000 0111). Open the DIP switch positions one at a time, input the data and verify the results. An error indicates a crossed wiring error of the bit-line circuits. The address of the control data output port is at base address + 2, or 03BE hex. Send and read back data to and from the port to verify its operation.

The port can be checked using BASIC and the decimal number system in GW-BASIC. The BASIC statement for output to port 03BC (956 decimal) is OUT (956), n. Data *n* is limited to values from 0 to 255. The input statement is A = INP (956), with data read back and stored in variable A. Then, use PRINT A to observe its value on-screen.

Output & Input Port Circuits

Mechanical and solid-state relays control the power elements of a control system. Figure 5 shows how to connect relays to the data output lines. Figure 5(A) shows a sensitive magnetic reed dc relay with a 5-volt, 300-ohm coil energized directly from a data output line. The relay is energized when data line D0 is pulled low to logic 0. Temporarily installed, the LED and *R1* in series with the relay contacts verify operation.

Relay power-handling capacity can be specified in maximum switched volt-amperes and maximum ac or dc current. Check the specifications of the reed relay for its ac and dc load current ratings, which vary from 0.5 to 2.0 amperes. The reed relay can, in turn, energize a power relay to handle heavier loads. Rectifier diode *D1*, connected across the relay coil, absorbs an induced voltage spike created when the relay is deenergized.

Relays that draw coil currents of greater than 15 milliamperes are energized by *Q1* in Fig. 5(B). Transistor *Q1* switches on and energizes the relay when data line D1 goes high to logic 1. Resistor *R2* limits current flow to safe values. Use any general-purpose 600-milliampere NPN transistor for *Q1*. The circuit accommodates 5- to 12-volt dc relays.

Make sure that the power supply can handle the greater current drain of larger relays. By using an adjustable-voltage ac wall adapter, the 12-volt relay can be powered from the unregulated dc voltage obtained at the voltage input side of the 5-volt regulator of the port interface.

Optical isolators or couplers protect the Interface Port and computer from damaging high voltage in the event of component failures on the load side. Figure 5(C) shows how to use dc optoisolator *IC1* containing a LED and a photo-darlington output transistor in a DIP package. When data line D2 goes low, current flowing through the LED causes it to irradiate the phototransistor. In turn, the phototransistor switches on and energizes the relay. Resistor *R3* limits the current flow in the LED. The relay can be a 5- to 12-volt dc unit. The ECG-3044 device affords 7,500 volts of dc isolation and handles up to 150 milliamperes of dc current.

Figure 5(D) shows use of a triac optical coupler to control a 117-volt ac power relay. The triac switches on when data line D3 is pulled low. The ECG 3047 optocoupler provides 7,500 volts of dc isolation and handles up to 100 milliamperes of ac current. The Radio Shack Cat. No. 275-217 125-volt ac, 10-ampere dpdt relay draws 15 milliamperes of coil current.

Exercise extreme caution when working with the potentially lethal 117-volt ac line. To exclude the

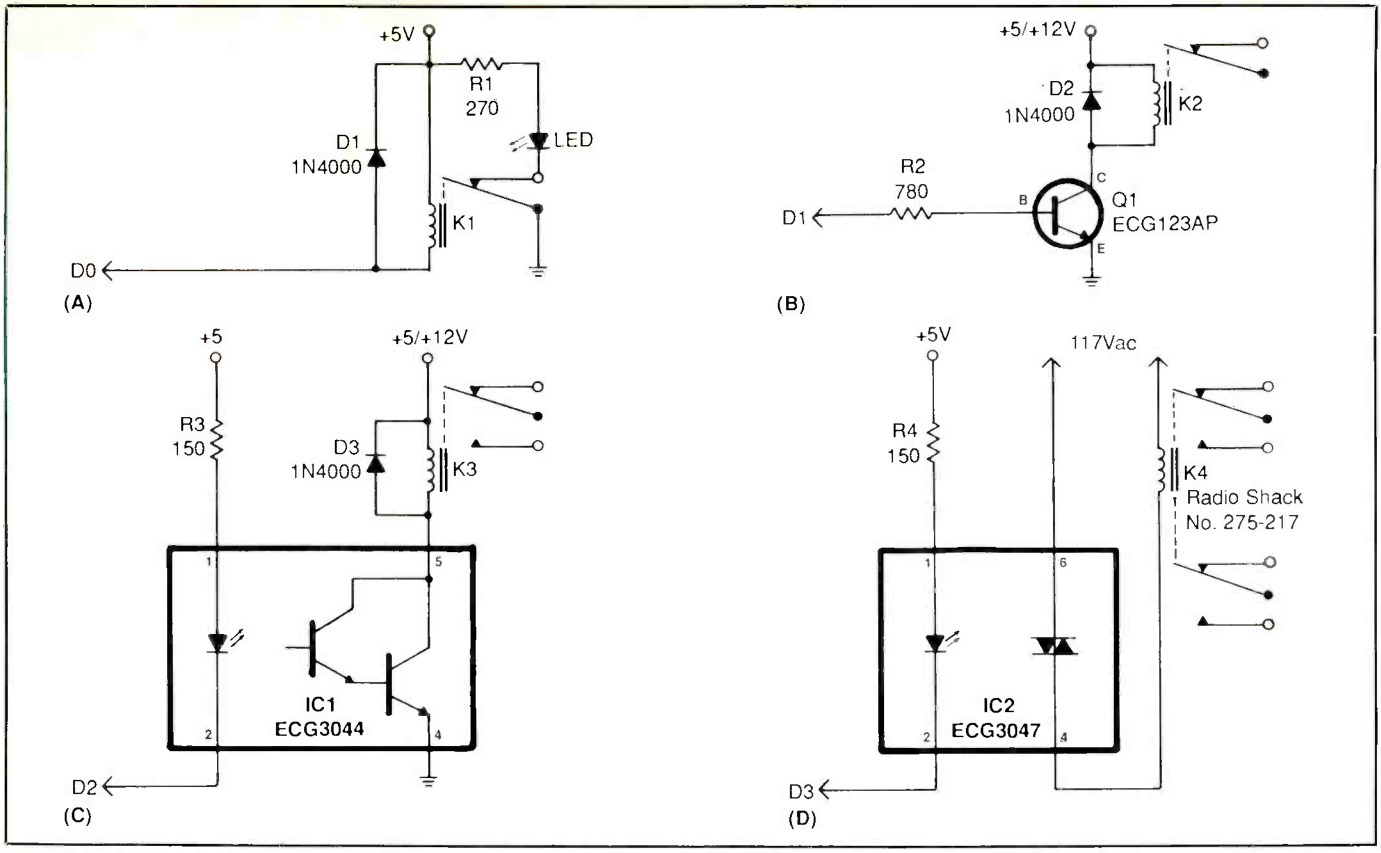


Fig. 5. Relay control circuits: (A) direct-drive of sensitive dc relay; (B) transistor drive of 5/12-volt dc relay; (C) optically-isolated drive of dc relay; and (D) optically-isolated drive of ac relay.

hazardous 117-volt ac line from the Port circuit board, install the opto-isolator and power relay in an enclosed box that is remotely situated at the controlled equipment. Run the data line signal to the optoisolator through a twisted-pair wire or shielded cable. Additionally, use a ground-fault circuit interrupter (GFCI) ac receptacle to obtain ac power.

Use the status input port to return normal or abnormal conditions of the control system. The status signals are interpreted by port software for further action. Figure 6 shows several input port circuits. Figure 6(A) shows use of one or more normally-open switches that return logic 0 when closed. A switch can be relay contacts, a snap-action microswitch, a magnetic reed switch, a thermostat or a pressure or vacuum switch. Normally-open switches can be connected in parallel, such as a number of magnetic reed switches in an intrusion alarm system. Normally-closed switches can be connected in series, as shown at right, in Fig. 6(A). The bit line rests at logic 0 until one of the switches is opened.

Use of light-sensitive components to control a status signal line is shown in Fig. 6(B). These include phototransistor *Q1*, light-dependent resistor *LDR* or cadmium-sulfide (CdS) photocell at center and a slotted photo-interrupter module at right. For proper switching, illumination of the optical device must be switched between very-low and very-high illumination. The light source must be "dc," such as sunlight or from a small lamp energized by dc.

The LDR should have a dark resistance of at least 10R2 and falls to less than 0.1R2 when brightly illuminated. The slotted photo interrupter switches to logic 1 when light traversing the slot is blocked by an opaque tape or metal arm. A wide variety of slotted and reflective photo-interrupters and photo-SCRs are available for use as sensors.

Figure 6(C) shows voltage-activated switches that report the presence or absence of dc voltages or pulses. Shown at right, *Q2* switches on and pulls the data line low when V_{in} is present. Shown at right, a low-current SCR switches and latches on when V_{in} is raised or pulsed high. The SCR is reset to off by pressing normally-closed pushbutton switch *S3*. Resistor *R6* determines SCR current once it is switched on. When SCR current exceeds its holding current, the device latches on. The ECG 5400 has a holding current of 5 milliamperes maximum but can be much less. A sensitive-gate low-current SCR can switch on spontaneously when powered up and, thus, may require installation of capacitor *C1* from gate to ground.

