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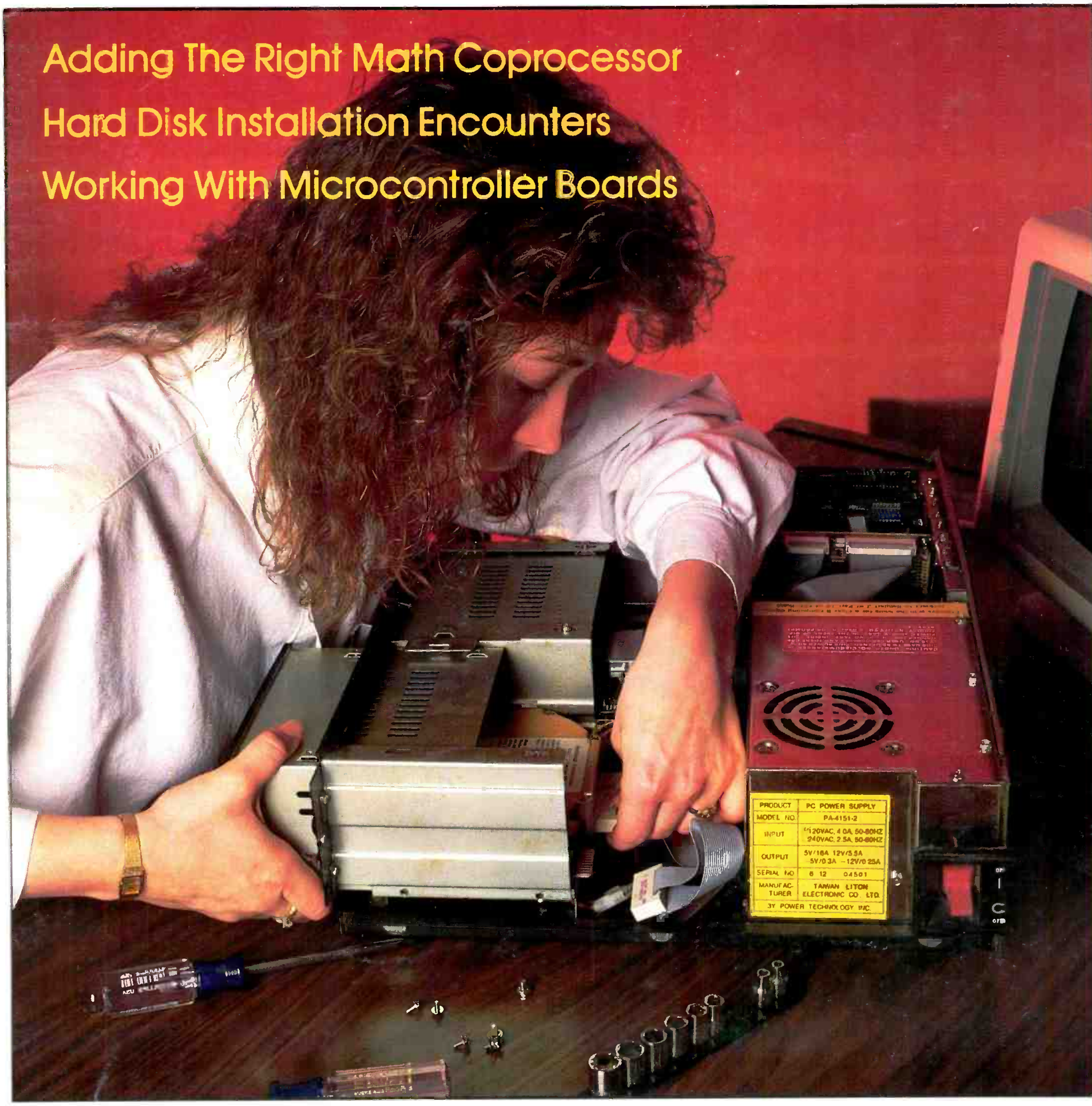

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Volume 1, No. 2 May 1991

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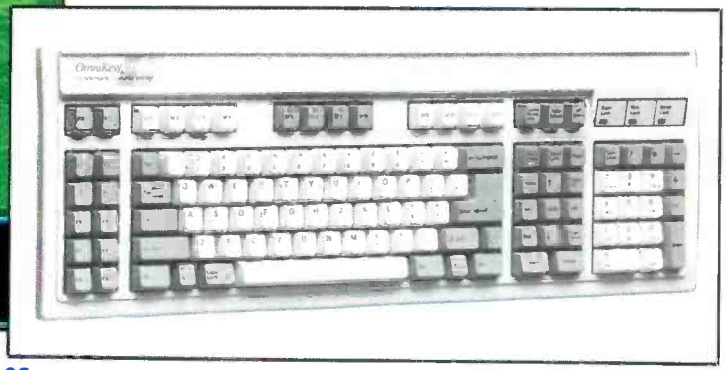

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ON THE COVER: Adding or replacing a hard disk in a PC or compatible computer is jut one of the many hardware upgrades *ComputerCraft* readers can perform. For the misadventures of one of our contributing editors, see the story beginning on page 42 of this issue.

Photo by Lorinda Sullivan

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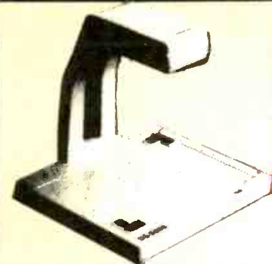

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CIRCLE NO. 84 ON FREE INFORMATION CARD

Hard or Soft?

Sounds like a choice to make at an ice-cream/custard store, but it's one for computer enthusiasts, too, who generally lean toward either hardware or software.

Most people who use personal computers are merely operators, of course, generally using a particular application program or two or three. The likeliest one is word processing, perhaps followed by computer games playing. Other people developed programming skills as their main strength. Still other personal computer users are more hardware-oriented, daring to install, upgrade, enhance and troubleshoot their own systems—even experiment with circuit designs and assemble their own boards for use with a personal computer or microcontroller. These are the activities upon which *ComputerCraft* focuses.

One can, of course, be a proficient programmer and also be involved in hardware. Conversely, you may be hardware-oriented but also have some programming competence, if only a limited working knowledge of assembly language, BASIC, C or Turbo Pascal for use when needed. Or you might be a computer operator who'd like to learn about hardware so that you can lessen your dependence on retail, servicing and consulting operations. This opens up money-saving avenues, inviting you to take advantage of the lower prices offered by mail-order outlets and, by "doing it yourself," eliminating the high cost of labor.

All of the foregoing people will likely find *ComputerCraft* to be right on target for their needs. We're clearly a hardware-oriented magazine, with a smattering of other personal computer aspects. Although we review selected computer hardware and software products, you won't find a comparison of all products extant—say, all types of printers or all types of word-processing software packages—being reviewed and compared to each other in one issue. Nor do we cover corporate computer business management, LANs for giant businesses, heavy programming techniques or the highest end of products that only large companies can afford. Enough dedicated publications already exist to cover these areas in far more detail than we could.

ComputerCraft concentrates instead on the "personal" in personal computer and microcontroller applications that can be extended to readers to use in small businesses and self-sufficient departments in large companies. Readers who are "techies" and those who'd like to learn a bit in this area, along with how-it-works information and how-to-do-it guidance, will happily adopt *ComputerCraft* as their kind of computer publication. It is, in fact, the only one of its kind being published.

Looking at our first two issues (this issue is Number 2), an average of seven articles in each were devoted to computer upgrading and applications and five articles and columns to computer/software product reviews, buying guidance and activities. Finally, 1½ articles focused on electronic experimenting.

In these two issues were an average of twelve schematics plus a printed-circuit-board foil pattern and component layout, as well as four computer programs. This is close to the number of schematics that typically appeared in our predecessor magazine, *Modern Electronics*. Of the mix of features, an average of three required soldering in order to fully complete them, though many readers just read such articles with relish to learn how particular circuits work. It's there to build for the taking if something strikes one's fancy, though.

All of the foregoing is supplemented by new product information, computer and electronics book reviews, free literature offerings and PC news, of course.

As I write this, we're still about two weeks away from the on-sale date of the premiere issue of *ComputerCraft*. So I naturally have no feedback from subscribers and newsstand readers to digest and pass on to you. This will have to wait until next month at this time. Meanwhile, look over these two issues and let me hear from you. I'd like to know your likes, dislikes, suggestions, etc. Thanks.

Art Salsberg

Letters

Author Feedback

•In reading over my "What's On WWV" article that appeared in the February issue, I noted a few errors. In Fig. 1, the voltage at pin 4 of *IC1* should be shown as + 5 volts, not the − 5 volts shown. In Fig. 3, *IC3* should be noted as a 74LS390 (not 74LS380), and *IC4* and *IC5* should be noted as 74LS160As (not 74LS150s).

Thomas E. Hitt III

•Having read my "Triple-Head Photo Flash" article in the March issue, I thought I'd pass on to your readers the following:

In both Fig. 2 and Fig. 4, *D1* should be shown as a 1,000-volt part and *C1* as a 500-volt part. An omission in Fig. 4 will not complete the trigger circuit. The K terminal of *SCR1* should have a return to ground by adding a tie to ground at the junction of *D2*, *R5* and K terminal of *SCR1*. In the 300-Ws Parts List, T_T is described in a manner that might be misleading. The description should read 4,000-to-10,000-volt transformer.

Maurice P. Johnson

Coming In June

- Turn a PC/XT Into an AT or Better
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Heard in D.C. The FCC is soon to reallocate a large segment of available radio spectrum for some super new services, such as CD-quality radio broadcasts from satellites, international direct-dial cellular-type phone service from powerful low-level satellites and interactive video data services.

FCC policy will be, says Chairman Alfred Sikes, to encourage pioneering service ideas. Along these lines, Apple Computer petitioned the FCC for use of radio waves for data transmission by all computer makers. The petition requested that wireless computer communications be allowed exclusively on 40 MHz of bandwidth between 1,850 and 1,990 MHz to transmit data at high speeds up to about 150 feet.

What's Hot? Wondering what PCs are now installed and what's expected to sell next year? A recent survey of 100,000 business users may point the way.

Only 7% of personal computers now in use are based on Motorola 68000 processor chips—mostly Macintosh systems. And even Fortune-1000 companies expect the powerful i486 (80486)-based systems to make up only 0.1% of their purchases for the foreseeable future, although prices continue to drop.

Seems that third- and fourth-tier CPUs still make up a strong force in the workplace. Nearly 41% of business PCs now in use are 286-based, while fully 2.5-million 8088/86 systems are still utilized at surveyed sites. If anyone was worried that 32-bit applications would force out low-end software, this should alleviate concern. All this might also indicate that IBM wasn't so crazy after all when it demanded that OS/2 be 286-compatible.

Business sales for 1991 should tilt toward 386s. If this is the case, market pressure and large inventories of 80286 chips and 16-bit RAM should drive 286 computer prices down further, as well as lower prices for 386s due to increased production and sales competition .... Personally, I see big interest in 386SX (32-bit internal/16-bit external) systems because for many user applications they provide every bit as much usable power as more-powerful full 32-bit-capability 386DX and i486 systems . . . and they're less expensive, leaving bucks for more extended and cache memory. But if you're into extensive number-crunching, desktop-publishing or graphics programs, going whole-hog with the more powerful CPU makes sense.

Short pause . . . Well, I wrote the above section last week and now everything has changed. But I left that in to remind you just how fast things move in this business. Rumors out of Intel drastically change the outlook, as follows.

Hello, Mr. Chips! Hold onto your hats, folks. New chips are on the way from Intel! Consequently, future hardware choices aren't so clear anymore because my sources indicate that two new i486 chips will challenge the 386DX by bettering its performance at the same price, and the long-rumored "586" is rapidly reaching the last stages of preliminary design.

This will be a very different i486 from the versions we are familiar with because Intel is saving money by slowing down the chip to 20 MHz and amputating its built-in math coprocessor section. The chip itself will cost about a third as much as the full 25-MHz i486, or a bit more than a 33-MHz 386DX . . . likely offering the same performance as the faster-clock-speed 386DX. *IBM should be out this summer with the first computer that makes use of this new version of the i486!* Can clone makers be far behind?

When adding the new low-priced 20-MHz i486 chip to the fact that a 20-MHz computer is less expensive to build than a 33-MHz 386DX (if nothing else, memory is cheaper), by next winter we'll probably see a 20-MHz i486 system selling for about the same price as similarly equipped 33-MHz 386DX-based systems. A second-rumored i486 version will have the same 20-MHz clock speed but retain the coprocessor. However, it will reportedly cost nearly as much as the 25-MHz i486.

What will this do to the market as a whole?

The 80286 for new PCs might seem to be pretty well dead because the 386SX is faster, runs more software and doesn't cost that much more. Nevertheless, it still may sell briskly because many people don't yet know or don't care about the advanced capabilities of the 386SX. Furthermore, the vaunted slim price differential is big enough to equal the cost of a nice dot-matrix printer if one compares a slower 12-MHz 286 rather than a 20-MHz 286 to a 20-MHz 386SX. So even though the 386SX, whether 16 or 20 MHz, should now be the entry-level computer of choice, don't count the 286 out just yet.

Interestingly, Advanced Micro Devices of Sunnyvale, CA has a clone of the Intel 386DX ready to market; so look for Intel to aggressively price the new low-end i486 to drive out the 25- and 33-MHz 386DX chips from potential competitors.

Another big chip already being talked about in some detail is the "586," expected to run at a whopping 66 MHz and outperform the current best i486 by three to four times. The 586 will also boost memory demands by jumping to a full 64-bit internal and external bus, bringing it into the mainframe-computer performance category. Code-named "P5," it will include some diagnostic software, a 386-compatible coprocessor and two 8K internal caches (one for instructions and the other for data).

Add all this to the fact that the present design seems to call for two separate processor units, and you have in the 80586 a massively powerful processor that will probably be capable of some amazing performance. Look for the 586 to be shown about mid-1992, but don't expect these computers to be cheap. I suspect that you'll pay more for a 586-based system than for a new Volvo.

Although most home users and hobbyists won't need this much power, the same thing was said for the 80286 when IBM first introduced its AT computer. I already find myself starting to relax into the confidence of having a couple of 486s handy for some projects I'd never have tackled before (such as solving complex math problems involving simultaneous differential equations, doing my own layout of my next book, etc.).

Japanese Developments. The U.S. Department of Commerce just released a preliminary ruling that finds several Japanese makers of laptop computer displays have been selling (also called "dumping") their products in the U.S. market at below actual manufacturing cost. Such a finding could lead to imposition of big duties, but so far, Commerce has called for only a 5.4% tax on imports from the largest builder, Sharp Corp., and even smaller duties on a couple of other Japanese products. So increased selling prices aren't anticipated.

Reports from Tokyo indicate that 4-megabit DRAM prices have fallen by more than 22% in the past few months, a 400% drop from the initial introduction price in 1989. The 4-megabit chips now sell for about $30 in Japan.

Pi In The Sky? Donald Trump may have hit on a novel way to augment his New York-Boston-Washington air-shuttle income and, at the same time, ease worries of business travelers due to airport security delays. For $50 and up per day, travelers can now reportedly rent a laptop computer for their short hops between cities.

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: 321-7180. No phone calls, please.

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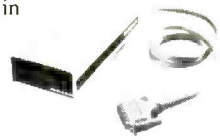
Connecting a high density 3.5 or 5.25 inch drive to your computer can allow you to back up your hard disk in half the time. Backpack allows you to connect high density drives to any computer, even older PC and XT compatibles, regardless which version of DOS you use.



Backpack comes in four configurations:

- 5.25" 360K drive, **Cat. #BACP360, $299**
- 5.25" 1.2M drive, **Cat. #BACP12, $299**
- 3.5" 1.4M/720K drive, **Cat. #BACP14, $299**
- 3.5" 2.8M drive (also read/writes 1.4M and 720K), **Cat. #BACP28, $399**

Let Your Voice do the Work of Tedious & Repetitive Keystrokes!

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How To Talk To Your Computer

If you have trouble memorizing all those complicated "Control-Alt-Shift-Function" commands then **Voice Master Key** is just for you. Now you can simply speak the command—"bold," "zoom," etc.— into Voice Master's headset and see it done instantly.

New Advanced Capabilities

The new Voice Master software recognizes up to 1,024 words, each of which can activate a different macro. Macros can include pre-recorded digitized speech or sound files which play back when activated.

A Sound Development System

Ideal for experimenters and software developers, you can make sound files for spoken advisories, music/sound effects, etc. Sound files can be played through the headset or Speech Thing external speaker. All of the functions can be controlled from C, BASIC, ASM.

Voice Master Key System II interfaces with your PC through the parallel printer port (you can plug your printer into the Voice Master System II box). System II also includes an external speaker and text-to-speech software.

- Voice Recognition—invokes macros w/ voice input.
- New software recognizes over 1,000 words!
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- Includes controller card, software, and headset. Voice Master Key System II includes headset & external Voice Master. Order Today!

Voice Master Key Cat. # VOIM, $149.
Voice Master System II, Cat. #VOIM2, $199.

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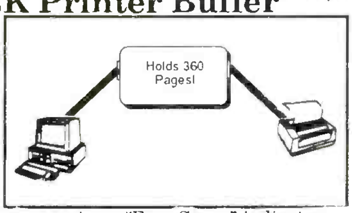
Waiting for a file to print can be frustrating unless you have a printer buffer. This buffer quickly absorbs your file so you can get back to work fast. The buffer quietly feeds the file to your printer *without slowing down your computer!* Don't wait, order today.



• Holds about 360 double-spaced pages • Includes power supply so it will hold data even if your computer or printer is turned off • Repeat function to print extra copies • "Free Space" indicator

512K Parallel Buffer, **$129, Cat. #PB512PP.**

Learn to Modify ANY Software!

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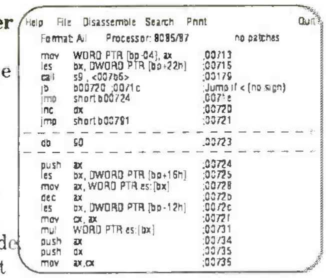
Powerful Disassembler

Snooper takes executable program code and turns it into assembly language source code. That's not so unique, but Snooper is intelligent. It automatically comments the source code and labels jump targets. Snooper even includes a patcher to make small changes to a program without time-consuming reassembly. For more extensive changes, Snooper is compatible with Microsoft and Borland assemblers.



Snooper gives you commented source code for almost any DOS file—including COM, EXE, SYS. Its pull-down menus and on-line help make disassembly fast and easy. So what's this good for? Well it's the best way around to learn assembly language and to make changes to software when you don't have the source code. **Cat. #SNPR $49.** Order today.

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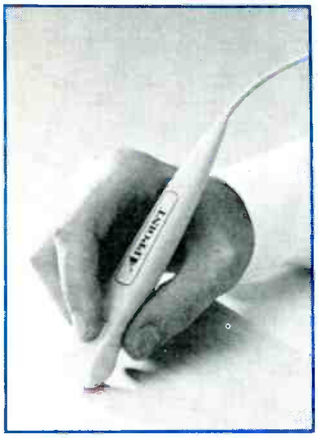
CIRCLE NO. 154 ON FREE INFORMATION CARD

MousePen Professional

Appoint's second-generation MousePen Professional features a small, round case design that closely resembles an ordinary ball-point pen. No pad, tablet or special screen is



required. Appoint uses friction, rather than gravity, to operate the mouse-like mechanism, resulting in a product that functions at any surface angle and on most surfaces. Even a pants leg, chair arm or pad of paper works. The device has point and alternate buttons as well as a mode switch for selecting linear or dynamic operation. MousePen Professional is available for IBM and compatible and Macintosh personal computers and lists for $110.

CIRCLE NO. 14 ON CARD

Remote PC Control

TeleSwitch 400 from EKD (Selden, NY) permits on/off control of electronic devices from a remote location via a telephone or modem. It works with most popular communications programs. It has fail-safe solid-state surge-clamping electronic circuitry for clean ac line power rated at 10 amperes. For long processing jobs, TeleSwitch 400 permits disconnection to save on phone charges while leaving the computer on. Simply call back later to resume or power down. There's a user-set hardware security code with 10,000 possible combinations.

CIRCLE NO. 15 ON CARD

Commercial BBS

The Star-Link BBS features over 2.1 gigabytes (2,100M) of on-line storage. More than 75,000 public-domain and shareware programs for IBM/compatible computers are available for downloading. All files are compressed and categorized into 48 directories and are checked for viruses. Other features include the electronic edition of USA Today Newspaper, CB simulator, private E-mail, 60 on-line multi-player action and adventure games, the latest transfer protocols and MNP error checking on all lines. Subscription prices start at $30 for 6 months with a 45-minute daily limit.

CIRCLE NO. 16 ON CARD

Digital Video In The PC Environment

By Arch C. Luther
(Intertext Publications/ McGraw-Hill Book Co. Soft cover. 346 pages. $29.95)

Focusing on digital video interactive technology (DVI), this text offers a convincing demonstration of the enormous potential of fully interactive video. Luther is one of the creators of DVI, and easily switches from an overview of where we are to specifics, such as the Intel i750, an inexpensive DVI chip set. He also provides source code in C for several control programs for the i750. In addition, he reports on the latest advances in writable and erasable optical storage media.

CIRCLE NO. 17 ON CARD

Personal Laser Printer

Epson recently entered the low-end "personal" laser printer market with the EPL-7000. The printer ships with 14 resident fonts and a slot for

adding an additional font cartridge. Two additional slots facilitate HPGL plotter emulation and other printer languages. An introductory promotion provides a UDP 65-in-one font cartridge with each EPL-7000 purchase. The cartridge's retail value is $250. Standard memory is 512K and is upgradeable to a maximum of 6M. Print speed is rated at 6 pages per minute, and duty cycle is 3,000 sheets per month. MTBF is estimated at 3,000 hours. Resolution is 300 dpi in text mode, 300 dpi for one-half graphics page or 150 dpi for a full graphics page with standard memory configuration. Dimensions are 19.5"W × 15"D × 7.3"H and weight is 40 lbs. Retail price is $1,400.

CIRCLE NO. 18 ON CARD

RMS Multimeter With RS-232 Interface

Extech Instruments is marketing its True RMS Multimeter that measures voltage, current, resistance and frequency. Diode and continuity checking are also possible with the 3¾-digit autoranging meter. The True RMS Multimeter captures peak-high and -low readings with MAX/MIN, data hold and relative functions.

Ranges (accuracy) include dc voltage to 1,000 volts (±0.5%); ac voltage to 750 volts (±0.75%); ac/dc current to 200 mA and 10 amperes; and frequency from 4 Hz to 40 kHz (±0.5%). An RS-232 interface permits easy connection to any computer or serial printer. Data-acquisition software and RS-232 cables are available from Extech.

CIRCLE NO. 19 ON CARD

New NRI Computer Training

NRI Schools (Washington, D.C.) introduced a host of new at-home training courses related to PC System Analysis, Computer Programming and PC Software Engineering Using C. Each course includes an AT-type computer system (80286 CPU with 12-MHz clock and 0 wait state, 1M of RAM expandable to 4M, a 1.2M high-density 5¼" floppy drive with space for three added internal drive, eight expansion slots and Hercules-compatible monochrome graphics adapter with parallel printer port. (Students will have the option of omitting this ready-to-run machine if they do not need it.) It is part of the new courses' "Action Learning Kits." The PC System Analysis course, for example, also includes an NRI Computer Demonstrator, Analysis and Design Tools, Programming in BASIC, Learning Microsoft *Works* and a 2,400-baud Hayes-compatible internal modem. Next year, an AutoCAD Computer-Assisted Drafting (CAD) correspondence course will be added.

CIRCLE NO. 20 ON CARD

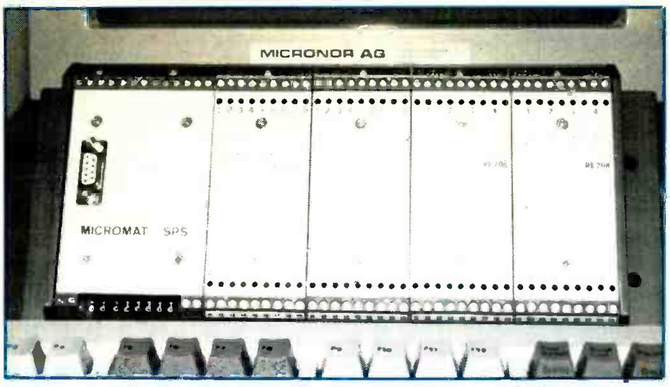
Floppy Offers 4M Storage Capacity

Fuji Film is marketing a 3.5″ "extra-density" floppy with a 4M storage capacity. These disks will be compatible with the 2.88M drives expected to be introduced shortly, which will allow a user to store twice as much data on a single floppy as can be done with DSHD disks currently available. This increased storage capacity is reportedly due to a barium-ferrite-coating formula that ensures accurate signal integrity and extends disk life. A pack of 10 disks carries a suggested retail price of $138.