Diagnostics and ML Programming

Use the Port Interface to test the printer-port circuit card and printer cable. Write data bytes 00H and FFH to the data and control ports and read back the data for comparison. Use either BASIC or DEBUG in the immediate mode. Try first with the cable disconnected from the computer, next with the cable alone connected and, finally, with the Interface Port connected.

To check the yet to be wired con-

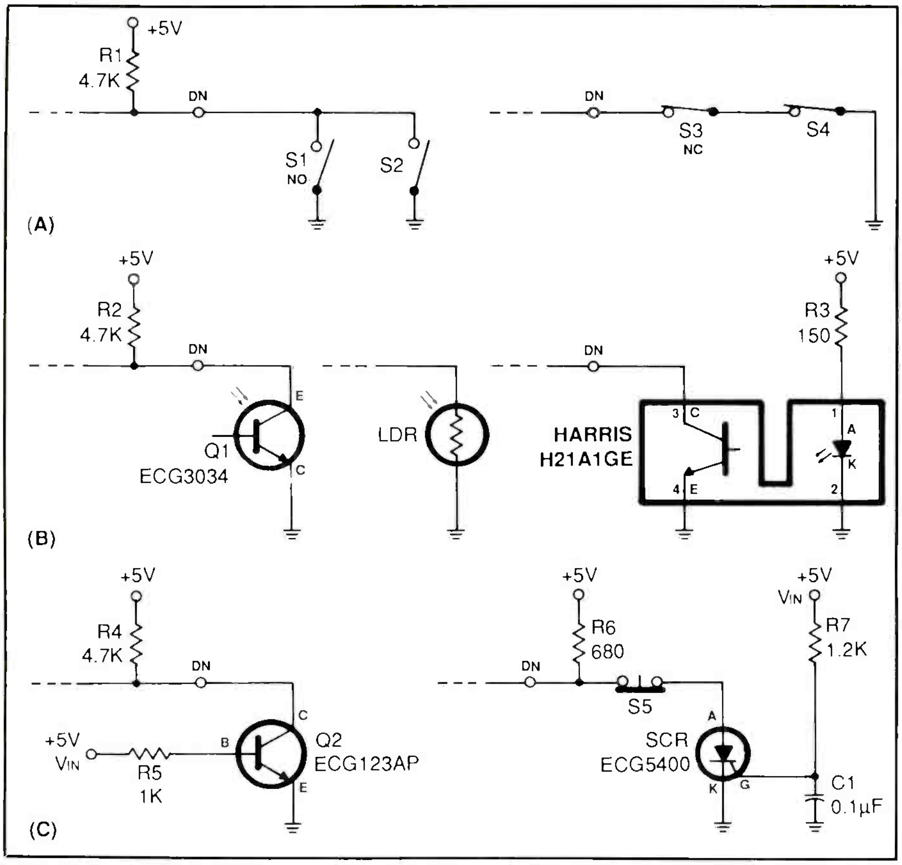


Fig. 6. Status input port circuits: (A) mechanical switches; (B) light-activated switches; and (C) non-latching (left) and latching (right) voltage-activated switches.

trol-port bit lines, pull the line under test up to +5 volts, using a 4,700-ohm resistor. Use a logic probe or voltmeter to check the logic state. Verify operation of the status input port by reading the port with the DIP-switch sections closed and open. If you find a stuck bit line, it could be a printer-cable problem or a defective line driver or receiver on the computer circuit card.

Diagnostic utilities that test serial and parallel ports can be used for tests with the Port Interface substituting for a printer. Among other tests, the utility sends individual ASCII characters, the ASCII character set and messages to the Port. Verify ASCII characters as displayed in binary on the LED bank.

Set BUSY bit D7 and FAULT bit D3 to logic 1, and send the messages to the Port. You should see activity on the data LEDs. Status bits D6 (ACK), D5 (PAPER END) and D4 (PTR SLTD) were "don't-cares" with the utility in use, but experiment with these status bit lines also.

For direct writes that bypass computer BIOS, the status port bits were "don't-cares." Indirect writes utilizing the BIOS and Interrupt functions sample the status port and respond accordingly. Keep in mind that the Port Interface does not fully simulate a printer.

Tests using the BASIC LPRINT statement can also be performed. Set the BUSY and FAULT bit lines to logic 1, or else error messages will appear on-screen. Using LPRINT, send a very-long string of any single ASCII character to the port in a looping program. Verify the ASCII value as displayed on the LED bank. Send mixed text and observe activity of the LED bank. The BASIC OUT statement behaved as a direct write ignoring the status port.

You can use the Port as a low-frequency square-wave generator. Write looping BASIC- or machine-language programs that repeatedly turn on and off a bit line. Include delay loops to adjust frequency or duty cycle. As an example, the following BASIC program (GEN1.BAS) is an up-counter that sends 0 through 255 to the Port. It generates eight synchronized frequencies simultaneously. Alter the port number 956 (03BCH) in line 20 to suit.

```
5 REM: GEN1.BAS
10 FOR N = 0 to 255
20 OUT (956),N
30 IF N = 255 THEN N = -1
40 NEXT N
```

For a 12-MHz computer running GW-BASIC, bit line D0 delivered a frequency of about 481 Hz. Proceeding from bit D0 through D7, the frequency divides by two at each step, down to a frequency of 3.75 Hz at D7. Exit the looping program by pressing CTL-BREAK.

Use machine-language programs to obtain the maximum possible frequency. The following program (GEN1MLP.COM) generated frequencies ranging from 217.5 kHz at bit line D0, down to 1,278-Hz at bit line D7:

```
MOV DX,03BC
MOV AL,00
OUT DX,AL
INC AL
JMP 0105
```

The first instruction loads pointer register DX with port address 03BCH. The second instruction loads register AL with zero. The third instruction sends the value held in AL to the port pointed to by DX. The fourth instruction increments AL by one. The last instruction causes a jump back to the OUT instruction, and the process repeats. Register AL counts up to FFH (255) and overflows with reset to zero. Exit the program by resetting the computer.

If you have not as yet used DEBUG, use this program to make a start by entering and assembling the program. Refer to your MS-DOS manual, which further details the DEBUG commands, while performing the following steps.

With DEBUG in the root directory, enter it by typing DEBUG at the DOS prompt and press ENTER. You will see DEBUG's dash prompt and a blinking cursor waiting for you to enter a command. You can use lower-case when typing DEBUG commands and program lines shown in upper-case. Type assemble command A and press ENTER. This brings up a two-part address, such as 9CAF:

0100 (segment:segment-offset). The 0100H offset address is the default starting address of the program within the segment. Ignore the segment address value that varies according to the various programs that are loaded at boot-up.

Type the first line of code and press ENTER. This automatically brings up the next address. Type the second line of code and press ENTER. Repeat until all lines have been entered. Press ENTER twice after typing the last code line to exit the assemble mode.

Type unassemble command U and press ENTER. You will see the five lines of source code you typed, beginning at offset address 0100 at right and the machine-language object code it generated at left. The machine code consists of 10 hex, or 0AH, bytes (a hex byte is made up of two digits). This value must be entered in register CX before saving the program. To do this, type register command RCX, press ENTER, type 0A and press ENTER.

Type registers display command R and press ENTER to display the register set. Verify that register CX holds 000AH. Next, assign a name to the program by typing N GEN1MLP.COM and press ENTER. Finally, type write command W and press ENTER to save the program. You can execute the program in DEBUG by typing the go command G=100 and pressing ENTER. You can also execute the program from the DOS prompt. In either case, the program locks up requiring a reset to escape the looping program.

Use the port as an aid in learning to use DEBUG and studying machine-language instructions. This becomes more palatable when you can see action on the bank of LEDs. Begin by testing the arithmetic shift and rotate instructions and sending the results to the data port for display. For another exercise, send the flags to the port for an alternative display. Devise other exercises, such as the classic chasing lamps display.

The status input port can be used to set up a live escape key to exit an endless loop without the need to reset your computer. Insert or patch a CALL to an escape subroutine inside the loop you are debugging. The CALLed subroutine reads and evaluates the status port using the compare (CMP) or other suitable instruction. The subroutine jumps (JMP) or exits to a debugger breakpoint when you close the status port escape key; otherwise, it returns (RET) to the looping program. After debugging the error, remove the patch. The few lines of code and several methods to accomplish this is left as an exercise for you to perform. (Hint: Be mindful of stack pointer SP when aborting a RET.)

It is impractical to write other than very short programs using DEBUG. Eventually, you will recognize the need for an enhanced debugger and an assembler. Look over the shareware debugger and assembler utilities. With some knowledge of the processor instruction set as a perquisite, you first type the program instructions including labels, symbols and assembler directives, and so forth, with a word processor to produce a readable commented source code file. The assembler reads the source code file, produces an executable machine-code file and lists syntax errors. Once freed of syntax errors, the code is tested in the debugger for programming errors.