CIRCLE NO. 21 ON CARD

Clear-Language Programmable Controllers

MAXMAR's (Pleasantville, NY) new Micromat-SPS programmable controller can be programmed in clear language with any IBM or compatible computer. It accepts input signals from process or factory sensors, such as temperature, level, pressure and so forth, and provides output control signals to adjust valve openings, motor speeds and other parameters. The number of inputs or outputs is determined by the number of modules plugged into the system. Each module provides 16 inputs and/or outputs. Modules are available for analog and digital inputs, and outputs can be for relay or transistor technology. Disk-based software automatically converts clear English instructions into RODOS language before it is transmitted over an RS-232C link connected to the controller.



CIRCLE NO. 22 ON CARD

The Personal Computer Book

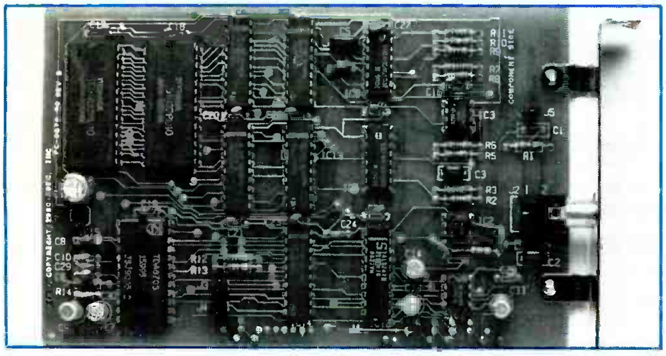
By Peter McWilliams
(Prelude Press. Soft cover. 672 pages. $19.95)

Few beginner books about the personal computer market have been written since 1985. Yet, many "non-techies" find themselves needing a quick education on the ins and outs of computers. For this, you might point them toward McWilliams' book. It is richly illustrated with drawings, prints, movie frames and photos (often blatantly retouched), all with humorous captions. McWilliams sprinkles his opinions in with the facts (he intensely dislikes Apple and IBM), which tends to bring a very human touch to an inherently cold subject. The final 140-page section of the book is devoted to the McWilliams II Word Processor—a No. 2 pencil.

CIRCLE NO. 23 ON CARD

Video Digitizer

IDEC's (Quakertown, PA) Supervision/8 image capture system connects to any IBM or compatible (ISA) computer. A B&W image in 256 gray levels can be acquired under simple software control. The system requires an external video source (camera, VCR, etc.). The half-size card plugs into any slot. Image-capture time is 1/60 second. Software is menu-driven and offers compatibility with HGC, CGA, EGA and VGA. Images can be saved in TIFF and PCX formats. Price is $270 wired, $170 kit.



CIRCLE NO. 24 ON CARD

PC Sound Boards

Forte announced two sound boards for IBM/compatible PCs. The AUDIO F/X provides a complete hi-fi digital audio system for the PC. It can record and play back sound bites or sound effects or create music. The stereo audio synthesizer can play up to six voices simultaneously without taxing the PC because of an on-board Z80 microprocessor. You install the AUDIO F/X in any full-size slot, attach stereo speakers to phono jacks on the rear of the card and turn on your PC. Software is included to record, edit and play back digital sounds or synthesized music.

AUDIO PRO is a professional quality two-channel version of the AUDIO F/X. The on-board synthesizer has been replaced with MIDI capability. With the optional MIDI kit, the AUDIO PRO can directly drive any MIDI-compatible keyboard instrument using the *Music Editor*. AUDIO PRO provides stereo digital recording and playback with FM-broadcast quality.

Sound Editor and *Music Editor* are included with the systems. Software drivers are provided with both FORTE's systems to interface digital recording and playback with several popular presentation packages. These drivers allow you to synchronize sound with on-screen images, play background music and record or play back voice files during a presentation. Options include programmer's toolkits, recording box (microphone input jacks) and the PRO MIDI kit.

CIRCLE NO. 25 ON CARD

Doing *Windows*

MicroSoft continues to add support for *Windows*, the graphic user interface running under DOS. Microsoft University, the company's training branch, now offers a course designed to teach professional support engineers how to support end users with *Windows* programs. The new course provides an in-depth look at the features and characteristics of the *Windows* environment and will give students hands-on experience in installing, configuring and troubleshooting their systems. Course tuition is $1,000 per student.

Microsoft also offers a video-based training package for *Windows* applications developers. This self-paced learning tool is an update of the previous *Windows* 2.X video course and has been modified to reflect the version 3.0 visual element and lab exercises.

The new *Windows* programming course consists of five videotapes, a course workbook, a lab exercise book and four software diskettes containing lab exercises and sample programs. Estimated time of completion is 25 to 35 hours. The full training course for a single student is priced at $2,995.

Microsoft is now bundling *Excel, Word* and *PowerPoint* into a single package, *Office for Windows*. The three products address the core productivity needs of general business users. If purchased separately at list price, the three *Windows* applications would cost nearly $1,500. Microsoft has set the suggested list price of *Office for Windows* at $995, a savings of approximately $500. Training courses are available for Microsoft applications programs.

The company also offers a productivity pack that consists of three applications: *Learning Windows, Working Smarter* and *Quick Troubleshooter*. *Learning Windows* is a computer-based tutorial for new *Windows* users. *Working Smarter* helps users become more proficient. It provides more than 45 tips, hints and strategies on how to do things faster and easier. *Quick Troubleshooter* provides answers to some of the most commonly asked *Windows* questions. Users learn what to do when things do not go as expected. Productivity Pack is priced at $59.95.

CIRCLE NO. 30 ON CARD

Scientific Software Catalog

The 32-page 1991 Catalog from MicroMath Scientific Software lists and describes a number of scientific software packages and presents a number of example problems that are solved in a step-by-step sequence. Among the programs detailed are: *GRAPH*, which plots scientific and engineering data; *MINSQ* for nonlinear curve-fitting and model development; *EQUIL* for interactively solving aqueous chemical equilibrium problems; *LAPLACE* for performing numerical inversion of Laplace transforms using one or both of two well-established Laplace algorithms; and *RSTRIP* for polyexponential curve stripping and parameter estimation. Model libraries are also listed, as are several related products that have been widely accepted by the scientific and engineering communities.

CIRCLE NO. 31 ON CARD

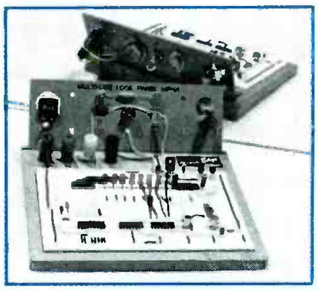
Parallel-To-Serial Converter

Telebyte Technology's Model 109 parallel-to-serial converter with buffer simplifies the communications link between PCs and printers. Since the converter is bidirectional, it is used to connect the computer parallel port to a serial device or *vice-versa*. The Model 109 contains a 64K data memory that acts as a buffer, allowing the sending device to immediately go back to work. Model 109 accommodates serial rates from 300 to 38,400 bps. Various operational parameters are set with DIP switches mounted on the side of the unit. The aluminum enclosure measures 6″D × 3″W × 1.2″H. A wall-mounted transformer supplies operating power, and the unit is equipped with standard parallel and serial connectors. Price is $99.

CIRCLE NO. 32 ON CARD

Solderless Breadboards

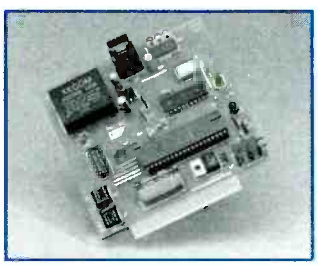
Chenesko Products is marketing a new-style solderless breadboard for use by circuit-design engineers, students and hobbyists. Each of the four sizes offered features an extra multi-use edge panel for organizing and mounting components that do not fit into normal DIP-spacing socket connections. The breadboard contacts are made of nickel-plated bronze for low-resistance contacts (less than 3 milliohm at 1 kHz) and are rated for a minimum of 10,000 insertions/removals. The four available models range in price from $17 to $60 and in size from 4.3″ × 7.4″ to 9.7″ × 7.4″.



CIRCLE NO. 34 ON CARD

Telephone Control Add-In Card

The TE 158 telephone control card from Alpha Products provides complete computer control of a telephone call. It offers a direct telephone line interface with line connect/disconnect, call progress detection and DTMF decoding/encoding. The user can dial out and send messages with tones or let the card answer the phone automatically. Models are available for most popular personal computers.



CIRCLE NO. 33 ON CARD

Tandy Learning Centers

Radio Shack has opened Tandy Learning Centers that offer supervised self-paced computer-based one-day instruction on a variety of software programs. There is also a generalized course called "Introduction To Personal Computers." Tandy Learning Centers are located in Radio Shack Computer Centers in 123 cities across the continental US, Hawaii and Puerto Rico. Each student works at his own pace in a hands-on environment. Trained instructors are present to assist and answer any questions. Weekday and Saturday classes are priced from $99 to $139 per student and cover such software as *WordPerfect*, Lotus *1-2-3* and *dBASE IV*.

CIRCLE NO. 35 ON CARD

(Continued on page 86)

Low Cost CAD Software

for the IBM PC and Compatibles

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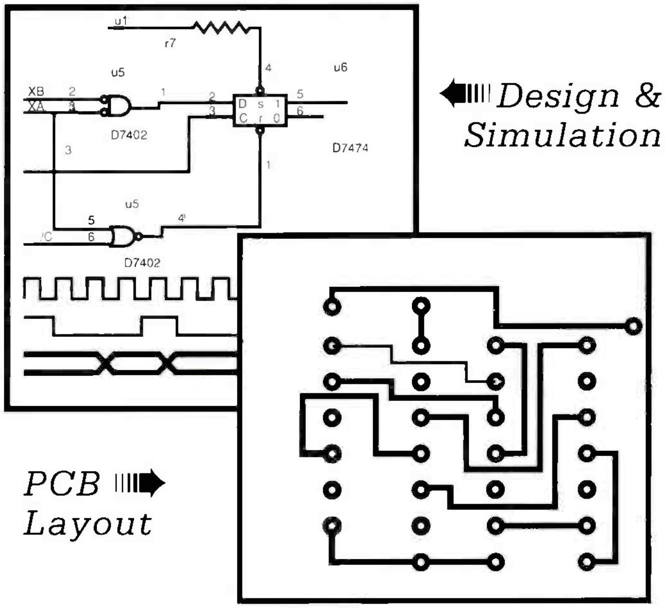

Design & Simulation

PCB Layout

- ★ Easy to use schematic entry program (**SuperCAD**) for circuit diagrams, only $99. Includes netlisting, bill of materials, extensive parts libraries, dot matrix printer output. More parts, HPGL plotter and laser printer output available separately or in enhanced CAD package (**SuperCAD+**) for only $199.
- ★ Powerful, event-driven digital simulator (**SuperSIM**) allows you to check logic circuitry quickly before actually wiring it up. Works directly within the **SuperCAD** editor from a pulldown menu and displays results in "logic analyzer" display window. Starting at $99, this is the lowest cost simulator on the market. Support for PALs, a larger library, and a separate interactive logic viewer are available in full-featured **SuperSIM+** for only $395. Library part models include TTL, CMOS and ECL devices.
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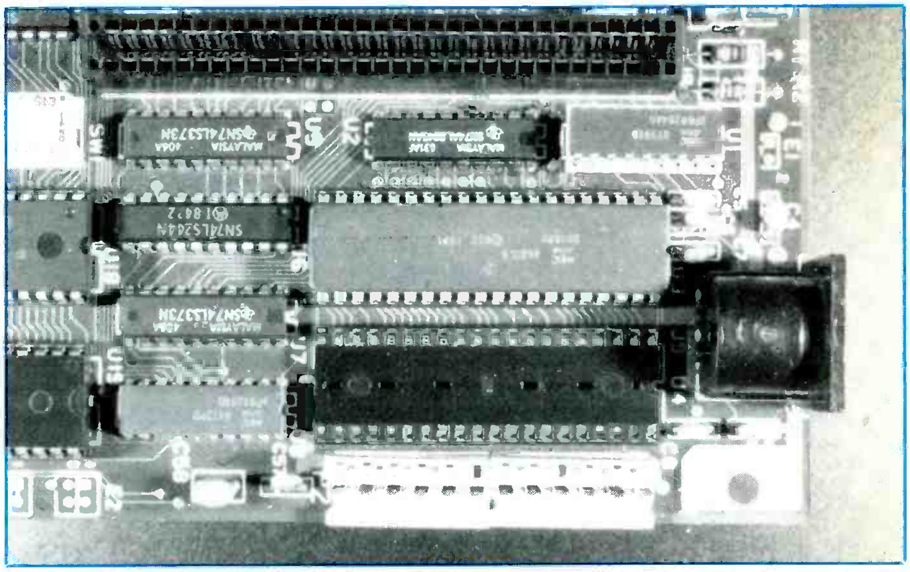
Adding the Right Math Coprocessor

If you are heavily involved in math-intensive or graphics applications, filling the empty math coprocessor socket in your PC with the proper processor can greatly speed up your work



If you're like many PC users, you've had your computer for a while and decided that, at least for some applications, it just isn't fast enough. Granted, there will always be a desire to move up to the next faster machine—the latest technical marvel—but this might be impractical or unnecessary. The alternative is to look for ways to get more out of the machine you already own, without shelling out more than a moderate amount of money. One of the ways to do this is to take advantage of an unpopulated IC socket that is present in virtually all PC compatibles: the math coprocessor socket.

Many users don't realize that by simply adding a math coprocessor to their system, floating-point calculations can be performed many times faster, and math-intensive applications will show substantial performance improvement. For example, I created a large spreadsheet (*Quattro Pro* 1.0) using scientific-like math and timed its calculation speed on a computer with a 20-MHz 80386SX CPU. Without a math coprocessor, it took 16.5 seconds. Installing a math coprocessor dramatically reduced recalculation time to only 5.8 seconds!

Typical applications that can benefit from the addition of a math coprocessor include spreadsheets when high-level math is used, computer-aided-design (CAD), desktop-publishing and other scientific, engineering and graphics applications. To benefit from the addition of a math coprocessor, however, the application software must be designed to use the math chip when present.

Although Intel was once the only maker of math coprocessors for PCs, users of 286 and 386 systems now have several coprocessor alternatives from which to choose.

How They Work

There are actually two different types of math chips in existence: *slave processors* and *coprocessors*. A slave processor appears as a peripheral device in the CPU's memory or I/O addressing space, just like a UART (serial port controller) or video controller. A coprocessor, on the other hand, interacts with the CPU, appearing to system software as an extension of the CPU itself.

A coprocessor, then, makes the CPU appear to have more registers (floating-point registers) and an expanded instruction set (with the floating-point and transcendental instructions) than it normally does; it doesn't require memory or I/O read/write operations to access the math functions. Intel math chips are coprocessors, but it's interesting to note that the term "coprocessor" has become so widespread in the PC world that some math-chip alternatives, in particular those from Weitek, are incorrectly referred to as coprocessors when they are in fact slave processors.

When a math chip isn't present and your spreadsheet needs to perform some floating-point calculations, the calculations are imple-

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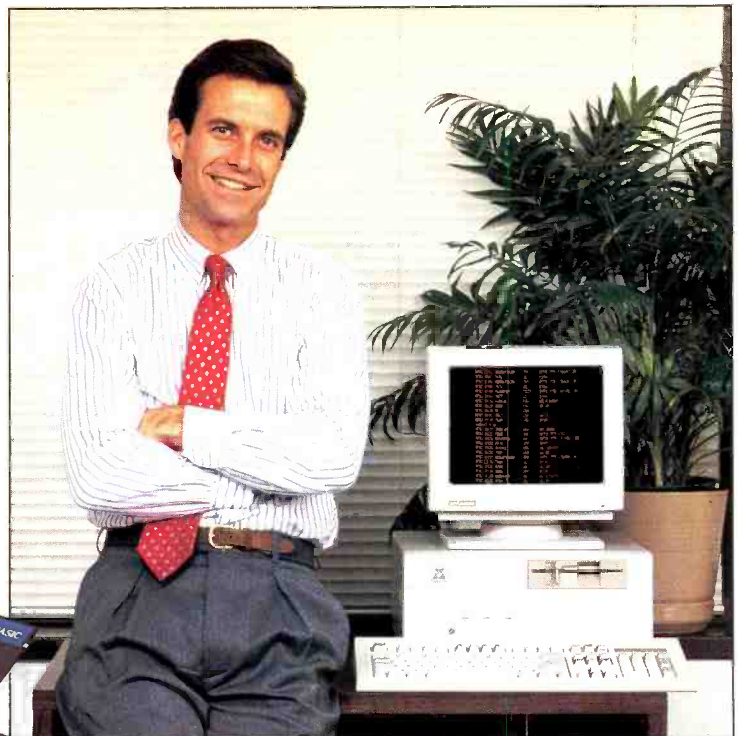

A top-paying career in computer programming is no longer out of your reach. Now you can get the practical training and experience you need to succeed in this top-growth field.

It's training that gives you real-world programming skills in <u>four</u> of today's hottest computer languages: BASIC, Pascal, C, and COBOL. Hands-on training that includes a powerful IBM AT-compatible computer, modem, and programming software you train with and keep. Comprehensive, at-home training that gives you the competitive edge to succeed in one of today's leading industries. The kind of experience-based training only NRI can provide.

As a trained computer programmer of the '90's, you can enjoy long-term career success. In fact, the Bureau of Labor Statistics forecasts that during the next 10 years job opportunities will increase by 71.7 percent for the skilled computer programmer. With NRI training you can be one of the increasing number of computer programmers using their skills to build a top-paying career—even a business of their own—in this professionally and financially rewarding high-tech field.

▼ The only programming course that includes a powerful AT-compatible computer system and programming software you keep

Right from the start, NRI training gets you actively involved in the challenge of real-world computer programming. You learn how to create the kinds of full-featured, powerful programs today's employers and clients demand. And, unlike any other school, NRI lets you experience first-hand the power of an IBM PC/AT-compatible computer system with modem, a full megabyte of RAM, disk drive, and monitor—all yours to train with and keep.

Plus you explore the extraordinary capabilities of not one or two but <u>four</u> in-demand computer languages. You learn to design, code, run, debug, and document programs in BASIC, Pascal, C, and COBOL. In the process you become uniquely prepared for the wide variety of programming opportunities available today.

▼ No previous experience necessary

Immediately, you start getting the money-making job skills you need to secure a future in computer programming—no matter what your background. With NRI training you move easily from computer novice to computer professional with step-by-step lessons covering program design techniques used every day by successful micro and mainframe programmers.

You'll find no heavy textbooks to plow through. No night classes to attend. Instead, NRI's at-home, step-by-step training covers all the bases, guiding you from the important fundamentals to real-world methods and techniques. With the help of your NRI instructor—offering one-on-one, personal guidance throughout your course—you quickly gain the skills you need to handle with confidence a wide variety of programming applications. You even use your modem to "talk" to your instructor, meet other NRI students, and download programs through NRI's exclusive programmers network, PRONET.

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mented in software, using refined algorithms. In contrast, a math chip uses specially-optimized electronic circuitry to execute floating-point calculations very fast in hardware. In terms of performance, the hardware approach improves on the software method by several hundred percent, making it clear why math chips are so valuable.

While the math coprocessor appears as an extension to the CPU from a software standpoint, the fact that it's a separate chip means that it and the CPU must conform to a prescribed means of interaction. The math coprocessor will either operate synchronously with the CPU, using the same clock and operating at the same speed as the CPU, or asynchronously, using its own, independent clock and operating at a speed that may differ from that of the CPU. Both of these varieties exist in PC systems.

Systems based on the 8088, 8086, 386DX and 386SX processors use a synchronous (8087, 80387DX or 80387SX) coprocessor, while those based on the 80286 CPU use an asynchronous (80287) coprocessor. Thus, for example, an 8088 XT running at 10 MHz will have an 8087 coprocessor operating at 10 MHz also. A 10-MHz 286 system, on the other hand, may run the 20-MHz base system clock to the 287 coprocessor, which then divides the frequency by three, resulting in a 287 operating frequency of only 6.67 MHz. Consequently, an outdated XT may out perform the AT in some math-intensive applications, contrary to assumptions!

The 287 coprocessor actually has two clock modes. One requires a clock with a ⅓ duty cycle (that is, for each cycle the clock is high ⅓ of the time and low ⅔ of the time) at the exact coprocessor operating frequency. The other mode accepts a clock with a ½ duty cycle at a higher-frequency, which the coprocessor then divides by 3 internally (to create a ⅓-duty clock), resulting in the actual coprocessor operating frequency. The first mode is preferred for best performance, but the second mode is often used due to the absence of an appropriate clock in the system.

Until recently, 286 systems have been further hindered from a coprocessor standpoint by the fact that Intel offered only 10-MHz and slower 80287s. Faster 286 systems, from 12.5 to 25 MHz, were therefore constrained to the performance of a 10-MHz math coprocessor. The past couple of years, however, have provided some relief in this area, as we shall see shortly.

"The hardware approach improves on the software method by several hundred percent. . . ."

Coprocessor Choices

Intel has been understandably reluctant to give out second-source manufacturing rights for its xxx86 family of math coprocessors. Sole-sourcing has allowed Intel to maintain a corner on the market, with substantial profit margins. During the past two years, however, other companies have encroached on Intel's math-coprocessor monopoly with chips that generally out-perform Intel's own that can be purchased for similar or lower prices.

"An XT may outperform an AT in certain math-intensive applications."

For its 8088 and 8086 processors (used in XT machines and early PCs), Intel offers the 8087 coprocessor. This part has remained unchanged over the past decade and is offered in speeds of up to 10 MHz, matching Intel's 8088/86 processor speed offerings.

For its 286 processor, Intel originally offered only its 80287 math coprocessor. Again, the part was available in speed versions up to 10 MHz, matching Intel's 286 CPU speeds. Last year, however, Intel introduced a replacement for its aging 80287, in answer to outside competition. The 80287XL (and its PLCC counterpart for laptops, the 80287XLT) includes the extended instruction set of Intel's 80387 coprocessor. It operates at up to 12.5 MHz (like Intel's new 80C286 CPU) and provides substantially better performance than its predecessor. Of course, other chip manufacturers —in particular, AMD and Harris— make 80286 micro processors with speeds of up to 25 MHz. Unfortunately, systems based on these processors can't offer comparable math performance when coupled with a math coprocessor chip operating at 12.5 MHz or slower.

Intel also had a brief flirtation with its 80C287A math coprocessor. Introduced about three years ago, the CMOS 80C287A required lower power and was faster than the company's standard 80287 but wasn't entirely pin-compatible with the standard part and couldn't be used in the standard 80287 socket. So it wasn't surprising that very few systems were ever made that supported the 80C287A, and the part eventually succumbed to a quiet death.

In the 386 lineup, Intel introduced the 80387DX coprocessor for its 386DX CPU (with a 32-bit data bus) and the 80387SX coprocessor for its 386SX CPU (with a 16-bit data bus). Since the coprocessor runs synchronous to the CPU in 386 systems, Intel offers 80387DXs at speeds of up to 33 MHz and 80387SXs at speeds of up to 20 MHz, matching the company's available CPU speeds.

When Intel developed the 33-MHz 80387DX, the company made some changes to the coprocessor's internal microcode, speeding up the overall performance of the chip—up to 20%, according to the company. Initially, this faster performance applied to only the 33-MHz part. Late last year, though, Intel converted its slower 80387DXs to the faster design and discontinued the earlier version. The Intel math coprocessor box now has a red sticker indicating "NEW-IMPROVED-FASTER," so it's easy

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With tens of millions of PC-compatible systems in use worldwide, each with an empty socket just screaming for a math coprocessor, the scenario was clearly set for some inventive entrepreneurs to develop alternatives to Intel's math coprocessor line. In recent years three companies—two of them start-ups—have succeeded in developing and marketing "Intel-compatible" math coprocessors: Integrated Information Technology (IIT), Cyrix and AMD. A fourth company, Weitek, offers high-performance math chips for the many 386DX and 486 systems designed to handle the Weitek parts. These parts aren't Intel-compatible (and, in fact, are slave processors instead of coprocessors).

For 286 systems, IIT offers its 2C87 math coprocessor and AMD its recently-introduced 80C287 and 80EC287 coprocessors. Cyrix is also expected to introduce a 287-compatible chip sometime this year. The IIT part features faster performance than Intel's original 80287 and includes the complete 80387 coprocessor extended instruction set—very much, in fact, like Intel's 80287XL coprocessor. Unlike the XL, however, the 2C87 part is offered in speeds up to 20 MHz. The 2C87 has an additional instruction that isn't supported in the Intel processors. It performs a 4 × 4 matrix multiply, which is often used in scientific and engineering applications. While I'm not aware of any commercial software packages that take advantage of the added instruction yet, the chip can potentially save a lot of processing time for applications that choose to support this feature.