This procedure often requires numerous trips through three large utilities, with irksome waiting for the disk to load the utilities each time. To speed this up, copy the assembler, debugger, any compact word processor and prior work files into a large RAMdisk. Automate RAMdisk loading of utilities and later saving of work files with batch files. Set DOS path solely to the RAMdisk. Preferably, include a DOS command-line editor utility to store and retrieve typed commands to eliminate repetitive typing. With this arrangement, using an assembler becomes a pleasure rather than a drudge. ■

Technical Notes

The Interface Port is currently used as an aid in studying the 80286 instruction set and as a "keyboard" for program direction control, such as an escape key to exit loop lockups. The following routines are examples of various aids facilitated by the Port. Their use requires only elementary familiarity with machine-language programming. After use, these and similar aids are deleted in the assembly listing and the code is reassembled. This moves along rapidly if you put all your needed utility software and work files into a suitably large RAMdisk.

As you can see from the foregoing, a parallel printer port can, indeed, be used for a lot more than just printing—using the appropriate interface circuitry.

```
; FLAGS: This routine sends five flag bits to I/O port address
;        03BCH for display on the LED bank. The LED display
;        (D7 - D0) is S Z x A x P x C. (Sign, Zero, Aux, Carry,
;        Parity, Carry)
org 0200            ;alter ORG to suit
startflags:
   pusha            ;save all registers
   mov dx,03bc      ;point to data port 03BCH
   lahf             ;put flags in AH
   mov al,ah        ;put flags in AL
   out dx,al        ;send AL to port
   popa             ;restore all registers
endflags:
;
;ESC: This subroutine is patched inside a loop and sets up an
;     escape key to exit loop lockups without resetting the
;     computer. Closure of any key of the input port effects an
;     exit from the debugger. With additional code, the routine
;     could exit to one of five destinations.
;
startesc:
   pusha            ;save all registers
   mov dx,03bd      ;point to status port 03BDH
   in al,dx         ;get port data
   cmp al,off       ;compare data with Off
   popa             ;restore all registers
   jnz L1           ;exit if not zero
   ret              ;else return to main program
L1:
   inc sp           ;adjust stack pointer
   inc sp           ;adjust stack pointer
endesc:
```

suggest that either *Q4* or *Q7* will cause the drain of *Q5* to select the alternate vocabulary word by letting pin 26 of *U1* go high.

With the circuitry thus far described, the Talking Logic Probe can vocalize "high," "low" and "open," depending on the condition sensed at the "hot" probe tip. The last vocabulary word that must be vocalized, "pulse," will be dealt with next.

Notice that the output at pin 7 of *U4B* is routed through a very simple adjustable integrator circuit at noninverting input pin 12 of *U4D*. As the input to the Talking Logic Probe rapidly switches between the high and low states, the output at pin 7 of *U4B* switches on and off, creating a square-wave pulse train. This pulse train is coupled across *C4* and integrated by *C5*. Trimmer control *R8* permits adjustment of circuit response.

When the pulse stream is coupled or "pumped" into this circuit, it produces a constant voltage across *C5*. This pumping action builds a voltage that soon exceeds the reference potential established by *R10* and *R11* at inverting input pin 13 of *U4D*. When a clock stream is encountered at the "hot" probe tip, the circuit pumps the voltage at pin 12 of *U4D* until it switches on pin 14. This high output gates on *Q6* and *Q7* to trigger vocalization of the word "clock."

The switching action at the "hot" probe tip during a clock pulse automatically creates a steady stream of trigger pulses at pin 1 of *U3*. This keeps the Talking Logic Probe vocalizing "clock" for as long as the clock input is present.

Digital data is converted directly to analog format by the R-2R ladder network at the output pins of *U1*. This rough analog waveform is coupled through *C7* to the audio amplifier made up of *U5* and its associated components.

Power for the Talking Logic Probe is supplied by a nominal 9-volt dc plug-in wall-type power supply. Separate +5- and +8-volt lines (the latter for the audio-amplifier circuit) are regulated by *VR1* and *VR2*, respectively, for delivery to the rest of the circuitry.

Construction

Point-to-point wiring isn't recommended for this project if you wish to keep it compact and easy to troubleshoot. If you like, you can fabricate a printed-circuit board on which to mount and wire together the components using the actual-size etching-and-drilling guide shown in Fig. 2. Otherwise, you can obtain a pc board from the source given in the Note at the end of the Parts List.

When your pc board is ready, orient it as shown in the wiring diagram shown in Fig. 3. Begin populating the board by installing and soldering into

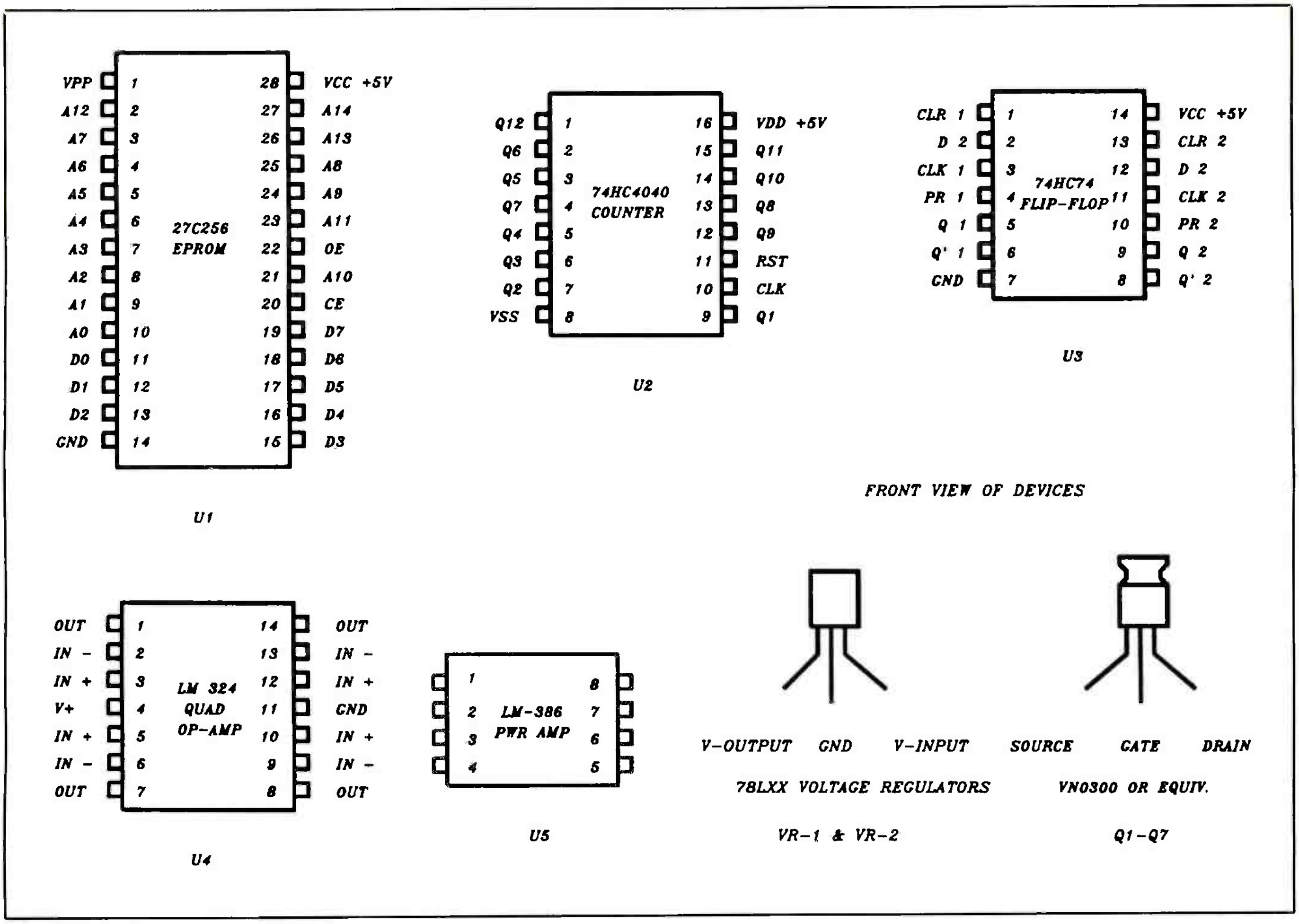


Fig. 4. Pinout diagram for ICs, voltage regulators and transistors used in Talking Logic Probe.

place sockets for all DIP ICs. Do *not* plug the ICs themselves into the sockets until after you have conducted preliminary voltage tests and are satisfied that all is okay.

Proceed with your wiring by installing and soldering into place the resistors in their various locations. Next, install and solder into place the capacitors and diodes. Make certain that all electrolytic capacitors are properly polarized and that all diodes are properly oriented before soldering any of their leads to the copper pads on the bottom of the board.

Install and solder into place the FET transistors and voltage regulators. Refer to Fig. 4 for basing information when doing this. Again, make sure all basings are correct before soldering any leads or pins into place. Then install and solder into place trimmer potentiometer *R8* and set it for about center of rotation.

You must also install 10 wire jumpers in the indicated locations. These can be cut-off resistor or capacitor leads or lengths of bare solid hookup wire.

Next, strip ¼ inch of insulation from both ends of 3-inch wires with red (two wires) and black (two wires) insulation. If you're using stranded hookup wire, tightly twist together the fine conductors at all ends and sparingly tin with solder.

If the plug-in dc power supply you chose comes with a connector at the end of its cord, cut this off and discard it. Then separate the conductors a distance of 1¼ inch. Strip ¼ inch of insulation from both conductor ends, tightly twist together the fine wires and sparingly tin with solder. Use a dc voltmeter or multimeter set to the dc-volts function to determine polarity of the supply conductors. Label each conductor according to polarity.

Plug one end of one black-insulated wire you prepared above into the BLK PROBE hole; one end of one red-insulated wire into the RED PROBE hole; one end of the remaining black-insulated wire into the SPEAKER GND hole at the lower-right of the board; and one end of the remaining red-insulated wire into the other SPEAKER hole. Solder all wires into place. Then tack-solder the free ends of the power-supply cable to the appropriate pads (observe polarity!) on the *solder* side of the board.

Loosely twist together the two SPEAKER wires. Do the same for the RED PROBE and BLK PROBE wires. The free ends of these wires will be connected later. Temporarily set aside the circuit-board assembly

The recommended enclosure for the size circuit-board assembly used for the Talking Logic Probe is specified in the Parts List. Machine the enclosure to permit the sound from the speaker to escape and mounting of the input banana jacks.

You need two or more same-size photocopies of the artwork shown in Fig. 5 to prepare the front panel. Use rubber cement or contact spray adhesive to tack one photocopy of Fig. 5 to the front panel of the enclosure and use it to transfer the required hole dimensions to the actual front panel of the enclosure.

Use a hot knife to cut the louvers for the speaker. The hot knife is a small razor-sharp knife fitted to the end of a soldering iron and is used to very precisely cut holes in plastic. If you don't already have one, you can obtain a hot knife from a hardware store. It's a good investment and will be used over and over again whenever you build a project that requires a home-machined enclosure.

When using a hot knife, work very carefully. If you haven't used a hot knife before, start out by making the holes for the louvers under-size until you're comfortable with the cutting process. You can always trim to final dimensions later.

Next, determine where the holes must be cut at the lower end of the panel for mounting the probe connector. Use the hot knife to cut these holes as well. Then test fit the connector assembly and make any adjustments necessary for it to fit flat against the panel. Finally, use the hot knife to cut a small slot in the top of the enclosure for the cord coming from the ac power supply. Thoroughly clean the tip of your hot knife, allow it to cool and then stow it safely away for the next time you need to use it.

Remove and discard the photocopy from the front panel of the enclosure. Touch up any rough edges of the slots and holes you cut with a small jeweler's file or fine-grit emery cloth. Then use rubber cement or,

Construction Notes

Though you might consider building the Talking Logic Probe on perforated board using point-to-point wiring, there are some good reasons why you shouldn't do this: (1) it will take much longer for you to build the project; (2) the project will probably grow as you build it to a size that won't lend itself to neat, compact packaging; (3) if troubleshooting the project is required in the future, you'll be in for a real headache; (4) without a printed-circuit board, the project will lack a "professional" appearance. The bottom line is, wouldn't you really like to give your project a really professional appearance and make it as compact as possible, to boot?

You have your choice of purchasing a ready-to-wire pc board or fabricating one of your own. Making pc boards can often be the most satisfying part of building a project. If you decide to make your own board, take your time. If you goof up on your first attempt, try again until you're satisfied that the board will provide a stable, solderable base for your project.

Once you've etched away all unwanted copper from your pc board and trimmed the board to size, use a No. 60 or 65 bit to drill component-lead holes. Holes of either size will provide plenty of clearance for component leads. You can, of course, use the usual No. 68 bit to drill component-lead holes, but you run a greater risk of bit breakage as you drill holes.

When your board is ready to be populated, take care in properly installing components, referring to any schematics and wiring guides as you go. Double-check all your work as you go along. Be sure to form component leads with long-nose pliers to assure a neat fit into the holes drilled for them.

Solder all components into place with 60/40 or 63/37 solder, and use a fine-point soldering iron. Good soldering is everything when it comes to quality construction. Time spent carefully soldering each connection always pays for itself in the long run.

When you finish soldering a circuit-board assembly, carefully inspect it. If you see you missed soldering a connection, solder it immediately. If you see any connections that appear suspicious, reflow the solder on them, and add more solder if needed. If you note solder bridges, clear them with desoldering braid or a vacuum-type desoldering tool.

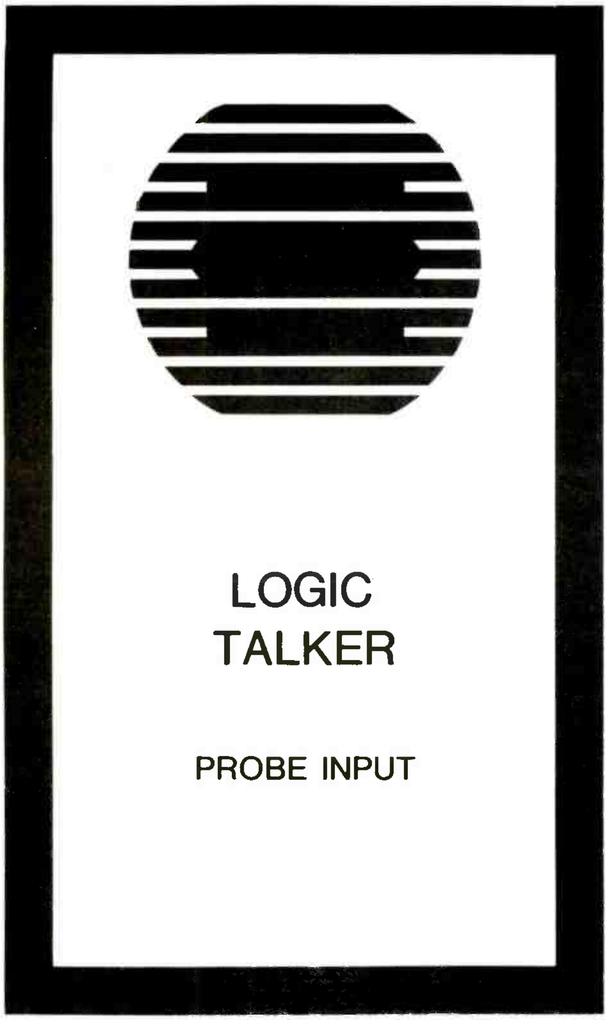


Fig. 5. Actual-size front-panel artwork.

Fig. 6. Assembled Talking Logic Probe just prior to final enclosure assembly.

preferably, spray contact adhesive to secure a fresh photocopy into place. Use a sharp, fine-tip utility knife to carefully cut away the paper in the areas of the slots and holes you cut into the front panel of the enclosure. Smooth out any bumps or bubbles in the copy. As a final touch, carefully color or darken the edges of the front-panel grille to blend them into the color of the enclosure.

Mount the input connector to the front panel of the enclosure and secure it in place with the supplied hardware. Use fast-setting epoxy cement or silicone adhesive to to mount the speaker centered over its grille cutout. Allow the cement or adhesive to fully set before proceeding with final assembly.

When the cement or adhesive has fully set, mount the circuit-board assembly inside the enclosure. Crimp and solder the free ends of the RED PROBE and BLK PROBE wires to the red- and black-coded connector lugs, respectively. Similarly, crimp and solder the free ends of the SPEAKER wires to the lugs on the speaker.

Test & Calibration

With no ICs plugged into the sockets on the circuit-board assembly, clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to the GND lug of the speaker. Plug the power supply into an ac outlet and touch the "hot" probe of the meter to pin 28 of the *U1* socket, pin 16 of the *U2* socket, pin 14 of the *U3* socket and pin 4 of the *U4* socket. In all cases, you should obtain a reading of approximately +5 volts. Touching the "hot" probe of the meter to pin 6 of the *U5* socket should yield a reading of approximately +8 volts.

If you fail to obtain the proper reading at any mentioned socket pin, power down the project. Rectify any problem before proceeding.

When you're certain that you correctly wired the circuit, power down and install the ICs in their respective sockets. Make sure each is properly oriented (refer back to Fig. 4 for pinout details) and that no pins overhang the sockets or fold under between ICs and sockets. At this point, your Talking Logic Probe should look like that shown in Fig. 6.

Plug the test leads into the input connector on the front panel of the Talking Logic Probe. Plug the power supply into an ac outlet and short together the probe tips. The Talking Logic Probe should vocalize "low." Separating the probe tips should cause the word "open" to be heard.

Taking care to observe proper polarity, touch the Talking Logic Probe probes across a low-voltage source. If the potential applied to the input of the project is greater than 2 volts, the Talking Logic Probe should vo-

Ted Needleman

(from page 71)

that I'm not going to bring a live pet into this house for at least a couple of years.