AMD's 80C287 is basically a CMOS clone of the original Intel 80287. It has lower power consumption than the Intel part but no performance improvement, being unable to compete with the faster 80287XL and 2C87. The part competes primarily on price (only a fraction of Intel and IIT prices) and power consumption. AMD has also promised parts that will operate at speeds up to 16 MHz, although only 10-MHz parts are currently shipping. The 80EC287 is like the 80C287, but it also has a low-power standby mode that can be useful in some laptop applications.

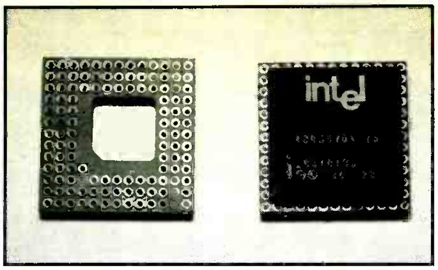


Fig. 1. The 121-pin EMC socket can support an 80387DX coprocessor chip by using the innermost 68 pins and leaving the outside row of pins around the socket unoccupied.

The future seems to belong to the 386 main processor, and competition is fierce for it in the 386 math-coprocessor arena. In addition to Intel's own 80387DX coprocessor, IIT has its 3C87 and Cyrix its FasMath 83D87 to work with the 386DX CPU. Cyrix also offers an 83S87 to work with the 386SX CPU (32 bits internal extended), and IIT is expected to introduce a chip for the less-costly 386SX sometime this year.

Even though Intel has improved the performance of its 80387DX, both IIT and Cyrix offer enhanced performance over the Intel device. Again, IIT includes its 4 × 4 matrix multiply in its 3C87 part. When it was first introduced, the 3C87 had a problem with its ArcTAN transcendental function, generating incorrect results. This was quickly corrected, and most of the initial parts that had the problem have been replaced. Parts with a manufacture number of 2097 or higher are okay.

A large majority of the 386DX systems now being produced, excluding those made by IBM, include a coprocessor socket that has more than the 68 pins used by Intel's 80387DX. This extended math coprocessor (EMC) socket is designed to handle the Abacus WTL3167 math processor from Weitek. A 80387DX coprocessor can also be installed in the 121-pin EMC socket, using only the center 68 pins of the socket (Fig. 1).

Unlike the other math chips for the 386DX, the 3167 isn't functionally compatible with Intel's 80387DX coprocessor. Instead, the Weitek slave processor has its own distinct instruction set and appears near the top of the processor's memory addressing space as a memory-mapped device. The 3167 performs very fast floating-point calculations, and its memory-mapped design further enhances performance. Of course, only programs specifically designed to take advantage of the 3167 will benefit from it.

To capitalize on the extra performance potential of the many available EMC sockets in the market, Cyrix recently introduced its EMC87 math chip. This chip can function as a coprocessor just like an Intel 80387DX, but it can also be accessed as a memory-mapped device (like the

Table 1. Performance Results for 80287 and 80387DX Math Coprocessors

Manufacturer	Device	CPU	QA Plus*	Power Meter**
Intel	80287	80286	282.1	195
	80287XL	80286	495.1	275
AMD	80C287	80286	282.1	195
IIT	802C87	80286	497.7	300
Intel	80387DX original	80386DX	1,143.8	627
	80387DX new	80386DX	1,197.7	660
IIT	803C87	80386DX	1,246.1	710
Cyrix	83D87	80386DX	1,427.2	812

*Version 4.21
**Version 1.2
Units are in K-Whetstones/second; 10-MHz 80286 system; 20-MHz 386DX system

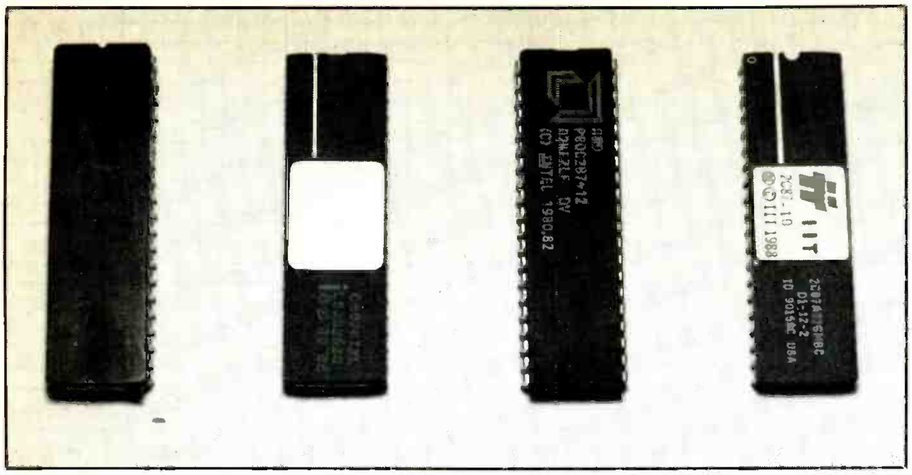


Fig. 2. The 80287-type math coprocessors evaluated in this article include from left to right: Intel 80287, Intel 80287XL, AMD 80C287 and IIT 2C87.

"Intel's 80287XL displays a huge performance boost compared to the 80287."

Weitek part) to achieve a performance boost of about 20%. However, it doesn't support the Weitek instruction set.

The Intel 80486 processor took a new step in processor design by incorporating a streamlined 80387 math coprocessor directly on the chip with the CPU. Consequently, 486 systems don't need to offer an "80487" math coprocessor socket. For 486 users who want a little extra floating-point boost, however, Weitek now offers its Abacus WTL4167 math processor. Like the 3167, it's compatible with, the 4167 is a fast memory-mapped slave processor that many systems support and some programs can take advantage of.

Coprocessor Comparisons

Since there now exists a variety of math coprocessors available from different manufacturers, I decided to compare the performance of the various alternatives, using some informal benchmarks, to see how the chips stacked up against each other. To do this in an unbiased manner, I chose two readily-available third-party benchmarking programs that were able to generate performance values for an installed math coprocessor. I used *QA Plus* (version 4.21) from DiagSoft and *Power Meter* (version 1.2) from The Database Group.

Since PC and XT users are stuck with the 8088, and the Weitek parts aren't IBM 80387 compatible, I didn't test these parts. Instead, I restricted my testing to 80287- and 80387-compatible devices. I also didn't test the 80387SX-type parts. I used a 10-MHz 286 and 20-MHz 386DX clones for the test.

Table 1 summarizes the benchmark numbers. As you can see from the Table, the relative numbers vary substantially between *QA Plus* and *Power Meter* for the 80287-type devices but correlate quite closely for the 80387-type parts.

The tested 80287-type parts are shown photographically in Fig. 2. As expected, AMD's 80C287 functions identically to Intel's original 80287, having the same internal microcode. Intel's 80287XL displays a huge performance boost compared to the 80287: about 75% according to *QA Plus* and 41% according to *Power Meter*. The IIT 2C87 just edged out Intel's 80287XL, with a mere 0.5% performance improvement according to *QA Plus* and about 9% according to *Power Meter*.

The 80387-type parts are shown in Fig. 3. According to the numbers from both *QA Plus* and *Power Meter*, the new Intel 80387DX outperforms the old version of the same part by only about 5%, which is substantially less than the 20% difference indicated by Intel. IIT's 3C87 shows a modest performance improvement over the new Intel 80387DX, of between 4% and 8%. The real performance winner is Cyrix, revealing a performance gain over the new Intel chip of between 19% and 23%!

Despite the numbers, keep in mind that the amount of performance improvement you'll actually see between one math coprocessor and another will depend on you application's specific mix of floating-point instructions and percentage of floating-point instructions executed compared to all instructions executed by the CPU. For example, I've heard reports from users that the measurable performance difference between using an Intel 80387DX and a Cyrix 83D87 in recalculating a Lotus *1-2-3* spreadsheet may be only 5% to 10%, while the difference is much more noticeable when using Borland's *Quattro Pro*. Interestingly, Lotus *1-2-3* Release 2.01 doesn't even bother to transfer basic math operations to a math coprocessor, even if it's pres-

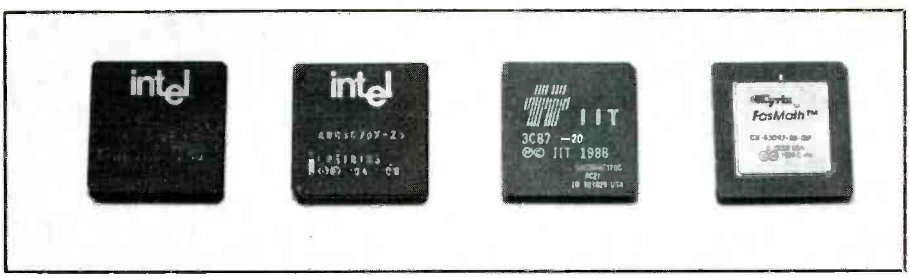


Fig. 3. The 80387DX-type math coprocessors evaluated in this article include from left to right: Intel 80387DX (old), Intel 80387DX (new), IIT 3C87 and Cyrix FasMath 83D87.

ent. A math coprocessor is brought into play only when the spreadsheet uses exponentiation, logarithms and the like.

Of course, looking at the various 80287 and 80387 coprocessor alternatives, one has to wonder about how "Intel-compatible" the non-Intel chips are. Aware of this, both IIT and Cyrix have published compatibility reports that show floating-point calculation results that are consistent with Intel's to all but the very least-significant bits—a resolution detail rarely, if ever, used in any application. Cyrix has even gone a step further to show that calculations from its math chips are actually more accurate than those from Intel.

Of course, no comparison is complete without a look at prices. Table 2 gives the list prices for all currently-available math coprocessors. In the 80287 arena, AMD's 80C287-10, at $99, has a price that can't be beat. IIT is also pricing its processors substantially lower than the Intel baseline. Among 80387 processors, IIT again lags Intel substantially, while Cyrix chooses to match Intel's prices.

Don't be misled by the prices listed in Table 2. Use these as guidelines only. As with everything else in the microcomputer world, "street" prices are substantially less than manufacturer list prices. Shop around for the best price. As an example, I've seen mail-order prices for an 80387XL ($370 list) for $173; an 80387SX-16 ($506 list) for $268; an 80387DX-33 ($799 to $999 list) for $450 to $579; a 2C87-10 ($278 list) for $176; and so on.

Installing Your Own Math Coprocessor

When selecting a math coprocessor to install in your own system, you must determine which manufacturer you want to go with and what speed version you need. If you have a PC or XT system, your choice is limited to Intel's 8087, and you have only to determine the correct speed version.

"Street prices are substantially lower than manufacturer list prices."

For all except 286 systems, you need to get a coprocessor with the same speed as your CPU. For example, if you have a 25-MHz 386DX system, you need a 25-MHz math coprocessor. Similarly, if you own an 8-MHz XT, you must get an 8-MHz 8087. All math coprocessors except the 8087 have a dash and suffix that indicate speed (e.g., 80287-10 is a 10-MHz part). The 8087 is identified differently (I'm sure it's intuitive if you don't think about it):

8087 = 5 MHz
8087-2 = 8 MHz
8087-1 = 10 MHz

For 286 systems operating at or below 10 MHz, get a math coprocessor that matches the speed of your CPU, unless otherwise indicated in your system's manual. If you have a 286 system that operates faster than 10 MHz, your system will probably want a 10-MHz coprocessor. Check your system's manual, though, to see if a faster coprocessor (like IIT's 20-MHz 2C87) can be used. Incidentally Intel's 80287XL is a "one speed fits all" device. It operates at up to 12.5 MHz and can be used anywhere a standard 80287 can be used, except in 80386DX systems that have an 80287 math-coprocessor socket (where you are required to use an original 80287 coprocessor).

If you're going to install an 8087 in an original IBM PC, be wary of your power supply. Early PCs had low-capacity power supplies, and addition-

Table 2. Manufacturer List Prices* for PC Math Coprocessors

Mfr.	Device	CPU	5 MHz	6 MHz (-6)	8 MHz (-8)	10 MHz (-10)	12.5 MHz (-12)	16 MHz (-16)	20 MHz (-20)	25 MHz (-25)	33 MHz (-33)
Intel	8087	8088/6	$142								
	8087-2	8088/6			$205						
	8087-1	8088/6				$270					
Intel	80287	80286	$212	$326	$374						
	80287XL	80286					$370				
	80287XLT	80286					$370				
AMD	80C287	80286				$99					
	80EC287	80286				$109					
IIT	802C87	80286			$239	$278	$298		$338		
Intel	80387SX	80386SX						$506	$550		
Cyrix	83S87	80386SX						$506	$550		
Intel	80387DX	80386DX						$570	$647	$814	$994
IIT	803C87	80386DX						$439	$499	$639	$779
Cyrix	83D87	80386DX						$570	$647	$814	$994
	EMC87	80386DX							$774	$865	$994
Weitek	WTL3167	80386DX							$495	$795	$995
Weitek	WTL4167	80486								$995	$1,295

*As of January 1991

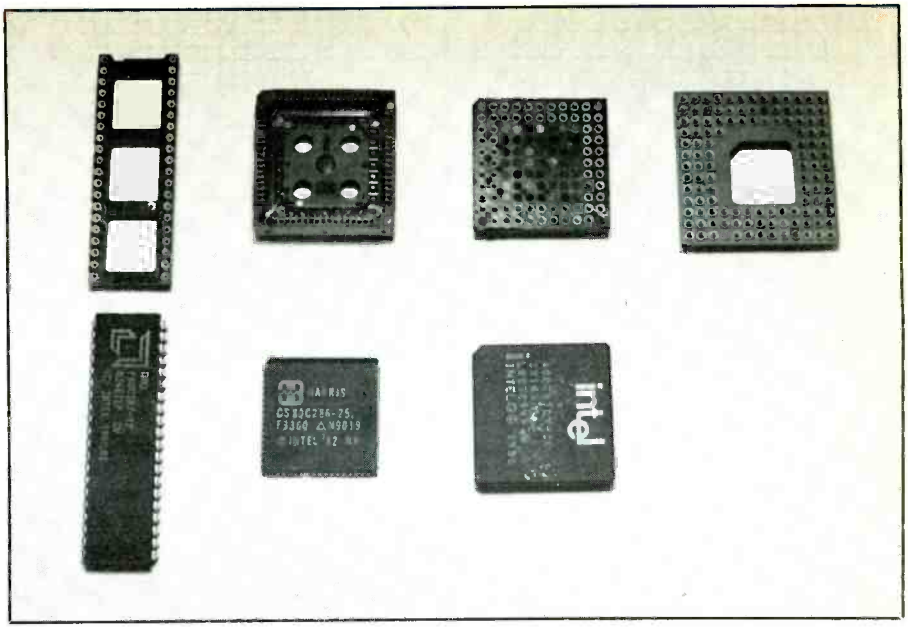


Fig. 4. Shown here are sockets for various PC and AT math coprocessors, all shown with the pin 1 located at the upper-left. The 40-pin DIP socket (far left) accommodates 8087 and 80287 math coprocessors like the AMD 80C287 shown below the socket. The 68-pin PLCC socket (second from left) accommodates 80387SX math coprocessors, which are packaged like the 80286 processor shown below the socket. The 68-pin PGA socket (second from right) accommodates 80387DX math coprocessors like the intel chip shown below it. The 121-pin PGA EMC socket (far right) accommodates EMC-type coprocessors like the Weitek WTL3167 but can also accommodate 80387DX coprocessors.

al loading—like the 8087's nearly 0.5 ampere—may create a problem. Problems typically appear as flaky system operation or the inability to fully power-up. Addition of an 8087 won't cause a problem unless your system is already heavily loaded with expansion cards and/or disk drives.

Figure 4 shows math coprocessor sockets for the various microprocessors. 8087 and 80287 coprocessors use the 40-pin DIP (dual in-line package) socket shown at the far left. The next socket to the right is a 68-pin PLCC (plastic leaded chip carrier) socket for the 80387SX coprocessor. Next to this is the 68-pin PGA (pin grid array) socket for the 80387DX math coprocessor, followed by the 121-pin PGA EMC socket for Weitek math chips and the Cyrix EMC87. As mentioned above, the 80387DX can also be plugged into the EMC socket, with the outside row of pins not used.

The math coprocessor socket is usually readily accessible when you remove the cover of your computer's system unit. In some models, you might have to remove adapter boards to get at it. For IBM Model 70s, you must temporarily remove the second floppy-disk drive (if you have one) to gain access to the socket, but this is easy enough to do.

Before installing your math coprocessor, make sure system power is turned off and that you're adequately grounded. Math coprocessors are expensive static-sensitive chips worth taking a little extra care for. Ideally, you should wear a ground strap while you install the new chip. Lacking this, make sure you touch something that's grounded (like your system's power supply case) before picking up the coprocessor, and avoid touching the chip's pins as much as possible.

A critical part of installation is verifying that the chip is properly positioned in its socket. Make absolutely certain that pin 1 is in the correct location in the socket before pushing it into place!. The sockets and corresponding chips in Fig. 4 are all oriented so that pin 1 is in the upper-left corner. When possible, refer to your computer's manual for the pin-1 location of your system's coprocessor socket.

The 40-pin DIP socket usually has

some kind of notch to indicate the pin-1 location on the socket, with the 40-pin DIP coprocessor also having a notch or dot at the pin-1 side of the chip. When installed, the pin-1 orientation of a DIP coprocessor should also follow the pin-1 orientation of surrounding DIP ICs.

The PLCC has one of its four inside corners beveled to serve as a pin-1 locator. This matches a corresponding bevel on the PLCC coprocessor. The PGA socket, in turn, usually has a beveled inside or outside corner to identify the pin-1 corner, and the PGA coprocessor has either a dot on top or a beveled corner to identify the pin-1 location.

While most systems require no further attention once the coprocessor chip is installed, a few sometimes require addition of a shorting jumper on the logic board. Others require you to run Setup to tell the system that a math coprocessor is present. For a PC or XT, you'll have to set switch 2 on a switch block 1 to the 0 (OFF) position. Check your system's manual for the specific requirements of your system.

How do you know if your newly-installed coprocessor works? Intel, IIT and Cyrix (and possibly AMD) all include a coprocessor test on a 5¼-inch diskette with their respective coprocessors, to confirm proper operation. (All three manufacturers also include illustrated installation instructions with their chips.) Alternatively, you can use a third-party diagnostic program, such as DiagSoft's *QA Plus*, to verify proper coprocessor operation, or simply run your application to see if it recognizes the new addition to the family.

If the coprocessor is installed incorrectly, the POST will let you know by not permitting a beep to sound and by displaying a blank screen. If you don't set a PC or XT switch to recognize the coprocessor, you'll obtain a screen error message. Keep in mind, too, that some early IBM documentation specified the wrong switch position. Again, it should be set to OFF.

Also, according to John Woram in his fine book, *The PC Configuration Handbook* (published by Bantam Books), some early-model ATs had the math-coprocessor socket installed backwards, with the notch facing the rear of the system unit. He notes that the device should nevertheless still be inserted with the device's notch facing forward.

Conclusion

It's easy to obtain increased performance from your aging computer by simply installing a math coprocessor. This assumes that your application software can take advantage of this hardware enhancement. As cited earlier, a math coprocessor can boost performance of math-intensive applications. Be aware, though, that this doesn't include word-processing applications, of course.

Roger C. Alford

The Modern Electronics Computer Experimenter Lab

(Part 4 of a Series)

Understanding and using operational amplifiers

The operational amplifier, or op amp, is perhaps the most widely used analog component in existence. It has often been referred to as a universal linear component. We find the basic configuration in all audio products, TV receivers, VCRs, test equipment . . . you name it and it probably has an op amp in it.

Here we'll explore the inner workings of op amps, examine how to match device specifications to circuit requirements, review basic equations for calculating gain and build and test a few typical circuits using the *Modern Electronics* Computer Experimenter Lab introduced in previous issues. Building, testing and experimenting with even the simplest circuits is the first step toward gaining the confidence needed to try your own experiments and designs.

One of the main reasons we'll be studying these circuits is to use them properly to feed analog data into a computer and to retrieve digital data back to the analog world. This will enable you to build linear and nonlinear amplifiers, servo amplifiers, instrumentation amplifiers, signal conditioning filters, comparators, sensor interfaces, oscillators, voltage-controlled oscillators, zero-crossing detectors, frequency doublers, lamp and motor drivers, current drivers, sample-and-hold circuits, signal integrators and differentiators, as well as mathematical operators . . . multipliers, adders, etc. Most of these circuits are built using operational amplifiers. These discussions will help you to design circuits and select the appropriate devices for them.

The classical op amp consists of three major sections (see Fig. 1). The input section consists of a differential amplifier that produces an output that is proportional to the difference between the input pins. The intermediate amplifier section resolves difference-signal voltages into a single signal that is amplified and level-shifted to drive the output stage. The output stage, in turn, determines the load-current characteristics, as well as how the output can be connected to other circuits. Such features as a strobe, latched outputs and open-collector designs facilitate connection to digital logic circuits.

Before we analyze individual sections, you should read the accompanying glossary of technical terms and specifications. Becoming familiar with them will help you understand what follows.

Differential-Amplifier Stage

In conventional amplifier circuits (see Fig. 2), the input voltage is connected between the input terminal and ground. Similarly, the output load is connected between the output terminal and ground. Op amps, on

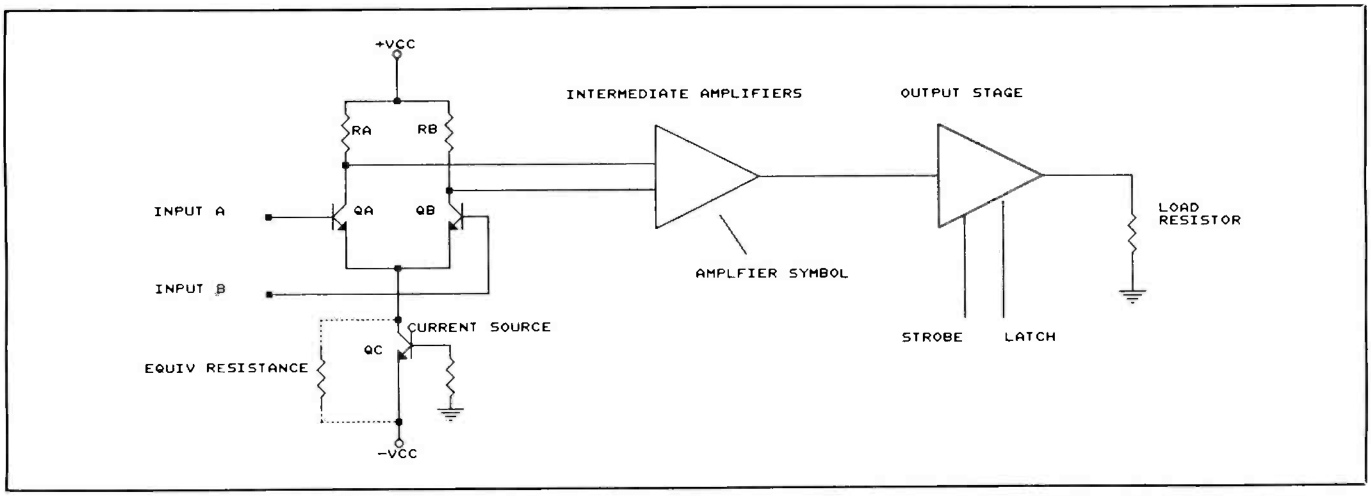


Fig. 1. The operational amplifier consists of three stages. These are identified as input, intermediate and output.

the other hand, all have a differential-amplifier input stage.

The circuit shown in Fig. 3 consists of two transistors, with their emitters connected to a common emitter resistor or, more generally, a constant-current supply that has the effect of a extremely large emitter resistance. The collectors, as you can see, have separate load resistors.

The power supply in the Fig. 3 circuit example is a split positive and negative supply. If Input A is connected to Input B and both are varied with respect to ground, the output at VA and VB would be very close to 0 volt. This is a very handy feature when combining op amps to form instrument amplifiers that rely on cancellation of noise or ac field pick-up that is common to both inputs. In real circuits, however, mismatched gains and the limitations of the constant-current source mean the outputs are not completely 0 volt, due to the common-mode inputs.

The ability of a differential input circuit to reject common-mode inputs is specified by the common-mode rejection ratio as follows:

CMMR = Amplifier Gain when the inputs are different
= Amplifier Gain when the inputs are common

For example, if the gain of an amplifier is 200 in the differential mode and 2 in the common mode, CMRR is said to be 100. Because common-mode rejection is often rated logarithmically, let us look the logarithmic equivalent.