The Sound Blaster also provides a built-in standard game I/O port. To test it out, I installed the latest version of Microsoft's *Flight Simulator* (V. 4.0) and plugged in a control wheel I bought several years ago on a close-out. It worked perfectly, though it did demonstrate how badly my piloting skills have deteriorated in the decade since I stopped real flying.

This game I/O port also serves, with the addition of an optional connector box, as a MIDI I/O port. The MIDI interface is built onto the Sound Blaster board, but the optional connector box is needed if you wish to connect the card to external MIDI devices, such as a keyboard, drum machine or rack-mount synthesizer.

Brown-Wagh also distributes a special version of Voyetra Software's *Sequencer Plus Jr.* MIDI sequencing program that supports the MIDI features of the Sound Blaster card. I found the *SP Jr.* software very easy to use (at least as any sequencing software I've looked at).

When I plugged in the connector box, a MIDI keyboard and a rack-mount synthesizer, I was able to assign different sound sources (including the Sound Blaster) with no problem. If you're more advanced at electronic music than I am, Voyetra also offers versions of its more advanced sequencers for the Sound Blaster, as well as a MusiClips library of public-domain music in SP format and a voice editor for the Sound Blaster that allows you to modify the on-board instrument voices.

I'm the first to admit that I love gadgets. But I rarely give a whole-hearted, unqualified recommendation. If you use a PC for other than work, you really should buy one of these boards. Not only will it add a new dimension to your games and entertain your kids, it will give you a great start in the emerging fields of computer-assisted music and multi-media presentations. At $239.95, it's an outright bargain! ■

Products Mentioned

Life & Death 2: The Brain
The Software Toolworks
60 Leveroni Ct.
Novato, CA 94949
415-883-3000

CIRCLE NO. 77 ON FREE INFORMATION CARD

Sound Blaster
Brown-Wagh Publishing
130-D Knowles Dr.
Los Gatos, CA 95030
408-378-3838

CIRCLE NO. 78 ON FREE INFORMATION CARD

calize "high." If you obtain an "open" response from the project, increase the input voltage to a point where you hear "high" vocalized.

Using your dc voltmeter or multimeter or an oscilloscope, monitor the voltage at pin 12 of *U4*. Have someone tap together the input probes to the Talking Logic Probe at a fairly rapid rate as you observe the meter or scope. This should cause the Logic Talker to begin vocalizing "low" and "open" as the probes are touched together and separated, respectively. The voltage at pin 12 of *U4* should begin to rise. When it does, adjust the setting of trimmer *R8* until the Logic Talker begins to consistently vocalize "clock." By properly adjusting *R8*, you can compensate for various low-frequency clock thresholds.

This completes calibration. You can now disconnect the Talking Logic Probe from the ac power source and assemble its enclosure. The project is now ready to be put into service.

Using the Project

It's easy to use the Talking Logic Probe. Simply clip the black test lead to any ground point in the circuit you wish to test and touch the red-colored test-probe tip to any part of the circuit. There is only one precaution to keep firmly in mind when using this project. The Talking Logic Probe is designed for use in low-voltage circuits only. Though the input is equipped with an overvoltage protection circuit, it's good to only 20 volts. Therefore, *never* connect your Logic Talker to any higher voltages! if you're in doubt, always check first by taking a voltage reading with a meter to determine if it's safe to use this project on a circuit. In addition, your Logic Talker is a dc-only tester—do *not* use it on ac circuits.

You'll soon discover that your Talking Logic Probe is more than just a logic-level indicator. It can also be used as an event indicator. Try connecting it to a timer or the output of a project that involves a timed function. When the time-out period has elapsed, your Logic Talker will announce its occurrence.

Enjoy the freedom your Talking Logic Probe gives you when designing and troubleshooting electronic circuitry. ■

cated, tightly-integrated program that contains everything you need to go from design concept to actual printed-circuit board in one low-priced package. However, the modest size of the components library can be restricting and it's not the easiest program to use. Still it's a lot better than many modular programs selling for a lot more and is a package any serious designer should consider.

HiWIRE II *(from page 29)*

tion routine makes learning and using the program more difficult than it should be.

For an integrated circuit-design package, *HiWIRE II* has an amazingly weak interface between the schematic capture and PCB software. It's more of what you'd expect from a modular package, with pin connections being the only thing you can extract from the schematic. The advantage is that *HiWIRE* can and does convert a wide assortment of schematic capture netlists into *HiWIRE* format (18 in all, with seven of those different *HiWIRE* formats) because so little information is needed for conversion. On the downside, you have to do most of the PCB layout work by hand.

The PCB library contains about 140 patterns that are an array of pads spaced to accommodate a specific device footprint. There are also separate libraries of pad sizes and shapes that can be used to create or modify printed-circuit board patterns and of silkscreen outlines.

All board layout is done by hand, even if you intend to import a schematic netlist later. Parts are called from the library by clicking on the menu command and typing in the device name at the prompt. A screen listing of the library devices is available, which is very welcome because device names are case-sensitive (dip16 is *not* the same as DIP16), and being able to point and click on the desired object saves a lot of time and frustration. Devices are automatically numbered in sequence as they're placed on the circuit board.

Parts can be rotated or flipped to the opposite side for SMD layout only after they're placed. Every part placed on the board must be typed in individually because *HiWIRE* doesn't remember the last part entered or have a multiple-placement routine. The ratsnest is available only after all parts in the netlist have been placed on the board. Maximum board size is 64 × 64 inches.

The optional autorouter ($1,295 for the regular version and $1,695 for the EMS version) is Lee-based and allows a user to program four costing functions. Among the choices are the number of routable layers, number of routing passes to be made and number of allowed vias per connection. The router can route up to eight copper layers, which is the most *HiWire* supports. However, there are sixty-something layers up for grabs that a user can program for whatever purpose, for a total of 64 layers.

An equal number of ground planes are supported, with the two innermost layers dedicated to power and ground, and they can be connected to any net. There's no upper limit on either the number of router passes or vias. Protected areas are supported. No benchmark testing of the autorouter was done.

Manual routing is done by choosing the line command from the menu and scooting the rodent along to its destination, clicking once to change direction or twice to quit. Track width can't be done on the fly. You can change layers during routing, with automatic via placement. All copper layers can have a ground plane, and the plane can be connected to any net.

HiWIRE II has a scrolling auto pan that's in effect during both schematic and PCB line placement—quite an improvement over *HiWIRE Plus*. However, you still have to escape the placement routine to zoom in or out. Zoom range is 128:1, with highest magnification filling the screen with an eight-pin DIP. Block support, which *HiWIRE* calls BIND, includes all normal editing and drawing features.

Design rule checks include unconnected nets, air-gap violations and missing footprints.

HiWIRE II produces Gerber, N/C drill, PostScript and DXF files. Also generated are solder, SMD paste and silkscreen masks.

There's support for a wide range of printers and plotters. However, artwork from a printer can be used for draft proofs review only. Plotter output, on the other hand, is excellent and you have full software control over the instrument at all times.

HiWIRE II is a fairly difficult program to learn and use, but it contains all the elements needed for creating very complex circuit boards. Its support of 64 copper layers on a board size of 64 × 64 inches in unsurpassed. If you don't need these features, there are several easier to use programs to choose from.

OrCAD/PCB *(from page 29)*

called *Intelligent Menus Systems* from Velotec, Inc. of Anaheim, CA. Reportedly, *OrCAD/PCB III* will have an interactive menu.

OrCAD's netlist is undoubtedly the most popular in the industry, and is supported by most schematic capture programs in one form or another. However, you'll probably end up doing a lot of netlist tweaking either inside the schematic capture program or on the netlist file itself using an ASCII editor because most programs can't or don't include the *OrCAD* device outline as part of the netlist. The link between *OrCAD/STD III* and *OrCAD/PCB II* is very tight with both forward and back annotation.

The library contains outlines for more than 300 devices that include a generous assortment of connectors and SMDs. A board outline, which can measure up to 32 × 32 inches, isn't required before parts can be placed. You have to define a working area before device outlines can be extracted from the schematic netlist.

However, you aren't confined to the work area for placement. It's only required to load the parts, and you have the entire 1,024 square inches to work from while manually moving the parts to their desired locations. Parts can be rotated and flipped to the solder side for SMD placement during and after parts placement. Both a ratsnest and a force vector display are available for placement. The upcoming *OrCAD/PCB III* is said to have an automatic placement routine.

The Lee-based autorouter has six user-programmable costed functions that the program calls strategies. The strategies range from defining when a 45° track is permitted to no vias allowed. However, only one strategy and two layers can be in effect at a time. If you want to route four layers, you'll have to do two autoroutes.

If you're still left with unconnected tracks, you can change the strategy and try again—or use the rip-up router to place those dangling ends. You can define protected zones where tracks are prohibited. On our benchmark layout using the extensive option on OrCAD's fixed 5-mil grid, the autorouter scored 100-percent completion.

Autorouting track width is limited to one size per layer. Up to 16 layers are supported. To route tracks of different widths on the same layer, you have to autoroute them one net at a time or lay them down manually.

Manually routing tracks involves a rather lengthy sequence of events that has you walking through six menus. However, once a track is started, only two mouse clicks are needed to continue its path, and the width of the track can be changed on the fly for necking down. Via placement can be automatic or manual, as you wish. You can also move a track that's in place while maintaining connectivity of the track. All 16 layers can have a ground plane, and the planes can be connected to any net.

Panning is automatic, but scrolling isn't smooth. The screen abruptly jumps to the next area of the drawing indicated by movement of the cursor. Zoom range is 100:1, with highest magnification displaying about half a 14-pin DIP chip. Both pan and zoom are available during parts and track placement. Block functions include move, copy, delete, save and get. Find, locate and jump commands are also supported, but a help screen isn't.

The design rule check logs air-gap violations in a disk file, citing coordinates of the violation that you'll have to manually compare to the screen. The only other design check reporting occurs when doing an autoroute, in which the number of nets, vias and unconnected nets are displayed at the bottom of the screen.

OrCAD/PCB II generates both Gerber and N/C drill files. Other output files include solder and silkscreen masks.

Either a dot-matrix or a laser printer can be used to produce draft or final artwork in a range of scaled sizes. With some fine tuning on track width and spacing, a dot-matrix hard copy of 1 × artwork is suitable for prototype work and hobby projects. Of course, an HI or HP plotter drawing, both of which are supported, does a better job. But PostScript users, which *OrCAD/PCB II* also supports, may dispute that point.

OrCAD/PCB II is an excellent layout program that has essentially all functions a professional PCB designer needs, and its price is affordable. However, it lacks the sophistication you've come to expect from OrCAD —something OrCAD promises to correct in *OrCAD/PCB III*. But if you can't wait, don't.

PC Boards *(from page 30)*

Boards' hardware requirements are a miserly 384K of RAM and one floppy drive. Expanded memory and a math coprocessor aren't needed or supported.

PCBoards is easy enough to learn, but it may take some getting familiar with the sometimes awkward placement sequences. Nothing about the program is automated, forcing a user to essentially translate a schematic drawing into a PCB layout by hand. But that's a whole lot better than using transfer tape and a knife.

The component library, as it is, consists of DIP (dual in-line package) and SIP (single in-line package) pad patterns with standard ⅒-inch spacing. For DIPs, the footprint is selectable from 6 to 48 pins; SIP outlines range from 2 to 40 pins. Individual pads are used to place resistors and other devices.

Part placement consists of calling either the DIP, SIP or pad command from the menu, then positioning the cursor on the grid point that relates to pin number one of the device and clicking the mouse button or pressing a function key. Both DIP and SIP patterns can be rotated during placement, but it may take a while to get the hang of this because the DIP pattern doesn't become visible until after you click, leaving you to guess about the outcome. Maximum board size is only 6 × 13 inches.

Placement editing is very limited. Everything must be done as a block function. For example, to move a DIP part, you first have to define a block area around the pattern, erase it and then move the upper-right icon to its new location and request a block place. Again, many placement surprises may result until you get the lay of the land because the outlines aren't entities, but individual pads on the screen. Missing a row of pads when marking a block not only strips the pattern of needed pads, but leaves the forgotten pads behind to be reckoned with in a separate step.

Track placement is very much the same, with the user clicking on the beginning then the end of the track, with no visual display until the track is in place. Only ortho lines are permitted, with short (one grid-dot) 45° bends available for memory routing. *PCBoards* supports only a top and bottom copper layer, and vias must be manually placed when changing from one to the other.

Only two track widths are available: 20 and 50 mils. All tracks must first be laid down using the 20-mil format. Tracks that need to be fatter are then widened using the THICK command. Thick lines can't be initially placed.

If the thought of manually routing a circuit board doesn't thrill you, you can have the *PCRoute* autorouter do it for you by simply saving the layout to file and running *PCRoute*. *PCRoute* then combines the netlists produced by *SuperCAD* and *PCBoards* to route the board. However, the same trace width restrictions remain, and the schematic device outline interpretations are less than ideal. This means you'll probably end up doing a lot of manual touch-up in the end. No testing of our benchmark layout was done because of the track width requirements we built into the benchmark circuit that neither program can cope with.

PCBoards has a help screen, but no design rule check. Autopan is supported for all operations except track placement, where it's most needed. Zoom has but two levels, big and small, neither of which are practical for serious PCB work. However, a new zoom command with a wider range is in the works and should be shipping by press time.

There's no Gerber file generator, but there is a drill list of sorts. The drill list printout lists coordinates of the pad and via holes and gives a line in which you can manually write in the hole size on the hard copy. This is enough information for a PCB service to manually program an N/C drilling machine. Solder and component masks aren't part of the bargain.

Final artwork can be printed using either a dot-matrix or a laser printer in 1× and 2× scale. For crude layouts with 50-mil tracks, the 1× dot-matrix pattern can be used to etch a circuit board. A better plan is to print the pattern in 2× scale and photographically reduce it—or use a laser printer. In the 1× mode, the laser printer can produce very good artwork on a clear sheet suitable for immediate use.

Support for Houston Instrument and Hewlett-Packard plotters costs $49 extra. The plotter software incorporates advanced features like pad shaving to maintain proper air-gap spacing and fillets to relieve thermal stress at track corners.

PCBoards isn't the greatest PCB layout program, but its super-low price makes it ideal for hobbyist use. However, the software is in a constant state of upgrade, with some of the shortcomings mentioned here scheduled to be corrected by the time you read this, and upgrades are free for a year after purchase.

ProCAD *(from page 30)*

base file and library to switch from one to the other. Unfortunately, you have to quit the program to generate netlists that link the two together.

Learning and using *ProCAD* can be frustrating because everything is user-programmable, meaning it's easy to make serious mistakes. But if you don't like the way *ProCAD* does things, you can create your own menus and command structures.

The link between the three functions—schematic capture, PCB layout and autoroute—is very tight. Forward and backward annotation is supported, but the changes to the netlists must be done manually from the DOS prompt using an ASCII file editor. The PCB software also recognizes FutureNet netlists.

The program comes with nine library modules, two of which contain device outlines and PCB pads (about 50 devices in all). But parts count is so skimpy, lacking three of the devices needed in our benchmark circuit, that you'd want to consider obtaining one or more of the optional libraries, which sell for $35 each or six for $150. Only one library is active at a time, but there's an easy way around this to avoid forcing you to make frequent library changes.

While there's no automatic parts-placement routine, device outlines can automatically be called from the schematic netlist one at a time for manual placement. A board outline is required prior to netlist parts placement. Protected zones can also be defined at this time. Maximum board size is 64 × 64 inches. As devices appear, you can locate them anywhere you want (even outside the board), except in the protected zones, skipping those you wish to deal with later. Parts can be rotated in 1° increments both during and after placement. Unfortunately, there are no initial placement aids. A ratsnest is available only after all devices are on the circuit board.

The optional autorouter ($795 for regular and $995 for EMS) is an advanced grid-less router called a probe router that can actually look ahead to see whether or not placing the current track block placement of a subsequent track. Altogether, the router can route two layers at a time, using six pass options. Each can be programmed for a different route parameter and track size. The router can be stopped at any time for manual intervention. Track width and grid size are infinitely variable.

Although we couldn't run our benchmark layout because of library limitations in our evaluation package, routing tests of substantially more complex circuits, using only two layers, proved quite impressive, scoring 90% on a design with 200 logic ICs (designs of this magnitude generally require four layers). A rip-up router is available for $2,495.

Tracks are laid down manually by clicking once on the mouse and advancing the track to its destination or turning point. You can change layers during track routing, with automatic via placement, but you can't change track width. *ProCAD* supports nine copper layers out of the box, but you can define another 50 layers as copper, for 59 in all. A ground plane can be assigned to any of the layers and connected to any net. Connectivity is maintained when moving already placed tracks.

ProCAD has autopan, but only on three sides because bumping against the bottom nets you a menu rather than a screen scroll. This means the screen is on a continual up climb until you forcibly bring it back to earth using manual pan. You can get autopan on the fourth side, however, by sneaking in the cursor at the bottom-left or bottom-right sides.

Autopan isn't available during part or track placement, but you can activate manual pan from the keyboard. Zoom is infinitely variable—seemingly down to the atom—and is also available from the keyboard during placement. Anything you can do on-screen can be done as a block. Context-sensitive help is available.

ProCAD Xtra and *ProCAD Xtra-XL* have design rule checking software, and it only checks for broken tracks and air-gap violations. To save time when checking a modified layout, you can limit verification to a select portion of the board.

All of the standard netlists and manufacturing files are generated within *ProCAD*, including solder and SMD paste masks, and the usual range of silkscreen mats and layout documentation. However, a Gerber netlist generator costs $75 extra. Other extra-cost items include N/C Drill ($100), *PCAD* and DXF ($250).