To obtain the common-mode rejection (CMR) in decibels, use the formula:

$$\text{CMR (dB)} = 20 \log (\text{CMRR})$$

In this case, CMR would be 40 dB. Note that when comparing specs given logarithmically, each 6-dB improvement doubles the rejection ratio, such that 46 dB = 200:1, 60 dB = 1,000:1 and 80 dB = 10,000:1.

Now let's look at what occurs when the input signal is applied between the inputs of the op amp, as shown in Fig. 4. This can be done by grounding Input A and connecting the input signal between Input B and ground. The input at B causes a voltage to be developed that is in-phase with the input to appear across the common emitter resistor.

Signal VB at the collector of transistor B is 180 degrees out-of-phase with the input voltage. The voltage across the emitter resistor becomes the input for transistor A. Because it's grounded, the base causes signal VA to be in-phase with the input. The term difference amplifier is used for this arrangement because the output is a function of the difference between the input voltages.

Next for consideration of the input circuits is the technology used. If the input transistors are bipolar, devices the current drawn is relatively high, resulting in an input impedance of a few thousand ohms. If JFET (junction field-effect transistor) or MOSFET (metal-oxide semiconductor FET) technology is used, input current is almost zero and input impedance could be as great as 10,000 megohms. This is important when connecting the input to high-impedance sensors or to oscilloscope probes.

Analog Devices' AD843 has an input impedance of 10^{10} ohms. This allowed us to build the high-impedance attenuator at the input of the DSO (digital storage oscilloscope) featured in the January issue of *Modern Electronics*. Some op amps have terminals that permit modification of the current in the constant-current source to cancel the effects and to offset any unbalance that would have the effect producing an offset output signal when the input is zero.

Input circuits generally also include some form of protection that limits to a safe level the voltage to the input transistors. Even so, care must be taken to avoid exceeding the power-supply voltages. If you suspect that your inputs may exceed recommended power-supply voltages, make sure you use some form of current limiting, usually a resistor or diodes, to limit the current into the device to the maximum rated value.

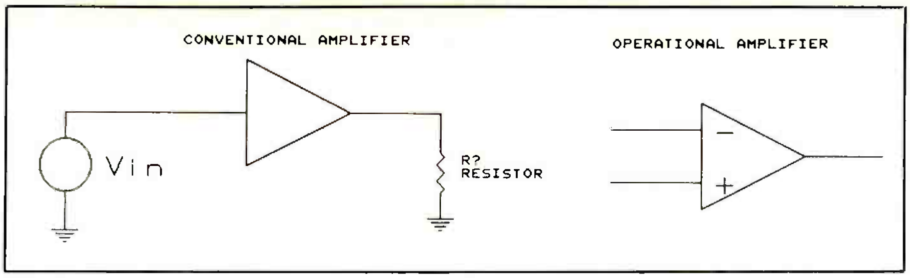


Fig. 2. In a conventional amplifier circuit (left), the input voltage is connected between amplifier input and ground and the output is connected from the amplifier output and ground. In an op amp (right), the same is true, but it gives you a choice of a noninverted or inverted output with respect to the polarity of the input signal by selecting the appropriate input terminal.

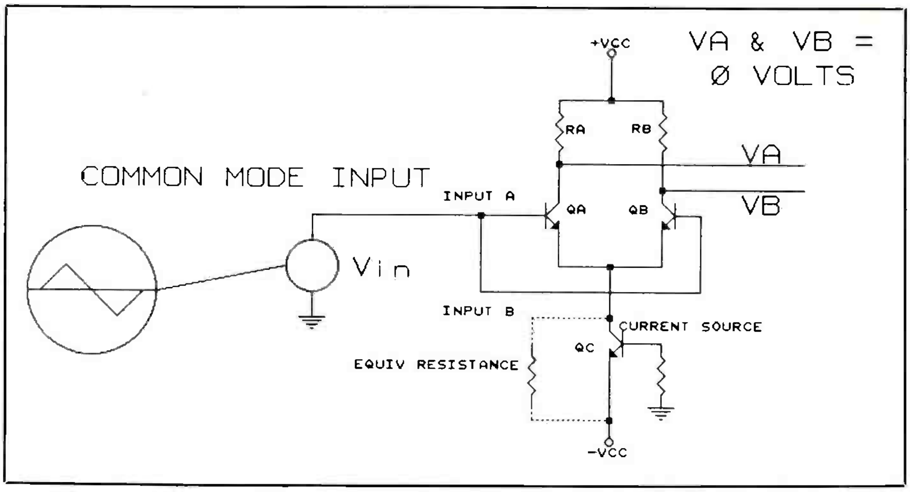


Fig. 3. How to make common-mode input connections.

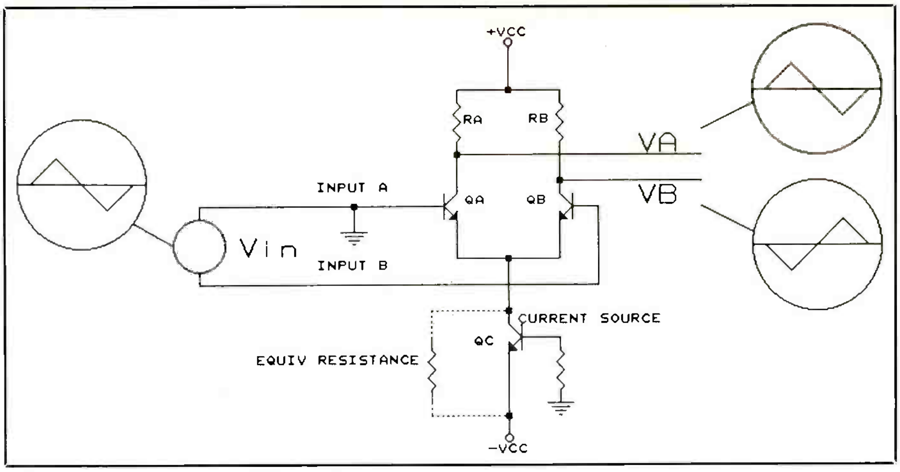


Fig. 4. How to make differential input connections.

Intermediate Amplifier

This part of the op amp (see Fig. 1) provides additional gain, level shifting and dc and frequency stabilization. Because these amplifiers can take many forms, you aren't generally interested in the means but the results of what they do. Most Manufactures publish in their specifications sheets an equivalent circuit of the entire op amp for those users who are interested in the internal design particulars.

The intermediate amplifier consolidates the two outputs of the differential amplifier and provides additional gain. Remember that the open-loop gain (without any feedback) can approach 200,000. The level is also shifted by these circuits to provide drive for the output circuits. The intermediate amplifier is sometimes compensated externally to give you some choices in compromises relative to gain *versus* frequency response.

Output Stage

Because the output stage (see Fig. 5) can take many forms, we'll examine the conventional complementary symmetry type here. The output from the intermediate amplifier connects to the base of transistors QD and QE. The reference voltage is either half the supply voltage for single-ended power-supply applications or 0 volt in the case of a dual-polarity power supply.

When the input signal goes positive, QD begins to conduct and supplies current to the load from the positive (+VCC) supply. When the input signal goes negative, QE begins conducting and supplies the load current from −VCC. This design doesn't have any voltage gain. It has the advantage that power dissipated is shared between two transistors. Internal feedback (not shown) from the output to the intermediate amplifier reduces distortion and improves the frequency response.

Maximum output voltage swing is limited by the saturation characteristics of the transistors used and is, of course, less than the supply voltages. It's important that you be aware that the output stage limits both slew rate and maximum voltage swing as the frequency increases. One look at the maximum peak output voltage *versus* frequency for the μA741 in **Fig. 6** (note that from here on in this article, figure numbers shown in **boldface** refer to actual figure numbers in the sample Texas Instruments manual pages shown later on) indicates that the maximum voltage output for frequencies beyond 10 kHz drops off from ±14 volts at 10 kHz to less than ±2 volts at 100 kHz.

Open-collector and emitter-follower outputs can be used in single supply designs and have the advantage of being able to be connected to digital circuits. In the open-collector output, collector load resistors are always outside the device package.

Circuit design and component selection aren't always as straightforward with op amps as they are with transistors and digital circuits. The op amp behaves differently with different input level changes. This being the case, we'll examine the typical characteristic curves for a μA741 op amp with both small and large signal changes and use the curves to try to predict performance characteristics. As you will discover, the curves—not the static data—are the real key to applying the right design to the op-amp circuit.

Voltage Comparators

We'll now examine six different configurations of the basic op amp when it is used as a voltage comparator. Our discussion will include the effects of transistor saturation in the output stages and the design limitations imposed by slew-rate spec.

The basic op amp provides gains on the order of 200,000. Therefore, a very small change in the voltage across the input terminals produces a large change in output voltage. To calculate the change required at the

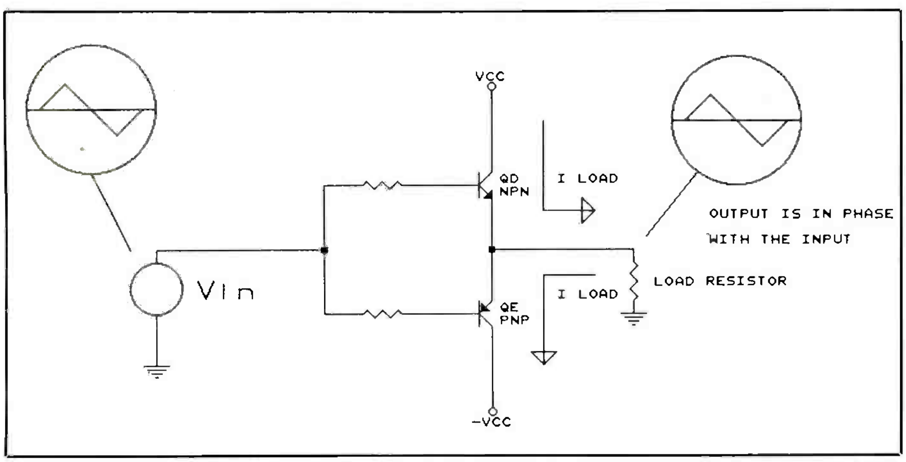


Fig. 5. Schematic details of a complementary-symmetry transistor output stage.

input for a 12-volt change at the output, use the formula:

$V_{out}/V_{in} = 200{,}000$
$V_{in} = 12/200{,}000 = 0.00006\ V\ (60\ \mu V)$

Thus, when the inputs differ by 60 microvolts in either direction, the output change is 12 volts.

This feature allows you to connect one input to a reference point and the other to the variable signal point. The output shifts from +VCC to −VCC as the variable input crosses the reference input voltage, which allows you to build various types of comparators.

The actual output swing never quite reaches +VCC because of the saturation characteristics of the transistors used in the output stage of the op amp. Consequently, when designing comparators, make sure that the supply voltages are great enough to supply the desired peak-to-peak output required in the design. Actual maximum output voltage is often referred to as $+V_{sat}$.

A finite amount of time is required for the output voltage to change with large signal inputs. This time is defined in the slew rate specification and is expressed in μs/volt of output change. This spec is important because it tells you how long it will take before the output changes after the input changes.

The slew rate specification for the 741 is 0.5 μs/volt of output swing. Thus, if the output change is 20 volts, the output will lag the input by 10 μs. A designer must carefully consider this when integrating these devices into high-speed digital designs.

Zero-Crossing Detector

If you connect the noninverting (+) input to a zero point and apply a posi-

Glossary of Technical Terms

Closed-Loop Gain. This is the gain obtained when feedback has been applied between the output and inverting input.
Common-Mode Input Resistance: This is the combined parallel resistance of both inputs with respect to ground.
Common-Mode Rejection Ratio (CMRR): A major advantage of an op amp is that input signals that are induced into both inputs simultaneously are canceled. This allows the use of long cables, such as would be used in an EKG machine. Noise and hum, picked up by both leads, are canceled in the input circuit. The ratio of differential voltage amplification to common-mode voltage amplification is known as the CMRR. CMRR is usually frequency-dependent. If you're battling a particular pickup problem, be sure to look at the plot of CMRR *versus* frequency.
Differential-Input Resistance: This is the resistance that exists between the two ungrounded input terminals.
Input Bias Current: This is the average current required at the input terminals to drive the output to 0 volt.
Input Offset Current: This is the difference between currents into or out of the inputs to force the output to zero or another specified level.
Input Offset Voltage: This is the voltage required between the input terminals to force the output to zero or another specified level.
Input Resistance: This is the resistance that exists between an input and ground with the other input grounded.
Inverting Input: When used as amplifiers, op amps are configured as either inverting or noninverting types. When configured as an inverting amplifier the input signal is applied to the inverting-input. The amplified output will be inverted (shifted 180°).
Latch Control: A latch input is included in some op amps/comparators to permit an event to be stored and reviewed at a later time. This feature allows a computer to poll the outputs and to reset an op amp.
Noninverting Input: When an op amp is configured as a noninverting type, the input voltage is applied to the noninverting (+) input. Voltage changes at this input will be in-phase with the output voltage.
Offset Adjustments: An op amp is a dc-coupled device. If a precision dc offset is required, you may have to apply a correction input voltage that compensates for voltages generated at the inputs due to mismatches and input bias currents. Many op amps have terminals that permit this type of compensation.
Open-Loop Gain: This is gain of an op amp with out feedback.
Output Current Range. This is the current at which the output voltage range of an op amp is specified.
Output Impedance: This is the small-signal impedance between the output terminal and ground.
Output Voltage Range: This is the maximum peak-to-peak output swing before signal clipping or a predetermined level of distortion occurs.
Power-Supply Current: This is the current that is drawn into or out of the supply terminals of the amplifier.
Power-Supply Voltage: This is the nominal voltage required to meet the general device specifications. Voltages less than nominal generally have a drastic effect on performance.
Risetime: This is the time required for an output voltage step to change from 10% to 90% of its final value, which is different than slew rate measured with a large-signal input.
Short-Circuit Output Current: This is the maximum output current delivered by the amplifier when the output is connected to either of the supply lines or ground terminal.
Slew Rate: The slew rate of an op amp defines the maximum rate of change at the output terminals when the input is changed by a large step function. Slew rate is generally limited by the ability of the output stage to rapidly change polarity. Risetime and frequency bandwidth, measured under small-signal input conditions, are generally different than the slew rate would indicate. To obtain a rough idea of maximum output swing as a function of frequency for a unity-gain application, you could use the approximation:

$$\text{Frequency (Hz)} = \frac{\text{Slew Rate}}{6.28 \times \text{peak output volts}}$$

Stability Compensation: Op amps have extremely high gain. External compensation capacitors may be required under some conditions of either open- or closed-loop amplification. Provisions for these capacitors are sometimes available at special pins to provide compensation of an internal section of an operational amplifier.
Strobe Control: Some op amps include a strobe pin that permits an external device to connect the amplifier circuit to an output pin. This feature allows a computer to control the output of an operational amplifier.
Unity-Gain Bandwidth: Amplifier gain drops off as frequency increases due to capacitive effects within the amplifier. When gain is reduced to unity, the frequency at which this occurs is defined as the unity-gain bandwidth.

tive voltage to the inverting (−) input, as shown in Fig. 6, the output of the op amp will swing to $-V_{sat}$. If you feed a triangular signal to the inverting input, you'll alternately change the input polarity, causing the output voltage to switch from $+V_{sat}$ to $-V_{sat}$. The output changes polarity when the input crosses the zero voltage point, which is the reason why such a circuit is called a zero-crossing comparator.

These circuits are very useful when activities must be synchronized to each other. An example of this is the turn-on of ac loads with an SCR during or close to the zero-crossing point. This limits current surges and voltage spikes that would otherwise occur if the circuit were to be turned on at a maximum voltage point. The output of the inverting zero-crossing detector is 180 degrees out-of-phase with the input voltage.

As shown in Fig. 7, connecting the inverting (−) input to ground and the variable input to the noninverting (+) input of an op amp produces a positive output ($+V_{sat}$) whenever the input goes positive. Circuit action is identical to the inverting configuration, except that the output voltage is in-phase with the input. A designer may choose a specific mode because of the symmetry of the input signal or the interface required by the circuit receiving the data.

Reference Comparators

A number of methods can be used to generate reference voltages. Simple resistive voltage dividers are easy to

uA747M, uA747C
DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

PARAMETER MEASUREMENT INFORMATION

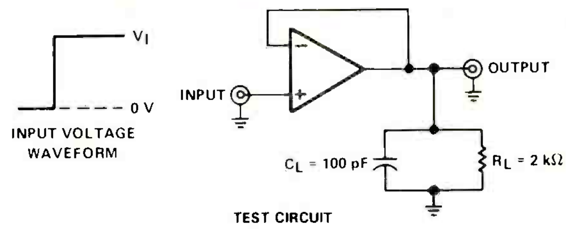


FIGURE 1. RISE TIME, OVERSHOOT, AND SLEW RATE

TYPICAL APPLICATION DATA

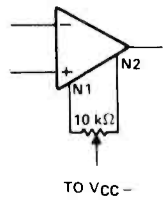


FIGURE 2. INPUT OFFSET VOLTAGE NULL CIRCUIT

TYPICAL CHARACTERISTICS

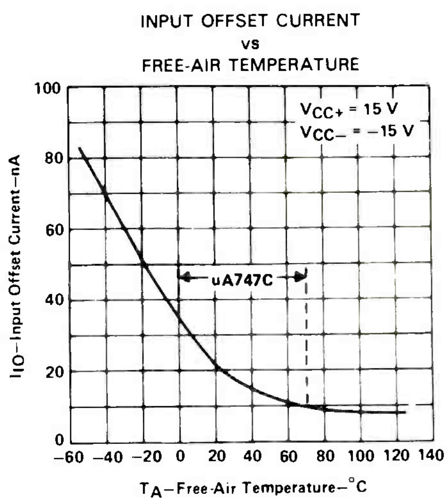


FIGURE 3

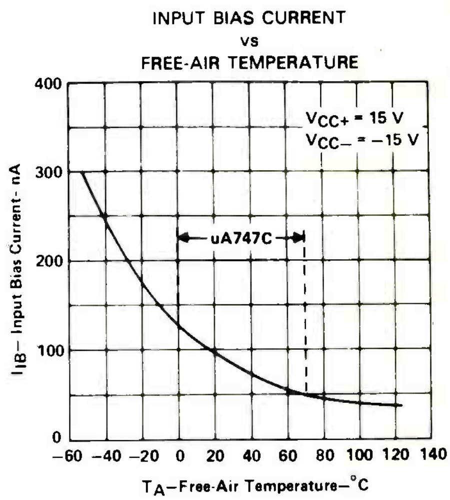


FIGURE 4

Courtesy Texas Instruments

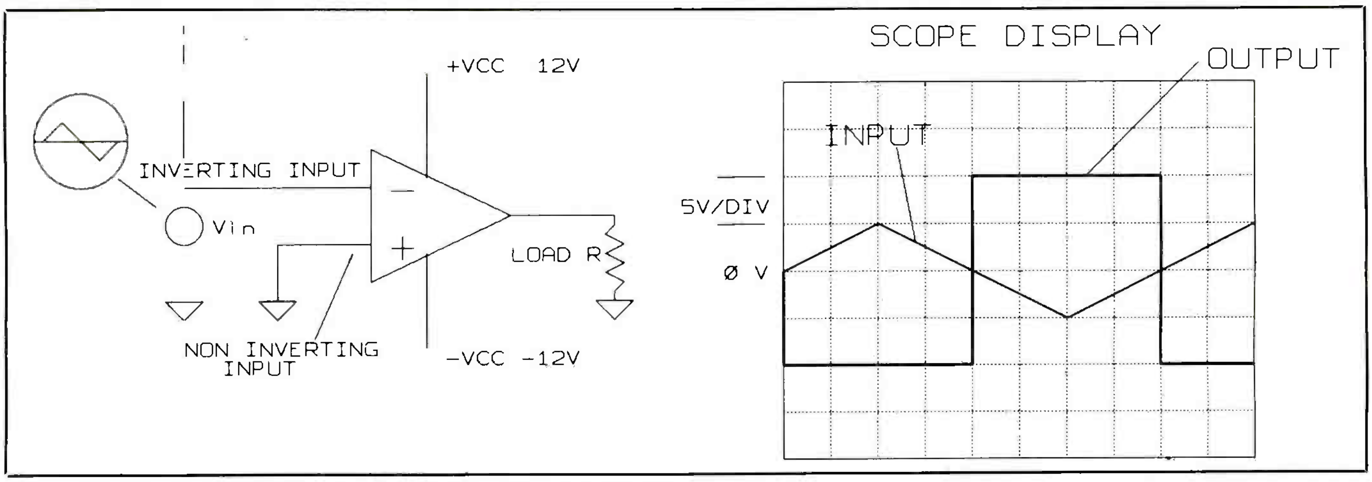
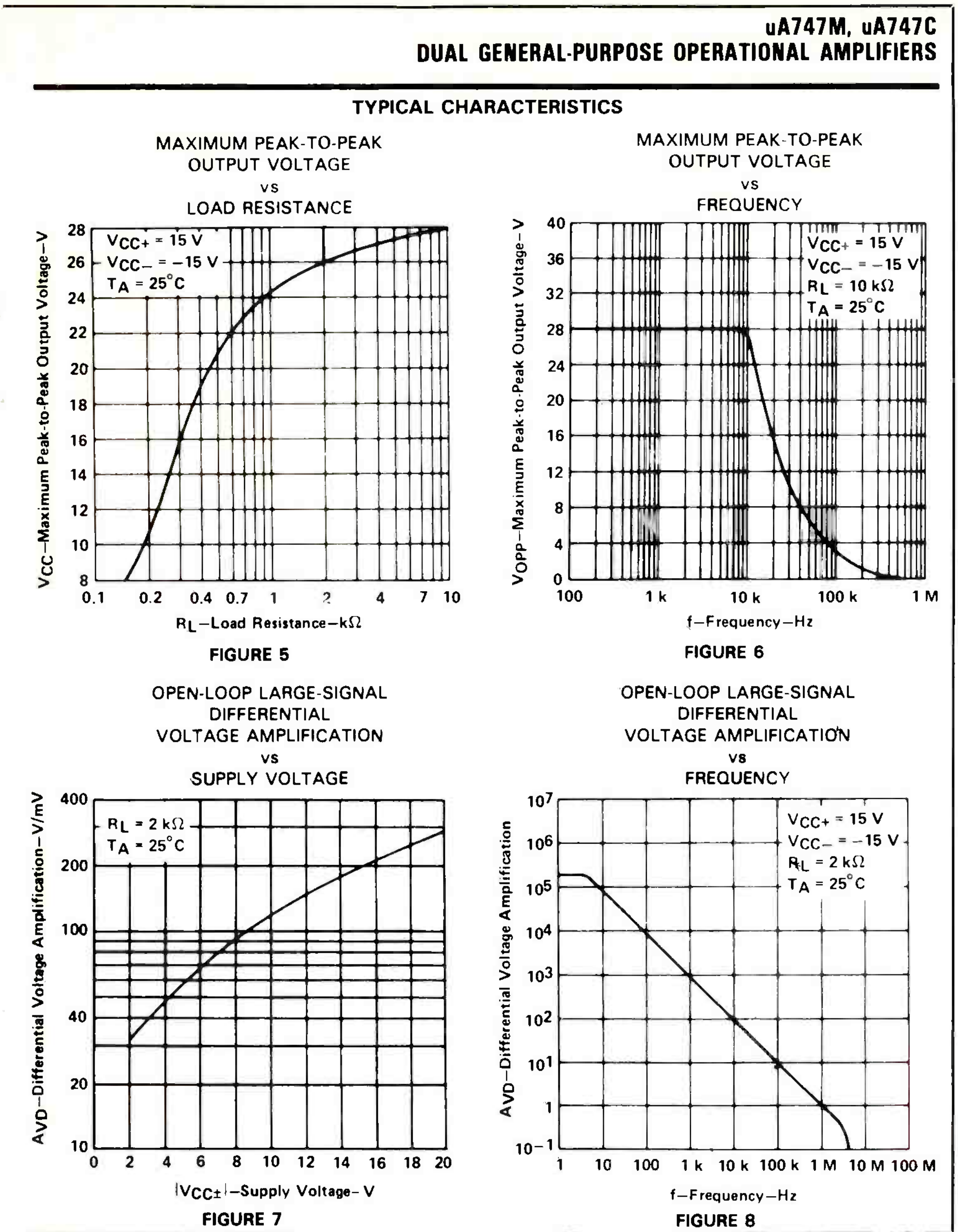


Fig. 6. Details of an inverting zero-crossing detector circuit.