In addition to the standard fare of HP and HI plotters, dot-matrix and laser printers can be used for producing final artwork. Of course, some dot-matrix patterns may be suitable only for proofing unless you watch your line widths and spacing.

ProCAD in any of its many versions is an excellent circuit-design package. While it may not be the most automated and certainly not the easiest to use, it has all the features you'll ever need for even the most complex design, and it's well suited for the most demanding circuit design task—provided you buy *all* the options. Even so, the total price for such a professional complete design package is reasonably priced.

Autotrax (from page 30)

gineering programs, and the mesh is flawless. Although there's no back annotation to the schematic, there is a NETCHECK utility that compares schematic capture and PCB netlists and reports all discrepancies. *Autotrax* provides a utility for converting *OrCAD*, *Schema* and *PADS* netlists into Protel format, all of which support automatic parts placement and, therefore, device outlines, but be prepared for heavy-duty manual editing of the netlist files because the device outlines lose more than a little in translation.

The component library contains outlines for about 170 devices. The inventory is evenly divided among passive, DIP and connector footprints, with a good number claimed by SMD devices. The outlines are not attached to any particular part number or device and are used over and over in a layout without regard to the actual device.

Before placing components, the board outline must be defined. Protected zones that prevent placement of parts or tracks within the zone can also be defined at this time. Maximum board size is 32 × 32 inches.

The automatic placement routine is on par with *EE Designer*'s. Parts that are manually positioned prior to or after automatic placement are glued in place automatically, allowing you to run the placement routine again for better device positioning. Parts can be rotated or moved to the flip side of the board for SMD layouts after initial placement. A ratsnest is available for placement.

The Lee-based autorouter is costed, which allows you to dictate the types of routing routines permitted. The router has 10 routing variables, all of which can be activated in any combination. In addition there are six optimization functions, like via minimization and loop removal, which can also be activated. Costing routines are implemented in order from simplest to most exhaustive, with the optimization routines running last. There's also a smoother routine that optimizes manually-placed traces without violating the designer's routing intentions.

Although all six copper layers can be included in the autoroute, only one track width can be routed at a time. To lay down tracks of different widths, you must specify the net to be routed, enter track width and then route the net to completion and proceed to the next net and do the same. For example, to have thicker power supply and ground tracks, you have to do three routings: one for V_{cc}, one for GND and one for the remaining signal nets.

The router grid is variable from 5 to 1,000 mils, and track width is variable between 1 and 255 mils. Our benchmark design with automatic placement and default autorouting parameters resulted in 13 uncompleted tracks. With a 25-mil grid and our own parts layout, the autorouter was able to achieve 100% completion. *Autotrax* interfaces with Protel's $1,495 *Traxstar* rip-up router.

Manually routed tracks are laid down by clicking the mouse button once, moving the track to its destination and clicking again to change direction. Tracks can be ortho, free style or curved. However, you can't change track type on the fly. Connectivity is maintained when a track is moved, with the track stretching or contracting to accommodate its new location. There's an un-delete command that systematically replaces deleted tracks in the order they were erased back to the beginning. Only two ground planes are supported and can be attached to any net.

Screen pan is automatic but not during automatic placement or autorouting. The 100:1 zoom, on the other hand, is available during placement and routing but isn't available when a pull-down command menu is displayed. Block functions include move, rotate, copy, inside and outside delete, hide and save. Macros are supported and can be nested.

The design rule check command reports spacing violations, broken or unrouted nets, missing components and extra pins. The coordinates and type of error are scrolled on-screen and saved to file.

Autotrax produces both Gerber and N/C drill files. Other output files include silkscreen, solder and SMD paste masks. Component-placement outlines and nomenclature are combined in one mask.

Final artwork can be produced on either a dot-matrix or laser printer and, with care, used as final artwork. PostScript format is supported, and the artwork can be scaled to any size. Several plotters are also supported, with plotter adjustments set from the software.

Protel-Autotrax is a medium-priced PCB layout program that tightly integrates with other members of Protel's circuit design family. Its strength lies in the size of its component library, the many costed functions the autorouter provides and the fact than a rip-up router is available. It's ideal for small production runs and prototypes but lacks the power needed for serious multi-layer work.

Easytrax (from page 31)

on the top side of the board, preventing use of SMDs. Once a device outline is selected, it can be repeated as many times as you wish. Maximum board size is 32 × 32 inches.

Tracks can be placed manually or by using the pad-to-pad autorouter. The single-minded heuristic router operates cleverly in finding a way between the two specified pads unless, of course, you've managed to box one of them in. The router does its own via placement and will search all available layers when plotting a path. Six copper layers and two ground planes are supported. The downside is that the router investigates ortho paths only, which may result in a number of vias than aren't really needed—vias that you'll have to optimize on your own.

When routing manually, tracks can be ortho, free style or curved. Tracks are laid down by clicking the mouse button once, moving the track to its desired destination and clicking again. Clicking the right mouse button ends a track. Track width is selectable in seven increments between 10 and 100 mils for both manual and autorouting, but you can't change path width on the fly. Track connectivity is maintained during track move, with the track stretching or shrinking to maintain the connection.

Like *Autotrax*, nested macros are supported, as are full-time autopan and zoom. The block functions are also identical in every respect, and the un-delete command still replaces tracks that were erased back to the beginning of the current drawing load. However, there's no design rule check.

Easytrax's only contact with the outside world is via its output files. *Easytrax* files can be converted into Autotrax files, giving the *Easytrax* designer the advantages of *Traxstar* and other Protel goodies, but Autotrax files can not be changed to Easytrax files because of *Autotrax*'s superior editing capabilities.

Like *Autotrax, Easytrax* produces Gerber and N/C drill files, as well as silkscreen and solder masks. *Easytrax*'s printer and plotter interface is identical to *Autotrax*'s, which means you can produce final artwork at scaled sizes on dot-matrix or laser printers and several pen plotters.

Easytrax is a complete PCB layout program that's easy to learn and use. But because it lacks support for an input netlist, you'll be doing all the work by hand, even when calling on the autorouter to make pad-by-pad connections. Still, its fantastic support of printers, Gerber and N/C files plus production masks at no extra cost make this program a good choice for an advanced hobbyist or the start-up business on a budget.

Schema *(from page 31)*

programs for converting *PCAD* or *Recad-Redac* netlists into *Schema-PCB* format are available for $995 and $1,500, respectively.

The library contains outlines for 159 devices, including several SMDs. The library also electrically links these outlines with 2,160 components, mostly ICs, that the program uses for automatic placement and package editing. However, the library is a bit touchy about how you specify parts in schematic capture. *Schema III*'s library contains the 7446 chip used in our benchmark circuit, but *Schema-PCB* wouldn't accept it until we changed it to 54L46.

Schema has an excellent automatic placement program that even includes a routine for properly placing decoupling capacitors. But get ready to up the ante again, because the utility costs an extra $350. Before you can extract device outlines from the schematic netlist, you have to define both a board outline (of up to 32 × 32 inches) and a parts matrix field. Practically, the matrix should contain the same number of fields as the number of parts to be placed; if it's less, more than one part is placed in a matrix block.

The matrix isn't sized to the board so that you can place sections of the board according to device type, such as memory chips and the like. While this is a great asset, it takes some planning because making a mistake on matrix sizing may net you a board with all the components huddled in a corner or scattered to the four corners of the globe. A matrix isn't required for manual placement.

Parts can be rotated or flipped to the solder side of the board for SMD layout after auto placement. Any part can be glued in place and the automatic placement run again for improved placement. A ratsnest is also available.

Router options are nothing short of fantastic; again, get ready to pony up more money. The standard autorouter ($750) uses a mix of heuristic and Lee algorithms that are under full user control. Altogether, there are 15 routing options, 10 of which are Lee based, which can be selected in any combination. The autorouter runs through the list beginning with power-supply tracks and ending in via optimization. However, you can autoroute only two layers and one track width at a time. Autorouting can be confined to a net or specific area of the board and can be stopped at any time for manual intervention.

The router grid is infinitely variable between 1 and 800 mils and can be changed on the fly. Using our benchmark layout with a 25-mil grid, not a single track was missed. But at 50 mils, the number of unplaced tracks rose to a rather high eight. An optional rip-up router that can route 12 layers simultaneously sells for a hefty $3,500 and a shove-aside router tips the scale at $1,495.

For manual routing, tracks are started by clicking on a pad and moving the pointer to the connecting pad. A ratsnest, which can hide power supply nets, is always visible. Changing track width for necking down can be done on the fly. Curved tracks aren't supported. Connectivity is maintained when moving a placed track. The program supports 30 copper layers, each of which can have both a power and a ground plane.

Schema-PCB is the only program in this review that automatically reassigns pin numbers when changing package type, including changes from DIP to SMD packages. However, this feature is limited to the 2,160 devices contained in the component library. This means that for package changes to generic devices, you're on your own. *Schema-PCB* supports gate and pin swapping. Blocks of components and tracks can be moved, rotated, deleted, mirrored, copied and saved to file. Connectivity to parts outside the block can be maintained using the rubber-band feature. Pan and zoom are manual, not automatic. However, both are available for parts placement and routing. Zoom range is 64:1.