Courtesy Texas Instruments

design. Calculations are straightforward because you can assume that the op amp input doesn't draw current. If you need a precision reference that's independent of supply variations and temperature, a wide variety of adjustable and programmable devices are available.

Basic operation of the comparator is identical to the zero-crossing design. There are four possible configurations, including positive reference inverting; positive reference noninverting; negative reference inverting; and negative reference noninverting. We'll now examine two configurations, leaving as an exercise for you to examine the others.

For our description of the positive reference configuration, we'll use reference voltage dividers built up from a resistor network (Fig. 8). Assuming that you wish to generate a 3-volt reference using a +12- or −12-volt supply, you use the voltage divider equation:

$$V_{ref} = R2\,(V_{out})/(R1 + R2)$$

If you make R1 = 1,000 ohms and V_{out} = 3 volts, you'll find that R2 = 3,000 ohms.

Current drain through the resistor divider will be 3 milliamperes. Current into the op amp is in the nanoampere range and is assumed to be zero for these calculations.

Carefully studying Fig. 8 and Fig. 9, you'll notice that in the inverting mode, when the input exceeds the reference the output goes negative . . . thus, inverting. Note, too, that the output waveform isn't symmetrical.

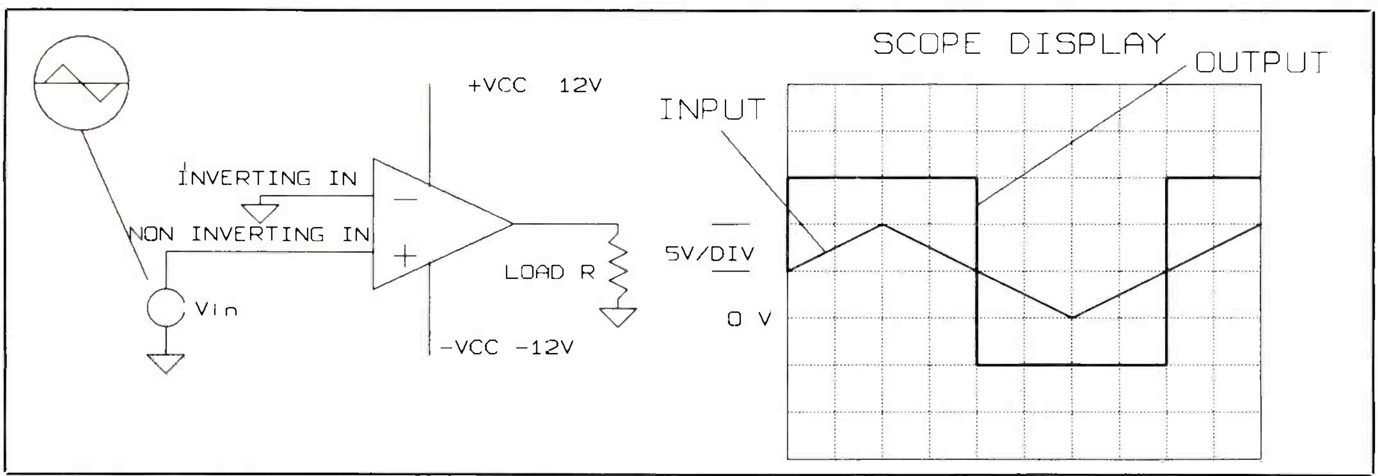


Fig. 7. Details of a noninverting zero-crossing detector circuit.

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TYPICAL CHARACTERISTICS

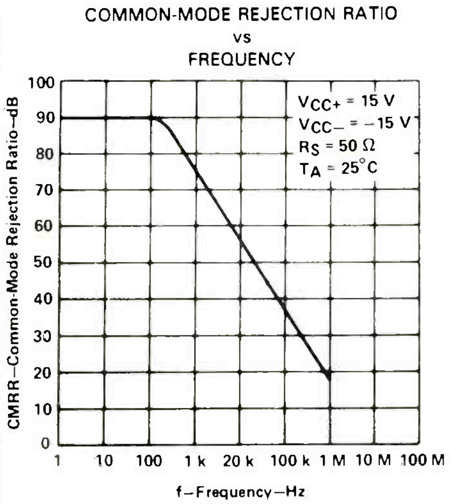


FIGURE 9

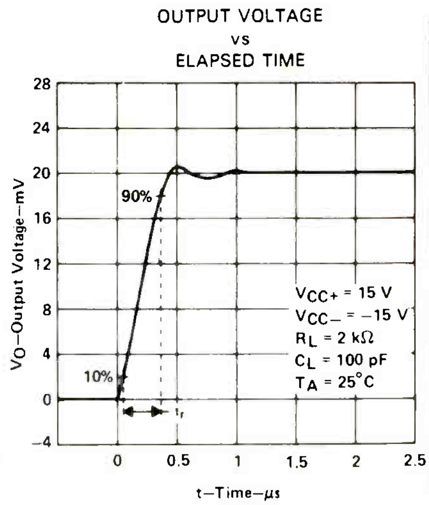


FIGURE 10

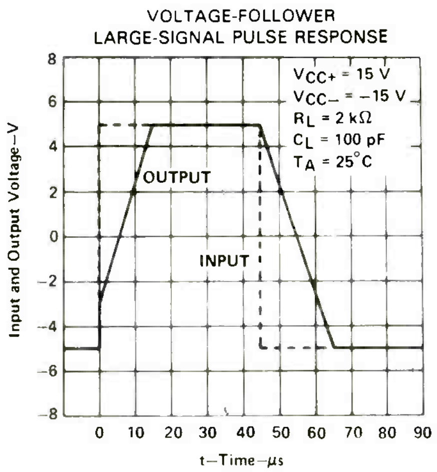


FIGURE 11

Courtesy Texas Instruments

This can be used to change the duty cycle of the square-wave output.

In the noninverting negative reference example (Fig. 9), the output swings low when the input falls to less than the reference voltage.

It's easy to understand which way the output goes if you remember that in the inverting mode the output swing is 180 degrees out-of-phase with (always going in the opposite direction of) the input. In the noninverting mode, input and output changes are in the same direction.

Lab Exercise

For this exercise, you'll build an inverting positive reference comparator using the μA741 op amp. Using the same components as in the above examples, conduct the following tests:

(1) Observe the action of a positive reference inverting comparator.

(2) Measure the slew rate.

(3) Measure the maximum output swing ($+V_{sat}$ and $-V_{sat}$).

For these tests, you need the following equipment:

Oscilloscope (DSO featured in January issue)
Triangle or sine-wave generator (Dual-Channel Function Generator featured in the February issue)
±12-volt power supply
μA741 741 op amp
10,000-ohm, ¼-watt, 5% tolerance resistor
3,000-ohm, ¼-watt, 5% tolerance resistor
1,000-ohm, ¼-watt, 5% tolerance resistor
20-μF nonpolarized capacitor (2)

(Continued on page 81)

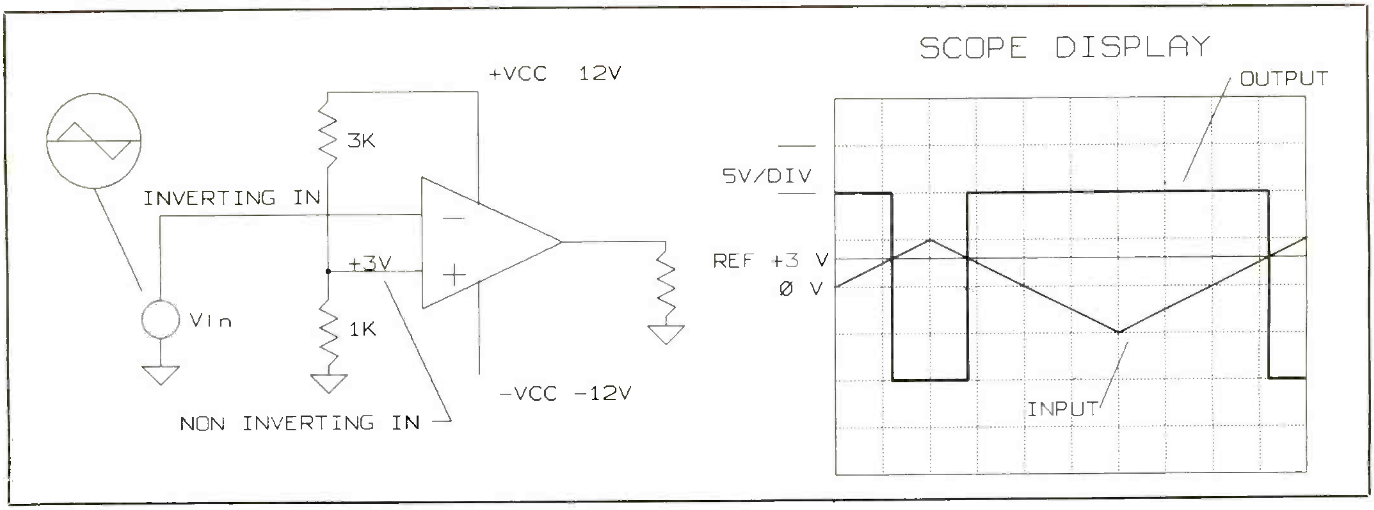


Fig. 8. Details of an inverting positive-reference comparator circuit.

 Say You Saw It In ComputerCraft

Keyboard and Keystrokes (Part I)

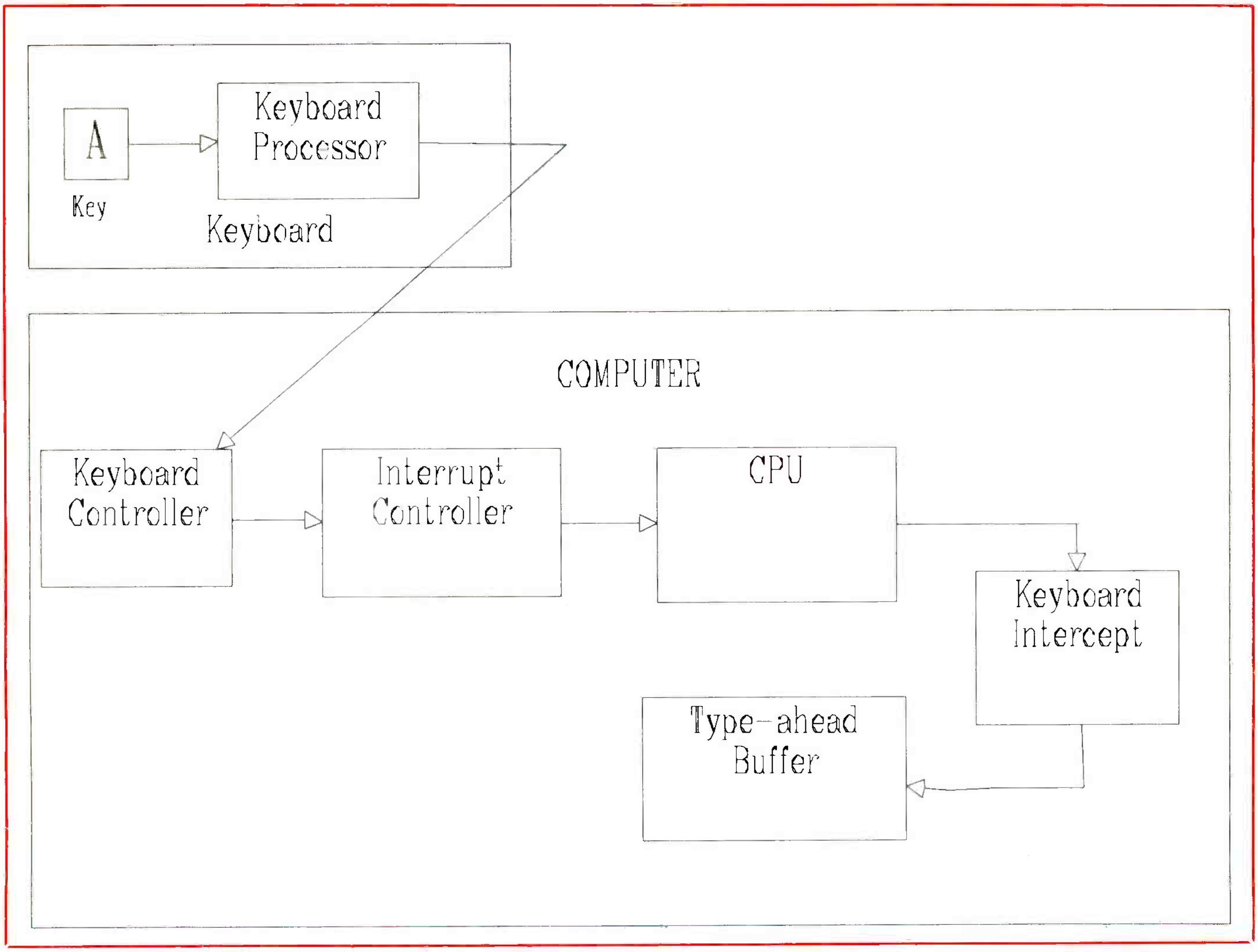
The electronic process of transferring a keystroke to a video screen

When you press a key on your computer's keyboard, a character appears on the screen almost instantly. Users who think of their computers as glorified typewriters probably have a mental image of an electronic type arm pressing a character into the electronic screen.

But the process from keystroke to visible character is nothing that simple. It takes four microprocessors and several pieces of program code to make it happen . . . fast. This month, we'll look quickly at the first part of the process (the entire route is too complex to cover in one article; so I'll address this further next month). Along the way, I'll suggest some ways you can enhance keyboard operations and explain why some keyboards are incompatible with some computers. Armed with this knowledge, you can improve the odds of buying a replacement keyboard that will work with your computer without problems.

Fast Tour

Keys are nothing more than switches that complete a circuit when you press them and open a circuit when released. When you press a key, a processor inside your keyboard recognizes that a keyswitch has been closed. The keyboard processor



Details of how a keystroke at the keyboard makes its journey to the type-ahead buffer.

Listing 1. Resetting Keyboard Lights

```
; Program to demonstrate how the keyboard lights can
; be reset with a BIOS call.
; Written for MASM 5.1
; Save as    BLINK.ASM
; Compile:   MASM BLINK;
;            LINK BLINK;          (ignore no-stack warning)
;            EXE2BIN BLINK.EXE BLINK.COM

cseg    segment
        assume cs:cseg

capson =        40h                     ;Caps lock is bit 6
capsoff=        not capson

numon   =       20h                     ;Num lock is bit 5
numoff  =       not numon

sclon   =       10h                     ;Scroll lock is bit 4
scloff  =       not sclon

stall   =       8000h

delay   macro
        mov     ah,1
        int     16h
        mov     cx,stall
  @@:   loop    @B
        endm

        org     100h                            ;.COM file format
start:  mov     ax,40h                          ;Point ES to BIOS memory
        mov     es,ax                           ;  table

        mov     dx,10                           ;Loop counter in DX
lp1:    or      byte ptr es:[17h],numon         ;Turn on Num Lock light
        delay
        or      byte ptr es:[17h],capson        ;Turn on Caps Lock light
        delay
        or      byte ptr es:[17h],sclon         ;Turn on Scroll Lock light
        delay

        and     byte ptr es:[17h],numoff        ;Turn off Num Lock
        delay
        and     byte ptr es:[17h],capsoff       ;Turn off Caps Lock
        delay
        and     byte ptr es:[17h],scloff        ;Turn off Scroll Lock
        delay

        dec     dx                              ;Decrement loop counter

        jz      @F                              ;Go if done
        jmp     lp1                             ;Else loop back again

  @@:   int     20h                             ;Return to DOS
cseg    ends
        end     start
```

looks up a code for that keyswitch in its internal ROM and sends that code number, which is usually one or two bytes long, over the serial keyboard cable that runs from your keyboard to the computer.

In the computer, another processor, the keyboard controller, receives the serial transmission represented by the keystroke. It assembles the serial bits into a byte and perhaps translates the byte into a new value. The keyboard controller then signals the interrupt controller that it needs attention.

The interrupt controller is the third processor in this chain. It waits until all interrupts with a higher priority than the keyboard have been serviced. Normally, only the timer has a higher priority; so the wait is short. The interrupt controller asserts hardware interrupt IRQ1, which forces the CPU, the fourth microprocessor in the chain, to execute software interrupt INT 9.

INT 9 is a short and quick routine. The CPU collects the keystroke from the keyboard controller. Then it checks whether the user has pressed a key combination that requires special processing, like Shift-Print Screen or Ctrl-Alt-Del. If so, the CPU executes the necessary code.

Next, the INT 9 code checks whether the user has pressed one of the shift keys (Shift, Ctrl, Alt, Caps Lock, Num Lock or Scroll Lock). If so, the CPU updates a memory table to show the new status of the shift keys.

If the user has pressed a normal keyboard key, the CPU combines it with the current shift key status and places a two-byte value into a buffer in memory. Then it signals the interrupt controller that it has finished processing the keystroke and returns to whatever it was doing before the keystroke occurred.

From the point of view of most programs, all these activities are invisible. When a program wants a keystroke, it either calls BIOS INT 16h to get the next key in the keystroke buffer, or it asks DOS to get the keystroke from the BIOS. If the program is written in a high-level language like BASIC or C, it normally asks a runtime routine like INKEY$ or getch() to call the BIOS and get the keystroke.

Different Keyboards

IBM has produced three different PC keyboards for its various machines. The PC and PC/XT, as well as most XT clones, had an 83-key keyboard, with 10 function keys and a combined numeric and cursor keypad. The earliest ATs had an almost identical keyboard, but a SysRq key was added to make a total of 84 keys.

Modern AT and later computers use a 101-key "enhanced" keyboard (European models have 102 keys), with at least 12 function keys, a separate cursor keypad and status lights for shift, number and scroll locks. Although many people think the arrangement of keys on this keyboard is anything but enhanced, the enhanced keyboard and its related electronics and software let you perform some interesting tricks.

On the XT keyboard, the keyboard processor is responsible for more than just sending occasional codes to the computer. It has logic in its ROM to suppress key bounce and to provide *n*-key rollover so that new keystrokes are read correctly even if the user is still holding down previous keys. The keyboard is also responsible for key repeat; so users can simply hold down a key if they want to type it several times in a row.

The processor in the 83- and 84-key keyboards has all the logic for these responsibilities built into its

ROM firmware. You either accept how it works or find a new keyboard that's more to your liking. The processor in the 101-key enhanced keyboard is more flexible. It can turn on and off status lights at the command of the computer. It can be programmed for different key repeat rates and for different sets of key codes. With the latter, the keys can be redefined to fit the user's wishes. It will also accept programming commands that are most useful for diagnostics and system initialization.

Unfortunately, many keyboards don't completely implement the most interesting programming possibility, choosing instead between key code sets. The other useful programming features are more easily accessed via the computer's BIOS.

The keyboard controller inside the PC/XT and compatibles performs its primary job of assembling the serial bits from the keyboard and invoking a hardware interrupt, but little else. The controllers in ATs and later computers that are compatible with the 101-key keyboard are programmable, but few programs actually send them commands. The controller can be instructed to turn on or off its capability of signaling the interrupt controller, to turn itself (and the keyboard) on or off, to watch or ignore the keylock switch on the front of the computer and to test itself.

The controller in AT-style computers has one other job. The key codes reported by 101-key keyboards are completely different from those from 83-key and 84-key keyboards. The controller uses a look-up table in its own private ROM to translate from the AT code set to one closer to the original XT code set. Without this translation, programs that use control and function keys would have to be rewritten for different computers.

The different codes reported by old and new keyboards also explain why you must buy a keyboard that's compatible with your computer. If you try to attach an XT keyboard to an AT or vice- versa, the controller will become hopelessly confused and refuse to work at all. Some keyboards have switches that let them operate in either XT or AT mode; these should be compatible with virtually any standard computer.

Listing 2. Setting Key-Repeat Rate

```
/* This program sets the typematic (key repeat) rates
 * based on command-line parameters.  For fastest
 * keyboard, use KEYREPT 0 0.
 *
 * Save as KEYREPT.C, compile to KEYREPT.EXE
 * Created with Quick C 2.5 but should be compatible
 * with most C compilers.
 */

#include <stdio.h>
#include <stdlib.h>
#include <dos.h>


void testkb(void);       /* Test for 101-key keyboard  */
void help(void);         /* Instructions for user      */

int main(int argc, char *argv[])
{
  int delay, rate;
  union REGS regs;

  testkb();                 /* Make sure we have a 101-key keyboard */

  if (argc != 3 )
     help();                /* Must be 2 command-line parameters!  */

  delay = atoi(argv[1]);    /* First is delay before repeat        */
  rate  = atoi(argv[2]);    /* Second is rate of repeat            */

  if (delay < 0 || delay > 3 )      /* Check parameter bounds      */
     help();

  if (rate  < 0 || rate  > 31)
     help();


  regs.h.ah = 3;            /* Pick Function 3, Service 5 of Int 16h) */
  regs.h.al = 5;            /* Note -- some versions of the Phoenic   */
                            /*   BIOS have a bug and require al = 6   */

  regs.h.bh = (char) delay; /* Set new values */
  regs.h.bl = (char) rate;

  int86(0x16, &regs, &regs); /* Call Int 16h */

  puts("New keyboard typematic values have been set");
  return 0;
}

void testkb()
{
  char far *fp;

  fp = (void far *) 0x496L;
  if ((*fp | 0x10) == 0)
     {
     puts("You must have a 101/102 key keyboard and supporting BIOS");
     puts("to use this program.");
     exit(-1);
     }
}

void help()
{
  puts("  This program sets the typematic (key repeat) rate for your");
  puts("  keyboard.  To use the program, type");
  puts("");
  puts("        KEYREPT d r");
  puts("");
  puts("  d is a number between 0 and 3.  It selects how long the computer");
  puts("  pauses before repeating keystrokes.");
  puts("     d = 0  -->  1/4 second pause");
  puts("     d = 1  -->  1/2 second pause");
  puts("     d = 2  -->  3/4 second pause");
  puts("     d = 3  -->  1   second pause");
  puts("");
  puts("  r is a number between 0 and 31.  It sets how fast keystrokes");
  puts("  repeat when a key is held down.");
  puts("     r =  0 -->  30 characters per second (fast)");
  puts("     r = 31 -->   2 characters per second (slow)");
  puts("     Other values are scaled between these extremes.");
  puts("");
  puts("  For example, you can set the fastest typematic rate by typing");
  puts("        KEYREPT 0 0");
  exit(-1);
}
```

Listing 3. Key Codes to Keyboard Intercept

```
comment |
  This program will show you the key codes as they are sent to the
  keyboard intercept (Int 15h, function 4Fh).

  Written for MASM 5.1
  Save as  Snoop15.asm
  Compile: MASM Snoop15;
           LINK Snoop15;        (Ignore no-stack warning)
           EXE2BIN Snoop15.EXE Snoop15.COM
  |

cseg    segment
        assume cs:cseg, ds:cseg
                org     100h              ;.COM file format
start:          jmp     short install

old15           equ     this dword        ;Original Int 15h vector
old15_off       dw      ?
old15_seg       dw      ?

hextable        db      '0123456789ABCDEF'

posn            dw      0                 ;Offset onto screen
vidseg          dw      0b800h            ;Use 0b000h for monochrome systems

new15:  pushf                   ;Save flags
        cmp     ah,4fh          ;Call to keyboard intercept?
        jz      @F              ;Yes -- get to work
        popf                    ;Else recover flags
        jmp     cs:[old15]      ;  and call original service

  @@:   irp     x,<ax,bx,cx,dx,si,di,ds,es>     ;Save registers
        push    x
        endm

        push    cs              ;Get current segment
        pop     ds              ;  into DS
        les     di,dword ptr [posn]  ;Get current video address
        cmp     di,160          ;Past end of first line?
        jb      bin2hex         ;No -- go
        push    ax              ;Save AX
        sub     di,di           ;Point to beginning of row
        mov     cx,80           ;Ready to blank line
        mov     ax,0720h        ;Space on black background
        rep     stosw           ;Store 80 of them
        sub     di,di           ;Point to beginning of row
        pop     ax
bin2hex:                        ;Display AL in Hex notation
        mov     bx,offset hextable
```

Programming Techniques

You can program the keyboard processor and keyboard controller directly to obtain the features that you want. But it's easier to let your computer do the work for you so you don't have to worry about needed timing delays, interrupts, I/O conflicts and other possible problems.

Changing the keyboard lights and shift-key status is easy. The BIOS keeps a record of the status in low memory. Each time a program or DOS calls INT 16h to get a key from the keyboard buffer, the BIOS updates the lights, based on the current values in the record. This is the same record that INT 9 uses to interpret each incoming keystroke. Therefore, changing the record also changes the way new keystrokes are interpreted.

As an example of the above, if you set the bit in the shift-key record that indicates that Caps Lock is on, all incoming alphabetic keystrokes will be modified to be capital letters. As soon as INT 16h is called, the Caps Lock status light will go on. To ensure that the light goes on immediately, your program can call INT 16h, Service 1, to ask if any characters are in the type-ahead buffer and ignore the results. Listing 1, which blinks all three lights on the keyboard several times, shows the technique.

To set the key repeat rate (IBM calls it the typematic rate), you can use INT 16h, Function 3, Service 5. A bug in some versions of the Phoenix BIOS misinterprets the service number; you have to use Service 6 instead of Service 5 on computers with one of these BIOSs.

The typematic service sets two values. The first sets the amount of delay before a key starts to repeat. By

```
        mov     ah,al           ;Save value in AH
        mov     cl,4            ;Bit positions to shift
        shr     al,cl           ;AL has high nibble
        xlat                    ;Get ASCII code
        stosb                   ;Put it on the screen
        inc     di              ;Point to next location
        mov     al,ah           ;Get back original value
        and     al,0fh          ;Low nibble is now in AL
        xlat                    ;Get ASCII value
        stosb                   ;Put it on the screen
        add     di,3            ;Move for next time
        mov     [posn],di

        irp     x,<es,ds,di,si,dx,cx,bx,ax>
        pop     x
        endm

        popf
        jmp     cs:[old15]      ;Let old handler do the rest

install:
  @@:   mov     ah,01           ;Check if key is in buffer
        int     16h
        jz      @F              ;Go if no key
        mov     ah,0            ;Else get the key
        int     16h
        jmp     @B              ;And loop back

  @@:   mov     ax,3515h        ;Get Int 15h vector
        int     21h
        mov     old15_off,bx    ;Save vector
        mov     old15_seg,es
        mov     dx,offset new15 ;DS:DX has our routine addr.
        mov     ax,2515h        ;Install our routine
        int     21h
        mov     ah,0fh          ;Get video mode
        int     10h             ;  in AL
        mov     ah,0            ;Reset video mode
        int     10h             ;  to clear the screen
  @@:   mov     ah,0            ;Read key from BIOS
        int     16h
        cmp     al,27           ;Wait for ESC key
        jne     @B
        lds     dx,[old15]      ;Get original vector
        mov     ax,2515h        ;Set as Int 15 routine
        int     21h
        mov     ax,4c00h        ;Return to DOS
        int     21h
cseg    ends
        end     start
```

default, the delay is set to 0.5 second, but it can be set between 0.25 and 1 second. The second value is the number of characters per second that will be typed automatically. The default value is 10, but it can be set between 2 and 30 characters per second. Listing 2 is a simple C program that I use in my AUTOEXEC.BAT file to speed up the typematic rate every time I boot up my computer.

Translating Keys

The keyboard processor translates incoming key codes so that most keys look the same to programs, regardless of whether they're typed on an XT or an AT with an enhanced keyboard. But the translation process doesn't end there.

After INT 9 reads a keystroke from the keyboard controller, it calls INT 15h, Function 4Fh. This function, which is also available on late-model XT computers, is called the Keyboard Intercept. Its purpose is to let programs intercept keystrokes before they show up in the type-ahead buffer and decide whether to leave them unchanged, substitute a different code or discard them completely.

To use this service, a program must hook itself into the interrupt chain and provide a new INT 15h, Function 4Fh. Then it must examine every keystroke it receives to determine what value should be returned. This function is called on each key press and key release; if you're going to change some keystroke definitions, make sure you also change the key-release definitions as well.

What value will your program receive for each key? Listing 3 will show you. This simple program displays, in hexadecimal notation, each key code it receives. You can use it to see the codes generated by each of the keys on your keyboard.

Two pieces of information in Listing 3 display are important. First, each key generates two codes: one when it's pressed and another when it's released. This lets the computer correctly interpret Shift, Ctrl and Alt, and limit their effect to the times when they're pressed simultaneously with another key. With a little work, you could turn any or all of them into "sticky" shift keys that remain on until they're pressed a second time, like Caps Lock and Num Lock. In general, the release code for each key is its press code with the high bit set.

Secondly, Listing 3 will show you that the difference between the different shift and cursor keys is often a prefix of 0E0H added to one key. The computer can tell exactly what key has been pressed, but it sometimes must wait for and store a prefix to distinguish between keys that look identical to the user.

A few keys generate codes that are several bytes in length. For example, you might want to press the Pause key while you're running Listing 3. These keys are a little more difficult to intercept and change or disable than the normal alphabetic keys.

Finally this month, Listing 4 shows how to change the definitions of some keys. It assumes that you'd like to be able to use *WordStar* commands without a painful reach to the control key. To do so, it swaps the Caps Lock and left Ctrl key.

The key code for the Caps Lock key is 3Ah, and the release code is 0BAh. Listing 3 shows the press code as 3A FA FA, but the two bytes of FA seem

Listing 4. Remapping WordStar

```
;Demonstration program to show how the Caps Lock and Ctrl keys can
;be remapped to make WordStar-type control commands easier on a 101-key
;keyboard.  You will have to reboot to remove this program from memory.
;
; Written for MASM 5.1
; Save as KEYSWAP.ASM
; Compile:   MASM KEYSWAP;
;            LINK KEYSWAP;     (ignore stack warning)
;            EXE2BIN KEYSWAP.EXE KEYSWAP.COM
;
cseg            segment
                assume cs:cseg, ds:nothing
                org     100h                    ;.COM file format

start: jmp      install

keytable        label   byte            ;Create a look-up table
                x = 0                   ;  from 0 to 0ffh
                rept    100h
                 db     x
                 x = x + 1
                endm

old15           equ     this dword
old15_off               dw      ?
old15_seg               dw      ?

;
;Here is the keyboard intercept routine:
;
new15: pushf                            ;Save the flags
                cmp     ah,4fh          ;Keyboard intercept call?
                je      translate       ;Yes -- translate it
exit:  popf                             ;Else recover flags
                jmp     cs:[old15]      ;  and let orig. Int 15h take over

translate:
                push    di              ;Save register
                sub     ah,ah           ;AX = key code
                mov     di,offset keytable
                add     di,ax           ;DI ==> position for this key
                mov     al,cs:[di]      ;Get translated value
                mov     ah,4fh          ;Restore AH
                pop     di              ;Recover register
                or      al,al           ;Is new code 0?
                jnz     exit            ;No -- exit through old Int 15h
                popf                    ;Else pop flags
                stc                     ;Set carry flag
                retf    2               ;Simulate IRET but keep flags
```

to be an internal signal that the status lights need to change (they can be safely ignored). The key codes for the Ctrl key are 1Dh and 9Dh. What we need to do is change every 3Ah byte to 1Dh, every 0BAh byte to 9Dh, every 1Dh byte to 3Ah, and every 9Dh byte to 0BAh.

Listing 4 begins with a look-up table that's generated by the assembler's REPT macro (you didn't really want to type in 256 hex values, did you?). This Table, as well as a new keyboard intercept routine, stays in memory until the computer is rebooted. The heart of the memory-resident code simply uses the current value in AL—the key code that INT 9 has received—to look up a Table value.

The remainder of Listing 4 checks to make sure that the keyboard intercept is supported on the computer, sets the changed values in the look-up table, and then installs the translation routine in memory.

Listing 4 ignores the difference between the two Ctrl keys. If you want to translate one but not the other, the translation routine could use two look-up tables. One would be used normally, and the other last key was 0E0 hex, which is the prefix added to the beginning of the duplicated keys on the AT keyboard.

This month, I've looked at the first half of the trip from keystroke to a character appearing on the screen. You've followed the keystroke through four microprocessors and into the type-ahead buffer. The second half of the trip will take you through the intricacies of the keyboard buffer, BIOS INT 16h and, finally, into the computer's video capabilities. It will, unfortunately, have to be deferred until a later article. ■

```
end_tsr         equ     $                       ;End of resident code

error   db      'Cannot install keyboard translation.$'
okay    db      'Keyboard translation now in effect.$'

                assume  cs:cseg, ds:cseg
;
;  Set new values in lookup table.  We want to exchange 3A/BA with 1D/9D.
;
setval  macro x,y                       ;;Replace X with Y
        mov     bx,x                    ;;Point to X
        mov     byte ptr [di][bx],y     ;;Put Y in that location
        endm

install:        mov     ah,0c0h         ;Make sure BIOS supports
                int     15h             ;  keyboard intercept
                jc      no_intercept    ;No -- go
                add     bx,5            ;ES:BX ==> feature byte
                test    byte ptr es:[bx],10h  ;Is bit 4 on?
                jz      no_intercept

                mov     di,offset keytable ;Point to key table
                setval 3ah, 1dh
                setval 0bah,9dh
                setval 1dh, 3ah
                setval 9dh,0bah

                mov     ax,3515h        ;Get current Int 15h vector
                int     21h
                mov     [old15_off],bx  ;Save the address
                mov     [old15_seg],es
                mov     dx,offset new15 ;Set new Int 15h vector
                mov     ax,2515h        ;  with address in DS:DX
                int     21h
                mov     dx,offset okay  ;Print message
                mov     ah,9            ;  to show we're installed
                int     21h
                mov     dx,offset end_tsr ;Point to end of resident code
                int     27h             ;  and exit but stay resident

no_intercept:
                mov     dx,offset error ;Print error message
                mov     ah,9            ;  to show we've failed
                int     21h
                mov     ax,4cffh        ;End with fail code
                int     21h
cseg            ends
                end     start
```

Hard-Disk Replacement Encounters

Adding an 80-megabyte drive as a second hard disk to an AT computer and replacing a defective 40-megabyte in an XT

The prime computer at my home office is a Heath 248 AT-compatible PC (a Zenith Z2D248 built from a kit) that's about three years old. At the time I put the kit together, I had the option of equipping it with either a 20M or 40M hard-disk drive. I chose the 20M drive, feeling that I'd never fill it up with just a little word processing and telecomputing.

Six months later, I had filled more than 15M of the disk. Soon I was swapping files to make room for other files and programs. When I became interested in desktop publishing, I knew it was time to upgrade my PC's hard-disk capacity.

The Search Begins

I couldn't readily identify the hard-disk controller in my H248 AT because Heath had used a number of different ones for its part number HWD20AT. Mine was marked Model Titan 3532. I had never heard of it, though I later learned that it was made by Lapine Technology. I wanted to use the same controller for the new drive since I intended to use the existing half-height hard disk as a second hard drive. A Heath technical person told me I could probably keep the same controller if I used it with a Seagate drive.

Poring through advertisements in computer publications, I decided that the Seagate ST-4096 full-height drive came closest to matching my needs for expanded disk capacity at a price I could afford. The drive features an 96M capacity, which formats to 80M, and 28-ms access time. It has 5¼-inch platters, and voice-coil actuation and uses MFM encoding. Using it together with my existing drive would give me a full 100M of storage capacity!

I thought the drive would work with the controller I already had, which I assumed also uses MFM encoding. If it was the equivalent of Seagate's ST412 interface, everything would be fine. To check this out, I logged onto the Zenith forum on CompuServe, where I left a message describing my hardware setup and asked if anyone with a similar configuration had experience with an ST-4096 drive. Several kind folks responded, all verifying that they used the drive with the same or similar computer model and that there were no problems.

I pulled the cabinet off the H248 to make sure that my controller card had, in fact, a connector for a second hard drive. Sure enough, the controller card had a second 20-pin connector. This is a typical arrangement: the card is equipped with two 20-pin connectors for data cables and a single 34-pin connector for the controller cable. Oddly enough, the 34-pin cable appeared to have only one plug on the disk end. But I couldn't see the entire length of cable clearly, and I didn't feel like ripping the computer apart just to verify things. Anyway, they *always* ship new cables with a new hard drive, don't they?

I called Heath's technical assistance line and asked about the controller and the cable. Sure, the ST-4096 would work with an H248, I was told. No, Heath had never shipped any computer kits with a single-terminated controller line, so the second plug must be buried out of sight in the computer, was the answer to my second question.

Next I called Payload Computers in Houston, Texas (best advertised price in *Remark*, a Heath Users Group magazine) and asked to speak to a technician. I told him what I wanted to do, and he said there would be no problems installing the ST-4096 in an H248. The company informed me that lots of them had been sold for that computer. The price last year was $548 plus shipping cost.

I told the order department to ship it via regular UPS. According to my calculations, the hard disk would arrive on the following Monday. It actually showed up the following Thursday. I carefully took the box apart and found that Payload had shipped the drive, a copy of Seagate's *Universal Installation Handbook* and a copy of *Disk Manager* partitioning software. But no data cable was included! Oh, well, I thought, I should be able to find it locally.

Installing a Second Hard Drive

I took apart the H248 to look for the other termination connector on the controller cable. There was none. The cable was just a simple flat one with a single connector for a single drive. I knew then that I needed a new controller cable, too—not a major problem.

I visited the local Heath store and the first salesman gave me that "I don't even understand the words you're using" look when I told him what I wanted. He just mumbled that he would have to get another salesperson to talk to me. It turned out to be a guy I had dealt with before, who does know what is going on.

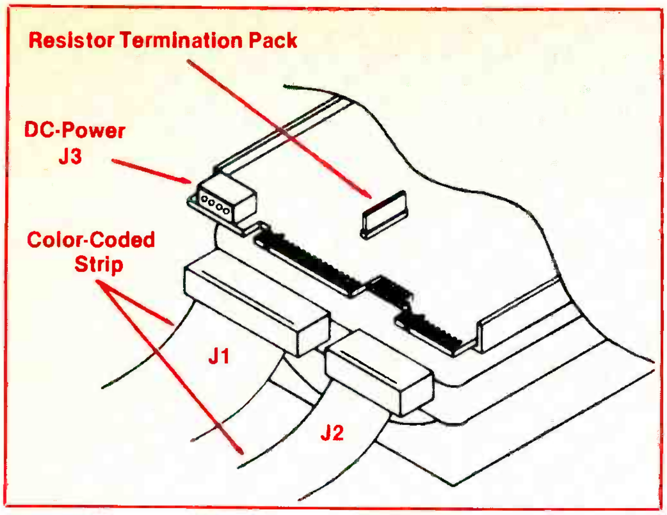


Fig. 1. When two hard disks are installed in a PC, you must remove the resistor termination pack from the first physical drive on the controller cable. However, do not forget that this corresponds to the second logical drive, usually drive D:.

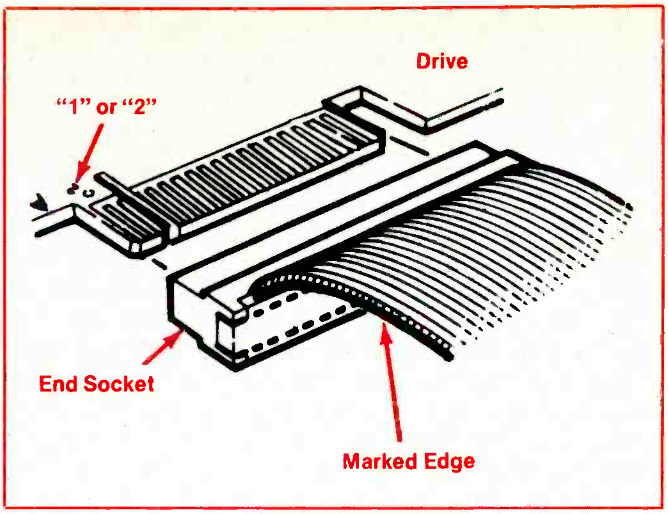


Fig. 2. The slot on the edge connector of the pc board helps you connect the controller cable correctly.

When he came out, I told him what I needed. Zenith has this crazy obsession with part numbers; so the salesman had to spend a few minutes with one of the display models before coming up with the right part number for the 34-pin controller cable. It was in stock and cost $18. The store was out of stock, however, on the 20-pin data cable. I paid the $18 for the controller cable and went to another computer store, where I bought the data cable for $3.

When I tried to install the cables, I found that the data cable fit just fine, but there was a problem with the controller cable. A pin blocker was in the plug that connects to the controller card. Therefore, I couldn't connect the darned cable to the card.

Since it was 30 miles to the Heath store, I decided to try a local computer emporium. Sure, they had the controller cable. No problem. I started to pull out my check book when the clerk looked at me and said, "I'm sorry, sir, but we don't take checks for less than $5." "Oh," I said, making a mental note about a Heath retail store's mark-up. I subsequently returned the controller cable to the Heath store and was given a refund.

It seems that the pin blocker could have been removed rather easily, if you know how. There was only one more roadblock to getting the disk installed and running. Seagate ships its drives with Torx screws in the mounting holes. Needless to say, I didn't own a single Torx screwdriver, let alone a No. 10 Torx driver. But I did have a flat-blade driver that could be wedged into the screw head. In about 10 minutes, I managed to remove the Torx mounting screws and replace them with Phillips screws. But I do recommend using the Torx screwdriver if you have one available.

Heath/Zenith computers are physically a little different than most other IBM compatibles. They have removable mounting racks that hold the disk drives. After taking the cabinet off, you simply remove a screw from the front panel, and the whole rack moves back, slides to the rear and then lifts out.

Since the ST-4096 is more than twice as fast as my original 20M drive, I wanted to use it as my main C: drive and make the 20M drive the D: drive. This would speed up disk operations considerably, and the 20M unit could be used for archiving files and such. However, I ran into a problem with this strategy. Here's why. Every disk drive comes with a resistor pack used for terminating the control line. In a daisy-chain setup, only the last drive in the chain should have the resistor pack. But the last physical drive on the daisy chain is the *first* logical drive (usually your C: drive). Instead of the usual plug-in resistor, my 20M drive has the resistor pack soldered in. Thus, I could use it only as my C: drive.

I carefully removed the resistor pack from the ST-4096 (see Fig. 1) and taped it to the top of the drive for safekeeping. If I ever move up to a 386 or 486 computer at some point and install the ST-4096 in the new computer, the resistor pack will be there when I need it. Never throw away a resistor pack.

The controller cable has attached to it at the disk end essentially card-edge connectors. Each has a key in it that matches up with a slot in the edge of the disk circuit board, as shown in Fig. 2. There is no way you can put them on wrong—if the key is in the connector. Also, most cables have a red stripe running along the pin-1 edge. This can assist you in connecting the cable correctly, since the slot in the disk circuit board is near pin 1.

At the controller card end, things are not so simple. Typically, you will find IDC connectors that have two rows of pins evenly spaced without benefit of a key system. In other words, it is physically possible to turn the cable upside down and connect it. If you look carefully, pin 1 and pin 20 or pin 34 will be marked on the circuit board. Just make sure that the cable stripe is near pin 1.

With everything now set, I turned on the computer and went into

Heath's monitor (a low-level interface below DOS that is used to configure the computer) to set up hard disk number 2. After flipping through the table, I found that Type 35 matched the characteristics of the ST-4096. The computer could now recognize the second drive. (For other kinds of AT compatibles, you usually run a setup program to enter drive type information.)

When I powered up the computer, it would not boot. Trusty, reliable drive C: wasn't there. What had happened to it? Why did it fail to boot? For the next hour, I tried everything that I could think of, including turning the controller cable upside down on the controller card. Looking back on that, I would say that it was a stupid thing to have done, but I was becoming a bit frustrated.

Time to review the literature again. It was all very confusing. I found a couple of reference books that gave me some insight. Not only do you have to be concerned with controller cables and terminating resistors, you must set up the drive-select jumpers properly as well. At the controller-card level, it is like giving each drive a different name.

My original drive had been set up as drive 1. It had been connected to the controller card with a flat cable. But the new cable had a second connector in the middle. Between the middle and the end connectors, a portion of the flat cable was twisted over, which reversed some of the pin connections. With this arrangement, *all* drives must be set up as drive 2. The twist in the cable assures that the controller signals go to drive 1. I figured my drive was not booting because I had not set it up as drive 2.

This was very easy to check. All I had to do was temporarily swap the single-termination flat cable for the double-termination cable. It took about 5 minutes to do that and boot up. Drive C: was fine again. It was then another 20 minutes to remove the disk rack, pull the drive out, find the drive-select jumpers and set them correctly.

One further point of confusion can arise: nomenclature is not standard. Some manufacturers call the jumper pins D0 through D7 and others call them D1 through D8. Regardless of which labeling system is in use, you simply connect the second set of pins, D1 or D2, respectively, with the tiny rectangular jumper connector, as shown in Fig. 3. Alternatively, you may have to set DIP switches to select drive 2. Similar to the jumpers, you set the second switch to ON and the first switch to OFF.

Some controller cables with two disk connectors are flat; that is, they do not have a twist between the connectors. For this type of cable, drive C:, the drive attached to the last connector on the cable, is set up as drive 1 with its jumpers, and drive D: is set up as drive 2 with its jumpers. But, as I said before, when you have the twisted cable, both drives are set up as drive 2 with their respective jumpers. Again, keep in mind that the drive farthest away from the controller card is the first logical drive (usually C:).

After I set the jumpers correctly, the H248 worked perfectly. Then I placed the *Disk Manager* disk in drive A: and ran that program. It takes about 40 minutes or so for *Disk Manager* to format and partition an ST-4096. There is nothing tricky at all to running the program. Just follow the on-screen prompts, select the ST-4096 from the menu, select the partitions you want, enter the data from the bad-sector map that comes with the drive and let *Disk Manager* do the rest.

If you are not using *Disk Manager* or a similar partitioning program, you must format and partition the disk using DOS commands. (Hint: it's a lot easier with *Disk Manager*.)

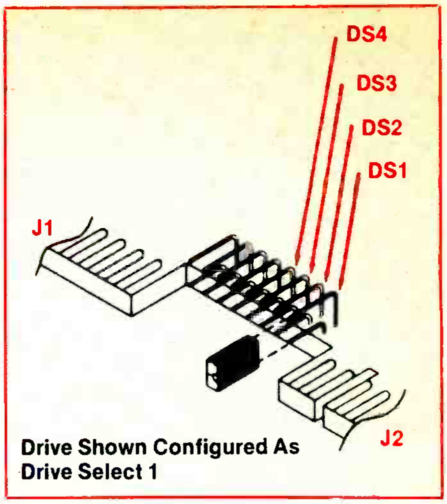


Fig. 3. To configure the hard disk as drive 2, remove the jumper from the first set of pins and connect it to the second set (DS2 in the drawing).

Hard Disk Blues

A few weeks after installing the ST-4096 in my H248 at home, I noticed that my *office* computer was making a strange noise. Within a few days, the computer failed to boot, presenting me with error message 1701. This error message was not particularly informative until one of my co-workers explained what it meant. A 1701 means either a hard-disk failure or a hard-disk controller card failure.

Since we had an identically configured computer available in the office, it was easy enough to check things out. I swapped out my controller card with the one from the other machine. My computer failed to boot, but I did get a slightly different pattern on the screen. Then I tried my controller card in the other computer. It worked fine. That was fairly conclusive evidence that the hard disk itself was the culprit.

I called a couple of local stores, looking for a 40M replacement drive and controller for an XT. One major chain did not have it in stock locally but suggested I order it from its main warehouse in Texas. An ST-251 with a controller card would cost $400. A local independent store had the ST-251 kit in stock for $470. I decided to call a couple of mail-order firms to check out the prices.

The person to whom I spoke in the first store was honest enough to tell me that he could not ship for several weeks. I then called another source. The salesman here assured me that the drives were in stock. This was late Friday afternoon; so it could not be shipped until Monday morning. I queried the salesperson about express shipping on Monday. "No problem. Trust me," was the response. The delivered price was around $370; so I chose to save the $100 and wait a day or two longer.

Delivery was expected no later than Wednesday. Nothing came Wednesday . . . nor Thursday. So I called the salesman back and asked what had happened. He said, "Oh, we shipped it yesterday."

"But you told me you would ship it on Monday."

"It's the flow. Sometimes the orders flow, sometimes not. Know what I mean?"

Yes, I knew what he meant. The drive did not arrive until Friday around noon. I could have purchased it locally for a difference of $100 the previous Friday. Since this is a computer used in business, mostly for word processing, I lost a lot of productive time just to save $100. That is something to keep in mind.

Since the existing controller and drive were quite old (by computer standards, anyway), I ordered the kit, which means drive, controller card and cables. I was pleasantly surprised to see that the controller was a Western Digital WDXT-GEN2 Plus board and not a cheap copy. Incidentally, the manual that comes with that board is excellent.

I started to remove the old drive and found that it, too, was secured with Torx screws. Although I found a Torx screwdriver set at a local hardware store, the drivers were all too large for the job. However, a nearby electronics store carried a No. 10 Torx driver. The two visible Torx screws came out of the side railing very easily. (It is so much better when you have the correct tool.) But the drive was still attached. I had to turn the case up on its side to get to an access hole in the bottom of the case. It turned out that an additional screw was holding the drive to the bottom of the disk-drive bracket.