Schema-PCB has the most sophisticated design rule check of any program in this review. In addition to the usual air-gap violation netlist, there's a density map that displays areas on the board where the concentration of tracks may cause problems. Furthermore, a histogram shows how to move devices for better routing.

The program can produce a full range of output netlists and files—at extra cost, of course. Gerber and N/C drill utilities are $300 each, and the DXF file generator is $495. The only things you don't have to pay extra for are the layer masks, which include all 30 copper layers, solder and SMD paste masks and top- and bottom-layer silkscreen artwork.

A dot-matrix or laser printer can be used to produce all artwork. Art can be sized to fit the page, scaled to a model size or printed actual-size. However, a wide-carriage printer is required to get it all on one page even at the 1:1 scale. When printed in sizes of 2 × or greater, the artwork is good enough for limited production and prototype purposes. Both HP and HI pen plotters are supported.

With support for 30 copper layers and a bevy of autorouters from which to choose, *Schema-PCB Layout* is one of the best PCB board layout programs around. What it lacks in ease of use, it makes up for in features. But you'd better get your pocketbook ready, because to get everything you want may cost a tidy bundle.

Tango *(from page 31)*

three modules: a main library holding 107 general purpose devices, a 120-device connector library and an SMT library with 90 SMD outlines. When browsing through the contents of a library, actual footprints are shown on-screen, eliminating the need for a pattern reference manual.

Since components can't be extracted from the netlist, you're required to call them from the libraries and manually place them on the board. A scrolling library list is available for placement. Maximum board size is 32 × 32 inches.

During placement, you can rotate the part or flip it for placement on the opposite of the board. When placing multiples of the same device type, *Tango* automatically increments the part reference number as you go along. For example, if you start with a series of memory chips beginning with *U10, Tango* labels the next one *U11*, the following *U12* and so on. If there's already a device on the board with the next consecutive number, that number is skipped and the sequence continues with the next available higher number.

Both a ratsnest and force vectors are available to aid you in your placement. However, neither is available until all the parts in the netlist are on the board, which forces you to either guess at a best placement scheme or line the devices up in neat rows somewhere on the board, which takes less time, and then use the move command in conjunction with either or both the ratsnest and force vectors for your layout.

Tracks are laid down by clicking the mouse button once and moving to the desired location. You can change layers while routing a track; vias are automatically placed when changing layers. *Tango-PCB Plus* supports eight copper layers, two of which are used strictly as power and ground planes. Track width can't be changed on the fly, but you can edit track width after routing. Connectivity is maintained when moving tracks. Parts can also be moved, rotated or flipped while maintaining track connectivity. But it's only a direct path between the two pads, cutting across other tracks without concern, that leaves a bit of a mess you have to manually tidy.

Tango-Route Plus is the autorouter companion to *Tango-PCB Plus*, and it also lists for $895. Purchased together, the price is $1,595. Like all Tango products, the autorouter runs alone, rather than under the control of a main menu. To route a board, you load both the schematic netlist and the circuit-board layout file from *Tango-PCB Plus*. The router then matches up the pin connections in the netlist to the device references in the PCB file and routes tracks accordingly. Protected areas are defined in *Tango-PCB Plus* before routing.

The router has eight user-selectable routing methods, six of which are heuristic and two Lee-based. The Lee Maze router lets you specify up to 99 vias to complete a connection. All eight circuit-board layers can be routed at the same time. There are two post-routing routines, one that minimizes the number of bends in a connection and another that minimizes the number of vias.

There are five grid sizes, ranging from 10 to 25 mils. Each grid comes with a specific track width and air-gap clearance, which the user can change if desired. However, only one track width can be routed at a time. If you wish to route tracks of different widths, the nets involved must be highlighted and the routing pass done separately for each different width. On our benchmark layout using a 25-mil grid, the router was able to complete 100% of the tracks.

Tango-PCB Plus has no pan feature. Instead, you use the zoom function to move about the board, either to center your work or to move in or out. You can zoom in increments of two or use the infinitely-variable window option. Zoom magnification ranges from filling the screen with a single pad to displaying the entire working area. Zoom is available from the keyboard during parts placement and routing. There's an undo command for both track placement and editing commands. Block functions include move, delete, copy and save. A context-sensitive help screen is also available.

There's design rule checking in both the PCB layout and autorouter programs. Among the many things they check for is correct air-gap clearance and unrouted connections. All discrepancies are displayed in on-screen message boxes and saved to file.

Tango-PCB Plus generates a wide range of output files, including Gerber, N/C Drill, DXF and PostScript. There's also a full complement of masks, including an SMD paste mask, and several layers of silkscreen artwork.

Like all Tango products, printer and plotter support is nothing short of fantastic. However, after running the autorouter using the default values you can't use a printer hardcopy for real artwork. But if you pay attention to track width and spacing manually, you can use the artwork from a dot-matrix or laser printer to etch even complex double-sided PCBs.

Tango-PCB Plus is a great package, if you don't mind paying the price and doing more manual labor than you should. It has everything you need to make professional multi-layer boards, and the autorouter is among the best. But no support for other netlist formats or an automatic parts placement routine in a program that costs this much might have you looking for a better deal.

PCB Layout Rating Summary

Program	Place	Route	Library	Schematic Capture Support (Own)	(Other)	Ease of Use
EE Designer III ($1,900; incl. schem. & simul.)	A	A	D	A	D	C
HiWIRE II ($1,995; incl. schem.)	D	B	C	D	A	C
OrCAD/PCB II ($1,495)	C	B	A	A	A	B
PCBoards ($198)	D	C	D	D	C	C
ProCAD XL ($1,995; incl. schem.)	C	A	C	A	D	C
Protel-Autotrax ($1,295)	A	A	B	B	C	A
Protel Easytrax ($450)	D	C	B	F	F	A
Schema-PCB Layout ($2,395)	A	A	B	A	C	C
Tango-PCB Plus ($1,790)	D	A	A	D	F	B

Note: Prices shown are totals with options taken.
Ratings range from A for excellent to F for no support.

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3D Space Combat Simulator

Game players who like science fiction and simulation are in for a real treat. Origin has released *Wing Commander*, a 3D space-combat simulator that is light years ahead of anything like it.

The time is the future, and the Terran Federation is locked in deadly combat with a race of sentient felines called the Kilrathi. Players begin as 2nd Lt. aboard the heavy space carrier *Tiger's Claw*. Here you are the Wing Commander of a two-fighter strike team.

This is a game that bustles with fine features. Graphics are one such feature. Graphic resolution is only 320 × 200, which might seem low, but 256 colors add depth. Its bold artwork and proper shading make the graphics appear quite stunning on the screen.

Playability is always an important item for a simulation. *Wing Commander* rates high in this area. Players never know what each mission will bring. During the pre-mission briefing, objectives, hazards and navigation routes are explained. But once you leave the *Tiger's Claw*, you are on your own. You decide how fast or how slow you want to proceed. You make the decision to engage the enemy or not. On some missions, you may have your wingman follow you through the heart of a tumbling asteroid field. On other missions, you may be cautious enough to skirt the edges of an enemy mine field. And if your wingman becomes badly damaged, you can send him home before he gets killed.

Another aspect of the game's playability is that your success or failure during a mission affects the total war effort. If you fail to escort a transport ship, hundreds of marines die. If you fail to eliminate an enemy destroyer, Confederation forces lose a vital tactical advantage. This knowledge makes each mission equally exciting. Also, there is the added spice of occasionally meeting up with some of the Kilrathi top aces who can quickly take out a good wingman.

One thing that gamers will especially appreciate is that there are no tricks in the game. There are no hidden secrets or goofy techniques that must be discovered to play well. It all depends on good dogfighting skills and making right decisions in combat.

Game sound and music cannot be overlooked. An original sound-track accompanies players through eager launch, lonely patrols, tense battles and victory. Each musical piece is appropriate to the mood of the scene. Surprisingly, though, the constant audio does not become obnoxious and, even after many missions, it does not wear on the nerves. Rather, it actually makes the game more enjoyable.

Wing Commander has an important negative aspect. It is negative only for gamers who do not have a powerful computer system. For optimum performance, a '386 machine with VGA graphics and a hard-disk drive are needed. A graphic-intensive game like this one places high demands on processor capability. Especially is this true during large dogfights that have many fighters plus large destroyers and space carriers. Navigating mine fields and asteroid fields also stresses the processor. A '286 computer, even a very fast one, tends to bog down to the point of frustration.

Two megabytes of memory is also recommended. The game uses expanded memory for extra graphics, extra sound and disk caching. Without it, the game will pause during play and make a disk access when it needs to. This can be annoying when you are right in the middle of pegging a Kilrathi fighter with your neutron cannon.

Wing Commander is the most thrilling computer game to come along in a good while. It effectively combines 3D arcade

(Continued on page 97)

Wing Commander's Mission Briefing (left) and Enemy Destroyer Going Up (right) screens.

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