The mail-order company had shipped two Phillips screws with the new drive, apparently after removing the Torx screws. I started to use the Phillips screws to mount the drive. But I noticed that they were too long and, when fully tightened down, appeared to place stress on the disk housing. Since I already had the Torx driver, I used the Torx screws from the old drive. It took less than 10 minutes to install the new drive, install the new controller card and connect the cables.

There was one thing that I did not like about the new controller card: it did not have a slot cover—just a plastic tab for securing it to the back of the case. My objection is based on the potential for radio-frequency interference (rfi). Lots of high-frequency electronic signals can leak out of a hole like that. A co-worker also pointed out that the hole can wreak havoc with the heat ventilation system of the computer. Fortunately, I was able to remove the slot cover from the old controller card and attach it to the new one.

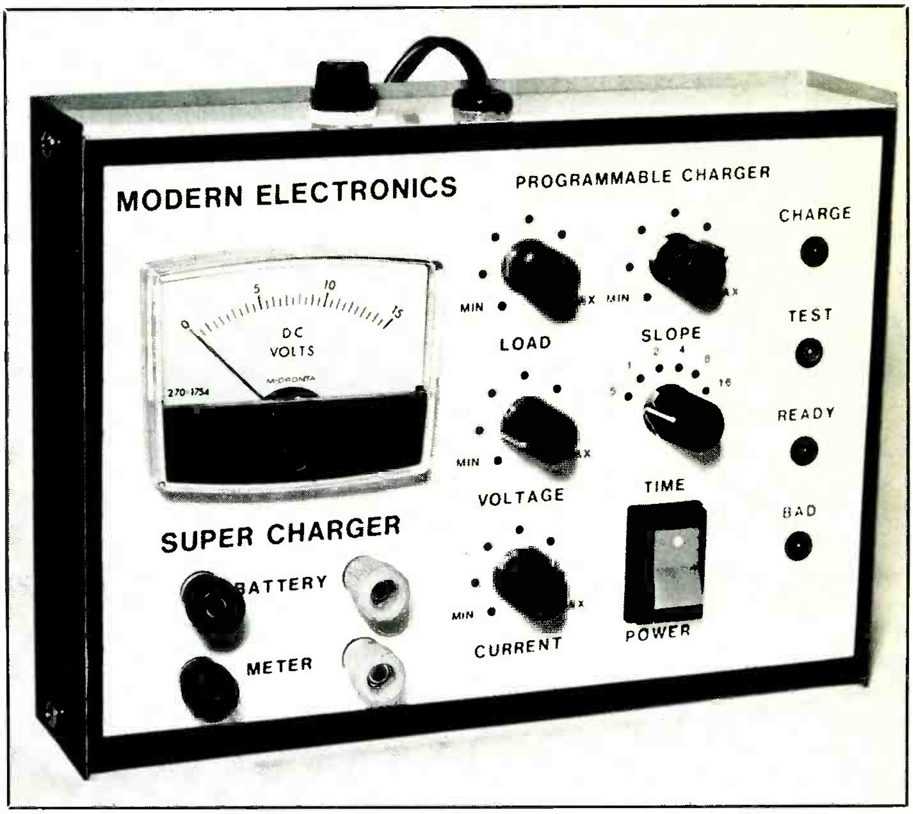
I booted the computer from a floppy, and then I used *Disk Manager* (supplied by Seagate with the drive) to format and partition the disk. *Disk Manager* was through in well under 30 minutes. Again, I found it a painless and foolproof method of formatting and partitioning the disk. After that, it was a simple matter of restoring data from my last back-up, using *Fastback*. Unfortunately, my last back-up was about a year old.

During the afternoon, several co-workers stopped by to marvel at the innards of the computer. One remarked, "How can you do that? I couldn't work on one of those things. I'd be afraid I'd break something."

So, aside from saving money by doing it myself, my ego has been buffed up a bit, making it all very worthwhile. ■

Super-Charger Programmable Battery Charger

Custom-configure your Ni-Cd battery charging profile with the ultimate battery charger!



Why is it that nickel-cadmium batteries and cells seem to create a "love-hate" relationship with most users? One reason is that often they aren't charged properly. *Dumb* chargers are usually configured to "blindly" charge a cell or cells for a predetermined amount of time, regardless of initial charge state. Other, *smart*, chargers sense cell voltage as a means of determining charge status. The Super-Charger described here avoids these approaches by actually determining the charge capacity of a particular cell and lets you control:

(1) The amplitude of the charge voltage applied to cells
(2) Charge current limiting to prevent damage to cells
(3) Charge time from 30 minutes to 16 hours
(4) Test-cycle current limiting for accurate capacity sensing
(5) Test cycle cell capacity slope
(6) Charge-to-test ratio duty cycle

In addition to manual operator controls, the Super-Charger provides fully automatic operation. It has four LED status indicators that light to indicate battery charging (green), battery testing (yellow), battery ready/good (green) and battery not ready/defective (red).

If you've ever had battery trouble, now is the time to build a Super-Charger for yourself!

About the Circuit

Super-Charger consists of two basic subassemblies: a power card and a sensor card. The power card provides the constant charge voltage, constant charge current, constant load current and the system time generator. This card could easily charge your Ni-Cd batteries and cells by itself. However, by using the sensor card with it, you can automate the charging and capacity testing process.

For example, if you wanted to charge the battery in your portable radio or flashlight, you would only want to charge them to full capacity. In some cases, this might take 10 hours. In others, it might only take a few minutes to "top off" the cells. This is why the sensor card is used to supervise charging. By charging the cells to full capacity and not beyond the Super-Charger provides more-efficient, and potentially less damaging, charging cycles. Let's look at how the assemblies work in detail.

We'll start with the power card since it's the heart of the Super-Charger. Referring to Fig. 1, the power card might at first appear to have some unfamiliar circuit configurations. As you'll soon see, however, operation of this subassembly is quite simple.

The simplest form of battery charger would require only a dc voltage source with a potential slightly greater than that of a fully charged battery. Applying this voltage across the discharged battery, we would, in time, expect to reverse the battery's internal chemical state to that of a

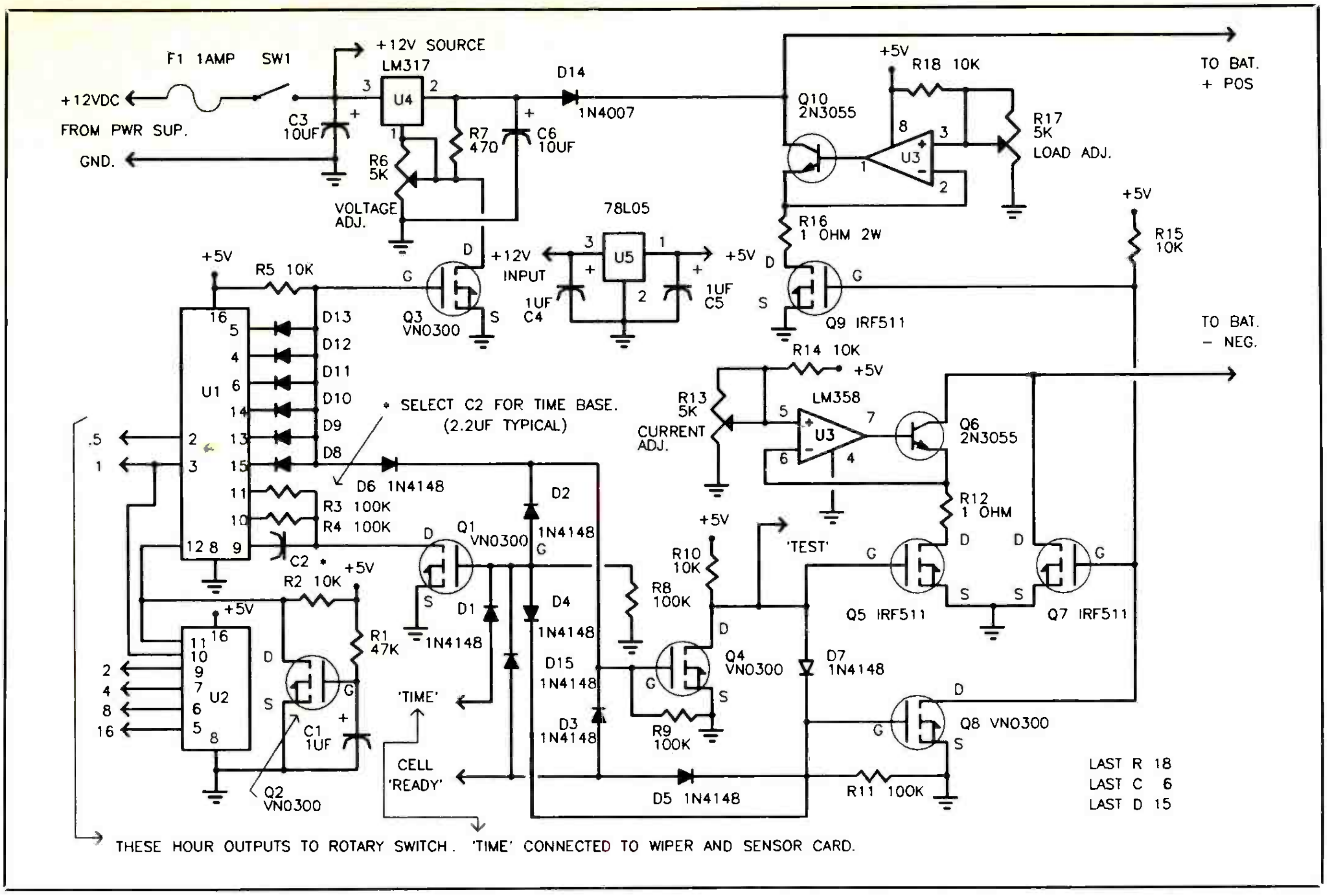


Fig. 1. Schematic diagram of power card circuitry.

fully charged battery. While this is a simple approach, it can create some practical problems.

It was assumed above that the dc voltage source was capable of providing a potential that's slightly greater than that of the fully charged battery. In practice, a fully discharged battery draws a considerable amount of current from the charging source, unless a means to limit the charging current is provided. In addition to "loading" the voltage source, allowing a battery to draw unlimited current can create excessive heat and even damage itself internally. Therefore, a good battery charger should provide a constant charging voltage, as well as allow for current-limiting action to keep from damaging the deeply-discharged battery.

In Fig. 1, the constant-voltage regulator circuit consists of LM317 *U4*. Trace the input voltage path from the 12-volt input, through *U4* and sourcing diode *D14* to BAT. POS. at the upper-right in the schematic. VOLTAGE ADJ. control *R6* sets the charging potential for each different type of battery or cell you charge.

Next, trace BAT. NEG., below BAT. POS. in Fig. 1, back through *Q6* and *Q5*. These two transistors, in conjunction with *U3*, make up a constant-current sink that permits only a certain amount of current to flow through them to ground. CURRENT ADJ. control *R13* allows you to control this charging current through the battery.

Now that you have a constant charging voltage, and a charge current limiter, you have to provide a means to time-out the charging cycle. If the basic battery charger were left connected without regard for time, the battery would soon be damaged and its future charge capacity degraded. In conjunction with *U2*, *U1* provides the timebase for the Super-Charger. All you need to know about this circuit for now is that *U1* and *U2* set a maximum time limit for the charging process.

If the battery being charged isn't fully charged after the time the Super-Charger is set for has elapsed, *U1* and *U2* automatically shut down the charging process and judge the cell as "bad." Hence, the Super-Charger could function with only the power card in-place. Without this card, however, this project could hardly be called "Super." What is next needed in our ultimate battery charger is a method for accurately determining the "state of charge" or "measure of full capacity" of the battery being charged. This is the function of the sensor card.

As shown in Fig. 2, the circuit configurations in the sensor card might at first appear to be unfamiliar to you. As was the case above, though, sensor card circuit operation is really quite simple.

In Fig. 2, CD4040 binary counter *U1*, in conjunction with resistor ladder array (*R6*through *R26*), is configured as a digital ramp generator. Using *U2B* as an oscillator, *U1* creates a

POWER-CARD PARTS LIST

Semiconductors
D1 thru D13,D15—1N4148 signal diode
D14—1N4007 power rectifier
Q1,Q2,Q3,Q4,Q8—VN0300 field-effect transistor (Siliconix—Cyberlab Part No. 3124)
Q5,Q7,Q9—IRF-511 power field-effect transistor
Q6,Q10—2N3055 npn power transistor
U1—CD4060 or 74HC4060 CMOS counter/oscillator
U2—CD4040 or 74HC4040 CMOS binary counter
U3—LM358 dual operational amplifier
U4—LM317 adjustable voltage regulator
U5—78L05 fixed +5-volt regulator
Capacitors
C1,C4,C5—1-μF, 16-volt tantalum or electrolytic
C2—2.2-μF, 16-volt tantalum or electrolytic (select for correct timebase; see text)
C3,C6—10-μF, 16-volt axial-lead tantalum or electrolytic
Resistors (¼-watt, 5% tolerance)
R1—47,000 ohms
R2,R5,R10,R18,R14,R15—10,000 ohms
R3,R4,R9,R11,R8—100,000 ohms
R7—470 ohms
R8,R12,R16—1-ohm, 2-watt wirewound
R6,R13,R17—5,000-ohm panel-mount linear-taper potentiometer
Miscellaneous
F1—1-ampere mini fuse
SW1—Spst switch
SW2—6-position, nonshorting rotary switch
Printed-circuit board; sockets for all DIP ICs; bayonet or block-type fuse holder; metal enclosure (Radio Shack Cat. No. 270-272 or similar); 12-volt dc plug-in wall-type power supply (Radio Shack Cat. No. 273-1653A or similar); five-way binding posts (two red, two black); pointer-type control knobs (5); threaded spacers; heat-sink compound; paint (optional—see text); dry-transfer lettering kit; clear spray acrylic; machine hardware; hookup wire; solder; etc.

Note: The following items are available from U.S. Cyberlab, Inc., Rte. 2 Box 284 Production Facility, West Fork, AR 72774 (tel.: 501-839-8293): Complete kit of parts, including silk-screened enclosure, pc boards and all components but not sockets, power supply or materials for finishing enclosure, $89.95; assembled Super-Charger with power supply, $124.95; both pc boards, $19.95; and silk-screened enclosure, $19.95. Add $2.95 P&H for pc boards; $4.95 for enclosure; $6.50 for full kit and assembled project. MasterCard and VISA accepted. Arkansas residents, please add 3% state sales tax.

linear analog ramp at the inputs of *U2C* and *U2D*. In conjunction with 74HC74 flip-flop *U3* and the ramp generator, these comparators serve as a digital sample-and-hold device that's capable of sampling the input battery voltage (BATT. POS.) and then holding this value as a reference.

In this manner, a battery voltage can be sampled at a particular point in time and a reference established. Later, after a constant-current-limited load has been connected to the battery for a predetermined length of time, a second sample can be compared with the established reference. SLOPE ADJ. control *R27* is used to set the amount of "sag" allowed from the reference voltage to the second sample. If the slope of an imaginary line drawn from the initial reference voltage to the second resting voltage exceeds that set by the SLOPE ADJ. control, the Super-Charger will allow charging to continue. However, if the battery being evaluated doesn't sag below the point set by the SLOPE ADJ. control, the Super-Charger declares the battery charged and stops the charging process.

As you can see, the Super-Charger won't declare a battery charged until it has actually been charged. As a particular Ni-Cd battery or cell ages, eventually it won't be able to pass the Super-Charger capacity test. When this occurs, you can decide whether or not to continue using the battery with diminished capacity.

Now that you have a good idea how the Super-Charger works, let's examine the circuitry in detail. Returning to Fig. 1, the power card utilizes LM317 adjustable regulator *U4* to provide the charging voltage. Power for this is obtained from a self-contained +12-volt dc power supply (Radio Shack Cat. No. 273-1653A or equivalent). Protection for the power supply is provided by 1-ampere fuse *F1*. Capacitor *C3* attenuates undesirable oscillation in the circuit. Capacitor *C6* provides the same protection on the output side of *U4* when no battery is connected to the unit.

Power diode *D14* blocks reverse voltages. Connection of field-effect transistor *Q3* to the voltage-control circuit of *U4* permits you to disable the output voltage of *U4*.

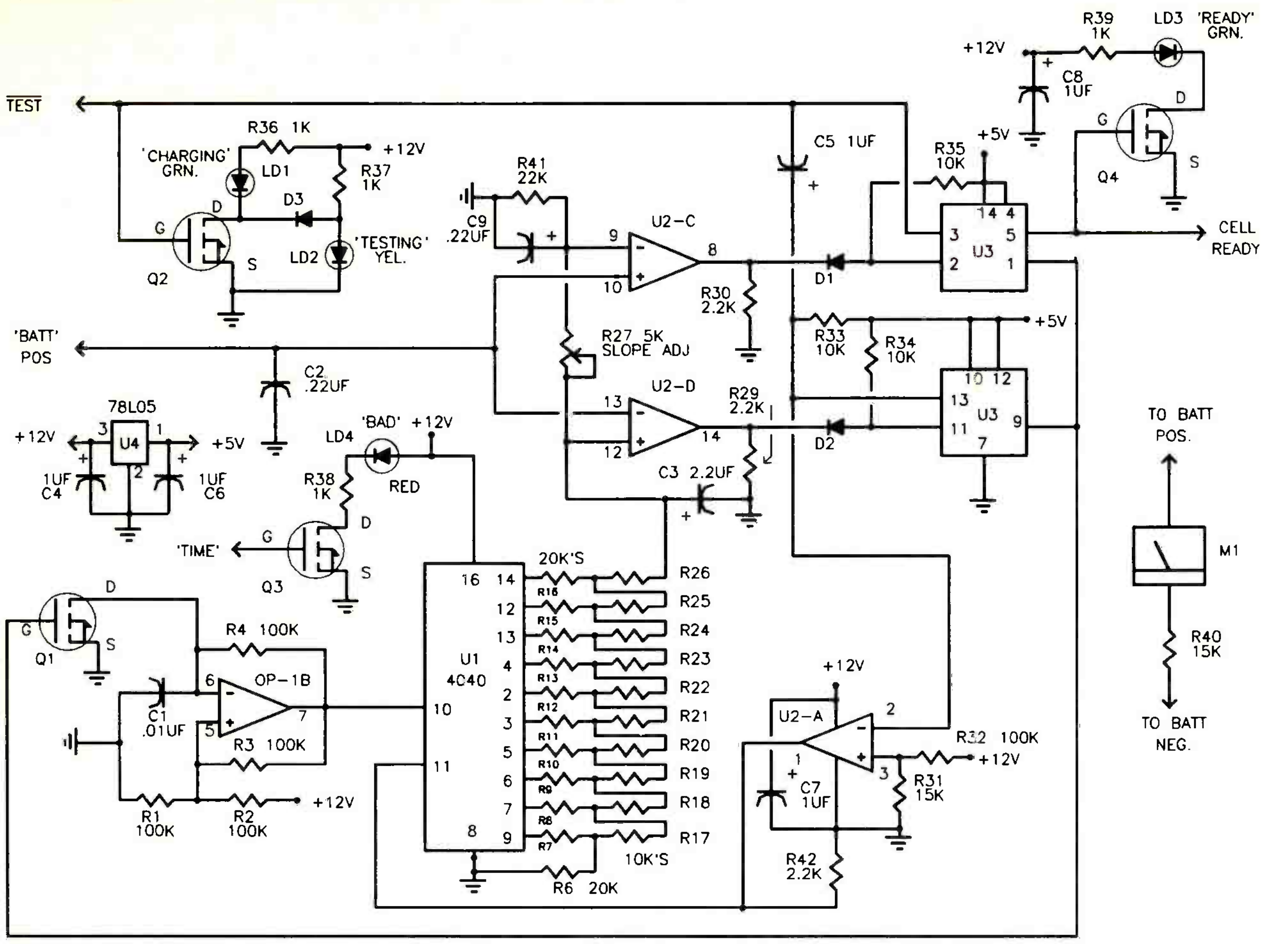
Charging diode *D14* is connected directly to the BATTERY terminals on the front panel of the Super-Charger. Notice in the lead photo that the battery terminals have positioned near them a second set of terminals. Labeled METER, these are in series with the BATTERY terminals and are provided for connecting an ammeter to the project.

A standard panel ammeter won't work in this circuit, owing to the polarity swing from charge to discharge states of the battery. Consequently, you must use an external meter, such as the milliammeter function of a digital multimeter, to monitor charging current.

If you don't have the required type of meter, shunt the METER terminals with a short length of heavy-duty hookup wire to complete the circuit to the BATTERY terminals. However, because charging-current monitoring is so important, it's a good idea to invest in a meter as soon as possible. When charging a new type of battery in particular, current drawn can sometimes be unexpectedly excessive.

In the Fig. 1 circuit, *D14* is shown connected to the collector of npn power transistor *Q10*. In this circuit, *Q10*, *Q9* and *U3* constitute a constant-current sink. Careful selection of the devices for these components can result in very accurate control over the amount of current conducted from the collector to the emitter of *Q10* and on to ground.

The *Q9/Q10/U3* circuit arrangement is also used in the charging current control section (CCS) of the power card circuit. The amount of current this CCS will sink is controlled by the voltage established at the noninverting (+) input at pin 3 of *U3*. The more voltage sourced by LOAD ADJ. control *R17*, the more current "sinks" to ground. Using 1-ohm resistor *R16*, a 1 volt/amp relationship is established in the circuit. Additionally, *Q9* serves as a FET switch that's controlled by



SENSOR CARD PARTS LIST

Semiconductors
D1,D2,D3—1N4148 signal diode
LD1,LD3—Green light-emitting diode
LD2—Yellow light-emitting diode
LD4—Red light-emitting diode
Q1 thru Q4—VN0300 field-effect transistor (Siliconix)
U1—CD4040 binary counter (do *not* use 74HC4040
U2—LM324 quad operational amplifier
U3—74LS7474 or 74HC7474 dual-D flip-flop
U4—78L05 fixed +5-volt regulator

Capacitors
C1—0.01-µF Mylar
C2,C9—0.22-µF, 16-volt axial-lead tantalum or electrolytic
C3—2.2-µF, 16-volt tantalum or electrolytic
C4,C5,C6,C7,C8—1-µF, 16-volt tantalum or electrolytic

Resistors (¼-watt, 5% tolerance)
R1 thru R4,R32—100,000 ohms
R5,R28—Not used
R6 thru R16—20,000 ohms, 1% or 5% tolerance
R17 thru R26—10,000 ohms, 1% or 5% tolerance
R29,R30,R42—2,200 ohms
R31,R40—15,000 ohms
R33,R34,R35—10,000 ohms
R36,R37,R38,R39—1,000 ohms
R41—22,000 ohms
R27—5,000-ohm panel-mount linear-taper potentiometer

Miscellaneous
M1—0-to-15-volt dc panel meter

Note: See Note at end of Power Card Parts List for details on parts and kit availability.

Fig. 2. Schematic diagram of sensor card circuitry.

changing voltages at its gate.

Below the load circuit just described, you'll notice that the same CCS circuit (this time made up of *Q5*, *Q6* and the second op amp inside *U3*) is again used. Likewise CURRENT ADJ. control *R13* is provided for setting the amount of charge current permitted in the battery circuit.

By connecting the negative side of the battery to the collector of *Q6*, very accurate control over the amount of current developed through the battery can be achieved. This current-limiting can't be over-stressed with regard to protecting Ni-Cd cells and batteries.

As with the CCS circuit used in the load circuit, *Q5* also acts as a FET switch to enable or disable the charging action. FET *Q7* is used to completely bypass the CCS circuit during the discharge cycle, when the negative side of the battery must be taken as close to ground as possible.

CD4060 timer *U1* uses resistors *R3* and *R4* and capacitor *C2* to form an internal RC oscillator, the output frequency of which is successively divided down by factors of 2 inside the

IC. As the oscillator runs, a binary counting sequence is developed along the various divide-by-2 outputs.

The wired-OR arrangement of signal diodes *D8* through *D13* is used to form a long-duration pulse-width modulator. As *U1* counts up the binary scale, different combinations (patterns) of highs and lows on the output pins are decoded to form a timing sequence that controls the charging process.

A closer look at the diode *D8* through *D13* arrangement reveals that the anodes are connected to pull-up resistor *R5*. This resistor sources current through the diodes and into any low output of *U1*. Only when all *U1* outputs are high is *R5* allowed to pull high the cathodes of the diode array. This pulse is of relatively short duration compared with the overall timing sequence.

Thus far, you have a method for charging the battery over a long period of time, with an occasional "break" during which the battery can be loaded and a quick capacity test can be made.

High-order outputs are also derived from *U1* and *U2*. Timeouts are available for limiting the maximum default charge time. The CD4040 used for *U2* is essentially the same as the CD4060 used for *U1*, except that it doesn't contain an internal oscillator circuit. Thus, *U2* receives its count input from *U1* and simply counts up until reset or "locked-off" by the action of *Q1*. If a battery or cell hasn't been declared "good" by the time for which the Super-Charger has been set, it will be deemed to be "bad" and charging will be discontinued.

Now that you have a better understanding of the timebase generator circuit, it's time to look at the timing logic sequence. Transistor *Q2*, timing resistor *R1* and capacitor *C1* make up a power-on reset circuit. When POWER switch *S1* is closed, *C1* begins charging through *R1*. This charging process takes several milliseconds, during which time the voltage builds exponentially at the gate of *Q2*. This input is inverted by *Q2* and begins to pull the drain of the FET toward ground, shunting the *R2* pull-up voltage to ground as well.

The resulting low on pin 12 of *U1* and pin 11 of *U2* recovers them from their reset mode and allows normal counting operation. Consequently, each time power is turned on, the counters reset and start counting from their zero states.

As counting begins, the outputs of *U1* are initially all lows. For the next few minutes, at least one *U1* output pin is low at any given time. Consequently, no voltage is present at the anode of *D6* to be sourced through the device and on to the gate of *Q4*. This keeps *Q4* in cutoff. With *Q4* off, *R10* pulls up the drain of *Q4* and the gate of *Q5*, as well as *Q8*.

With +5 volts on its gate, *Q5* switches on and provides a direct current path for the CCS circuit to ground. At the same time, the gate of *Q3* is also low, keeping *Q3* in cutoff and allowing the charging voltage output of *U4* to reach the maximum voltage to which the Super-Charger has been set.

At this point, the battery or cell connected to the Super-Charger is charging. Voltage is present at the positive side of the battery, and a limited amount of current-sinking is permitted through *Q6* and *Q5*. Because the gate of *Q8* is high at this point, drain of this FET pulls the gate of *Q7* and *R15* to ground. It's important for *Q7* to be in cutoff at this point to prevent the battery or cell from drawing excessive current.

Two additional inputs are on the power card—TIME and READY.

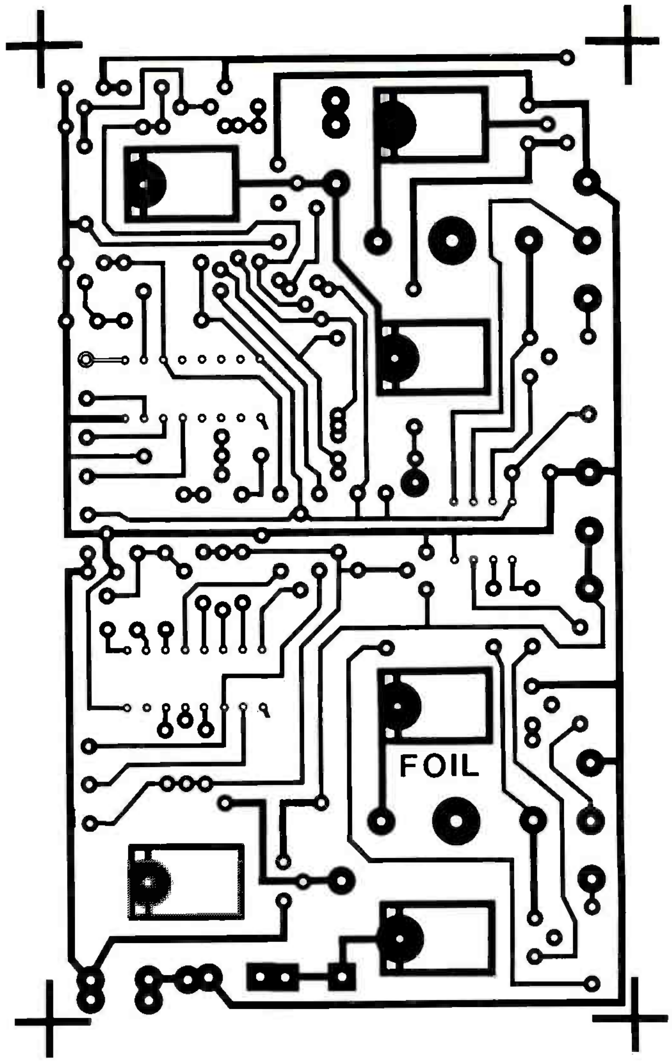
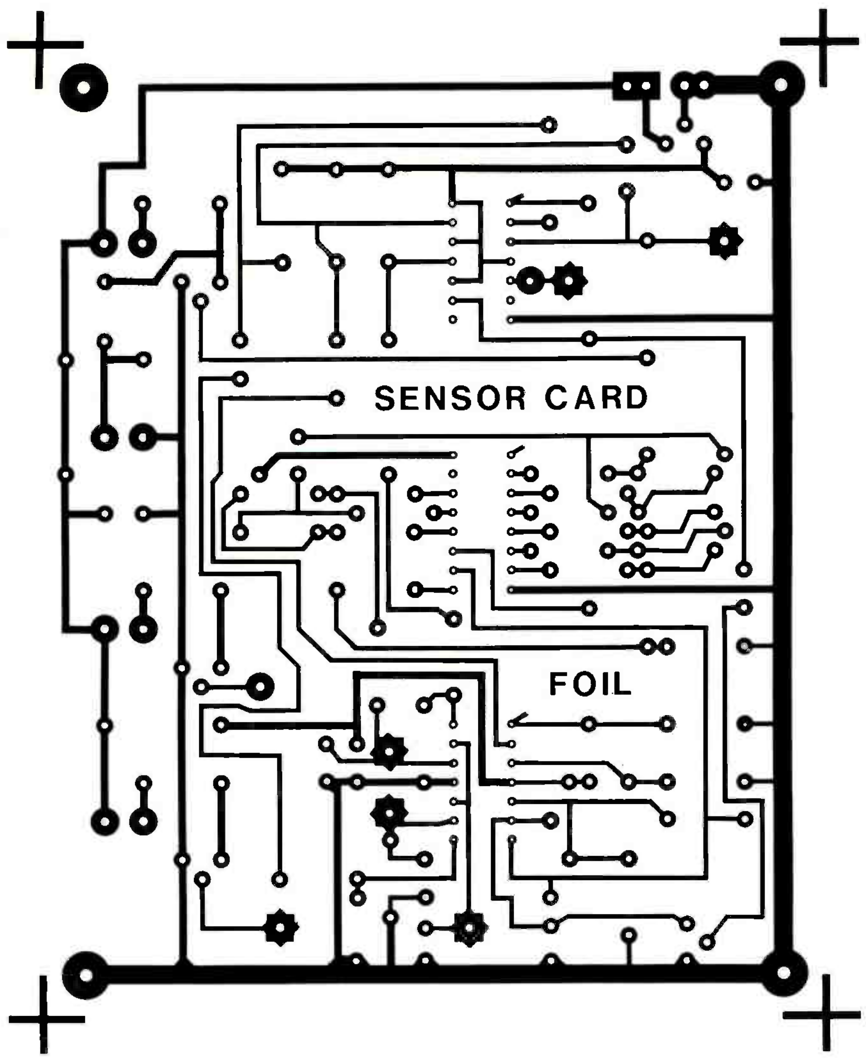


Fig. 3. Actual-size etching-and-drilling guides for (A) power card and (B) sensor card circuitry.

These are routed through *D1*, *D3*, *D4*, *D5* and *D15*. The TIME input is obtained from the wiper of TIME select switch *SW2*. It applies a control signal from the selected output of *U1* or *U2*. When the Super-Charger has timed out a bad cell, the TIME input goes high. This high is steered through *D1* to the gate of *Q1* and on to several other points in the circuit. Its action terminates the timing process by sending *Q1* into conduction and stopping the timebase oscillator. The TIME control signal also cuts off *Q5* and *Q7*, which stops charging of the battery. Similarly, the READY signal stops the charging process, but this is indicated differently on the sensor card.

Every few minutes, an "event window" opens, in which all outputs of *U1* are high. As a result, no current path to ground exists for *R5*. With a 5-volt high at the anode of *D6*, the charging action described above is reversed. FET *Q5* switches off, dropping the charge current to zero. FET *Q7* switches on to provide a current path directly to ground. FET *Q9* also switches on, creating a battery discharge path to ground through the load CCS circuit.

Also notice that *Q3*, now conducting, forces the output voltage of *U4* to minimum. This condition is called the "test" phase. It continues for a predetermined period of time, as dictated by the diode logic associated with *U1*. This test-phase mode is output to the sensor card, where it controls the actual testing process. If you wish to change the charge-to-test timing ratio, remove *D8*, *D12* or *D13*. You can experiment with these effects on the test duty cycle.



Referring now to Fig. 2, *U1* is a CD4040 binary counter. By connecting a resistor ladder network to the outputs of *U1*, you can create a simple, effective digital-to-analog (D/A) converter, such that any particular binary number represented by lows and highs at the outputs of *U1*, is directly converted to a corresponding analog potential between 0 and a little less than +12 volts. Furthermore, you can automate generation of these binary numbers by forcing *U1* to count at a specific rate, as set by the *OP1B* oscillator circuit.

If *U1* were permitted to count in a free-running mode, without interruption, it would produce a continuous ramp waveform at *R26*. This ramp action is very important because it provides a way to synthesize or digitally "remember" any of 1,024 specific voltages.

The test signal created on the power card indicated that the card's timebase had initiated the test phase of the charging cycle. During this phase, the battery is discharged through a constant-current sink to ground. What is to be accomplished is simple in principle but a little more complex in reality. When the test phase begins, you want the project to "memorize" the battery voltage at that instant. Then, when the power card has ended the test phase, you want the project to compare the final battery voltage with the digitally "memorized" reference voltage recorded at the beginning of the cycle.

Following the path of the test signal from the upper-left corner of Fig. 2 across to pin 3 of *U3* you'll notice also that the signal is routed through *C5* to the inverting (−) input of *U2A*. Resistors R*31* and *R32* make up a voltage divider that references the noninverting (+) input of *U2A*.

The TEST input is normally high, so that during the charging phase, the test signal is high. However, when the power card forces the test phase, the test signal goes low. This sudden voltage drop is capacitively coupled across *C5* and pulses low input pin 2 of *U2A*. Comparator action of *U2A* converts this pulse into a reset pulse that's then applied to pin 11 of *U1*. Hence, each entry of the time phase causes the D/A converter to reset to a zero state.

A zero state creates a voltage at *R26* that's very close to 0 volt. If you trace the path from the positive (+) side of *C5* to pin 2 of *U2A*, you'll discover that it also connects to the CLEAR input of one section of *U3*, sending low output pin 9 of *U3*. This disables *Q1* and ensures normal oscillator operation at pin 10 of *U1*.

Next, observe the sensor card input labeled BATT POS is routed to pin 10 of *U2C* and pin 13 of *U2D*. Both *U2C* and *U2D* voltage comparators are referenced to BATT POS. The A/D converter output at *R26* connects to pin 12 of *U2D* and through SLOPE control *R27* and resistor *R41* to ground. These two resistive elements make up a voltage divider that feeds pin 9 of *U2C*.

As the test-signal input goes low, the A/D converter output at pin 12 of *U2D* also drops to near zero. The BATT POS voltage is at the positive potential of the battery. As an example, let's say the battery is two D cells in series and assume that the battery is currently delivering 2 volts. Device *U2D* compares the 2-volt input from the battery with the near-0 voltage from the A/D converter. The output of *U2D* at pin 14 will be low. The ramp generator will continue to ramp its output voltage up, through the A/D converter.

When the voltage synthesized by the A/D converter exceeds the BATT POS voltage, output pin 14 of *U2D* now swings high. This high input pulse then latches a high data output at pin 9 of *U3*. This high signal also inhibits the ramp generator oscillator by clamping *C1* to ground through *Q1*, stopping ramping action and, in effect, memorizing the BATT POS battery voltage.

With this voltage memorized, a battery voltage reference is established at pin 9 of *U2C*. It won't be the exact output voltage of the A/D converter, though, due to the divider action of SLOPE control *R27* and resistor *R41*. The new voltage at pin 9 of *U2C* sets the minimum battery voltage allowed after test loading has run its course.

When the test phase has run its course, the test signal from the power card again returns to a normally high condition. This low-to-high transition clocks the *U2C* comparator output condition into flop-flop *U3*. If the battery passes the test, the output of *U2C* goes high and causes a high output to appear on pin 5 of *U3*. This information is fed back to the power card and is also used to drive the READY green LED circuit controlled by *Q4*. If battery voltage sags more than the level set by the SLOPE control, the *U2C* comparator output won't remain high long enough to be latched into flip-flop *U3*.

When no "ready" signal is received, the power card again initiates the charging phase. If the battery never reaches the desired charge, the power card eventually declares the battery bad and lights the BAD LED controlled by *Q3*. Likewise, *Q2* monitors the TEST input and drives the CHARGING and TESTING LED.

The battery voltage meter loop is also shown in Fig. 1. Be sure to use the 15,000-ohm resistor specified for *R40* in series with the meter.

Construction

It's best to build your Super-Charger into a metal enclosure. The circuitry is accommodated on two printed-circuit boards, which you can make yourself using the actual-size etching-and-drilling guides shown in Fig. 3. Alternatively, you can purchase ready-to-wire pc boards from the source given in the Note at the end of the Parts List. Wiring the circuitry on perforated board using point-to-point techniques is *not* recommended because problematic ground loops are easy to create by this method.

Mount the various components on their respective printed circuit cards, referring to the appropriate wiring diagram in Fig. 4 for each board. When wiring each board, start by installing the resistors and capacitors. Next, install and solder into place the transistors, diodes and IC sockets. Do *not* plug the ICs into the sockets until after you've conducted preliminary voltage checks and are certain that the circuitry has been properly wired. Also, make sure that electrolytic capacitors and diodes are properly polarized and that transistors are properly based before soldering their leads into place.

It's important to note that all power semiconductor devices on the power card mount on the *solder* or conductor side, except *U4*. See Fig. 4(A) for details. Use a small amount of heat-sink compound on each of the TO-220 cases before securing the devices in place with mounting screws. If you plan on charging high-capacity batteries with high charging currents, provide heat sinks for *U4* and power transistors *Q6* and *Q10*.

Mount standoffs and mounting screws on the power card before installing *R12* and *R16*. Make sure to mount these power resistors so that they have about ¼ inch of space between them and the surface of the board for air to circulate and cool them. Then install and solder into place the 12 jumper wires shown as heavy solid lines with no other identification and the long jumper wires identified as JP-1 and *JP-2* in Fig. 4(A).

Strip ¼ inch of insulation from both ends of nine 6-inch lengths of hookup wire. If you're using stranded hookup wire here or anywhere else in this project, tightly twist together the fine conductors at both ends of the wires and sparingly tin them with solder. Plug one end of these wires into the *R6*, *R13* and *R17* holes and solder into place. Crimp and solder the other ends of these wires to the appropriate lugs of the potentiometer controls.

Connect the rotary switch to the power card, using 6-inch lengths of hookup wire. Connect these wires first to the pc card via the holes labeled TIME (between the *U3* socket and *Q6*) and .5, 1, 2, 4, 8 and 16. When you terminate the ends of these wires, the one coming from the TIME hole goes to the rotary wiper lug and the ends of the others go to the appropriate stationary-contact lugs of the switch in proper sequence.

Finish up by installing and soldering into solder posts in all unoccupied holes, except those identified by the legend NC.

Details for wiring the sensor-card assembly are shown in Fig. 4(B). Wire this assembly as you did the power card, except that *all* components on this card mount on the component side in the usual manner. After all components are in place, use lengths of hookup wire for the 11 jumpers required (identified by heavy solid lines with no labels and a lighter line identified as JP1).

Off-the-board potentiometer control *R27* wires into the circuit via 6-inch lengths of hookup wire in the same manner as the controls for the power board. Locate these holes between *C7* and *C9* near the *U2* socket.

Install and solder into place solder posts in the holes labeled SWITCHED +12V, GND, TEST INPUT, CELL READY, BAT POS SENSE and TIME and solder into place. Finally, plug one end of eight 6-inch-long hookup wires into the holes labeled LD1 through LD4 and solder into place. If possible, color-code these wires so that those that are to go to the cathodes (K) of the LEDs have black insulation and those that are to go to the anodes have red insulation.

When you've completed wiring the circuit-board assemblies, set them aside and machine the enclosure in which you'll house the circuitry. You can use an enclosure like that shown in the lead photo or any other that accommodates the circuitry without crowding and has sufficient panel space on which to mount the rotary controls, POWER switch, LEDs, meter movement and binding posts.

Machine the control panel as needed. The lead photo shows a rocker-type POWER switch that requires nibbling or punching a rectangular mounting hole. If you prefer to avoid having to make such a hole, you can substitute a common toggle switch that requires an easily drilled round hole. The large hole for mounting the meter movement can't be drilled directly. Use a chassis punch or a nibbling tool to make this hole.

After machining the control panel, drill mounting holes through the floor of the enclosure for the circuit-board assemblies and an entry hole for the power cord through the rear panel. You have the option of using a bayonet-type fuse holder or a standard fuse block. Whichever you choose, drill a mounting hole for it near the power-cord entry hole in the rear panel.

With machining done, deburr all holes to remove sharp edges. If you are using a raw metal enclosure, you might want to paint it at this point. If

(Continued on page 84)

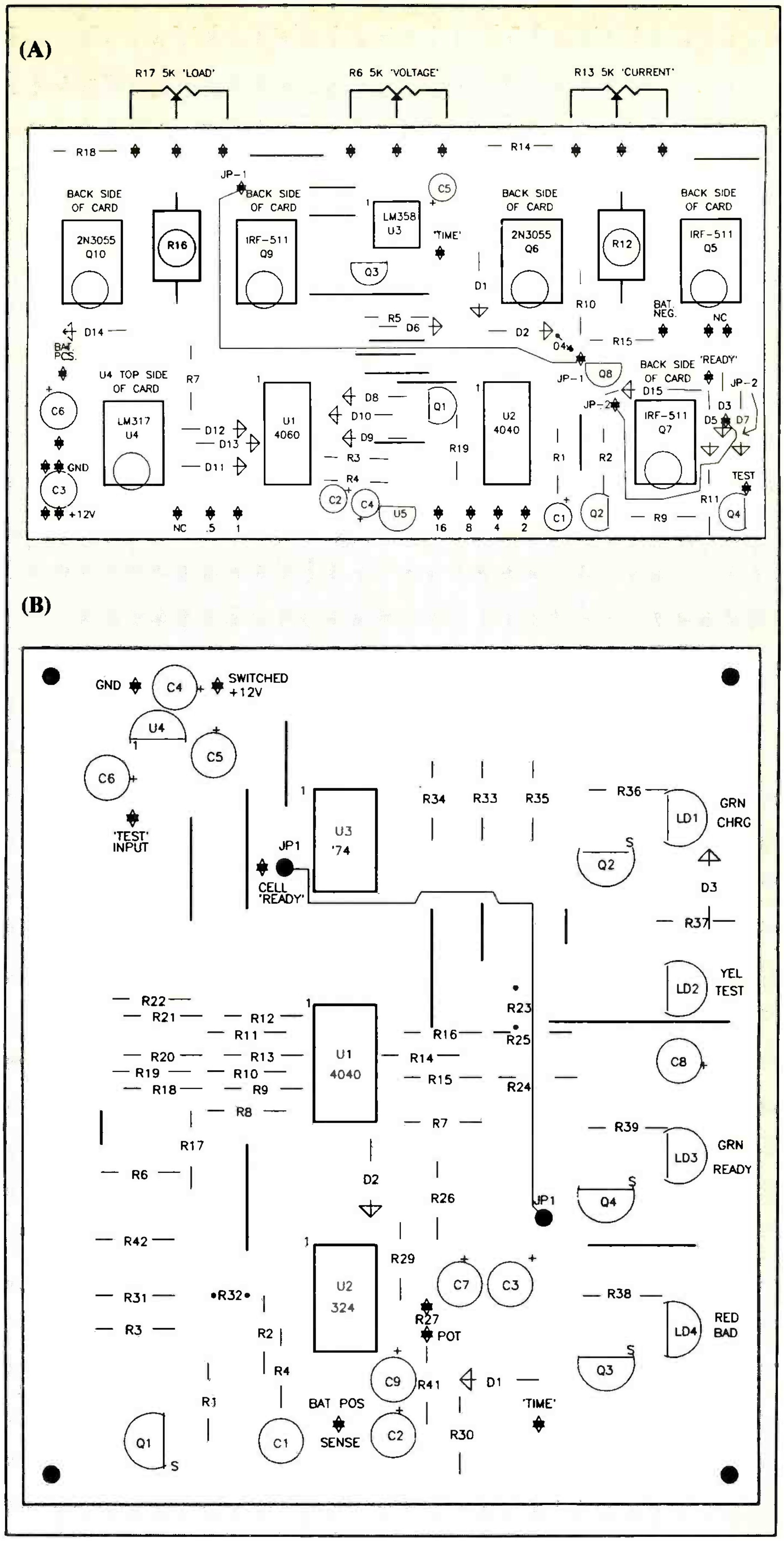


Fig. 4. Wiring guides for (A) power card and (B) sensor card.

Unshielded Twisted-Pair Cable for High-Speed Data-Transmission

Here is the real scoop on networking computers over unshielded twisted-pair wiring

Many people believe that LANs (Local Area Networks) can operate over any UTP (Unshielded Twisted Pair) wiring found in a building. Is this indeed true? Prudence leads us to question such advertised claims and test LANs connected in this manner to observe results for ourselves.

With this in mind, I set out to test various grades of UTP for their compatibility with LANs (4M-bit/second Token Ring, 16M-bit/second Token Ring and 10M-bit/second 10BaseT Ethernets). The results of these tests, including signal measurements are covered in this article. Resulting recommendations for UTP in LAN use are also included. Equipment used for the tests included a 400-MHz Hewlett-Packard Model 54502 dual-channel digital oscilloscope and an H-P ThinkJet printer on which the test results were printed.

Three types of cable were tested for signal quality at LAN speeds: Belden No. 1154A (IBM Type 3 Media or T3M), AT&T No. 1061/2061, and POTS (Plain Old Telephone Stuff). The results of these tests indicated that not all cable is created equal. As important as the cable selected for high-speed data-transmission media are the methods and practices used in cable installation. Because of this, some cable-installations and recommendations will be discussed, too.

Test Results

These tests were performed on a 300-foot length of cable inserted in a Proteon P7202 MSAU (Multi-Station Access Unit). This length of cable is supportable because lobe lengths up to 525 feet are supported by Proteon on a 4M-bit/second Token Ring network.

The cable ends were prepared with IDC crimp-on RJ-45 plugs. One end of the cable was inserted into a port on a Proteon MSAU and the other was connected to a Proteon Media Filter that was modified by adding signal-monitoring points.

The media filter was connected to

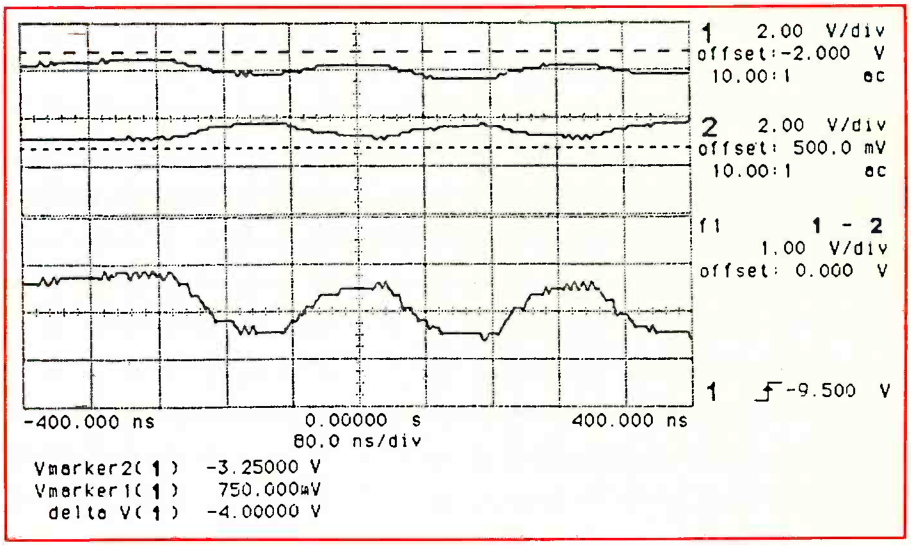


Fig. 1. RX signal transmitted through 300 feet of Type 3 cable at 4M bits/second.

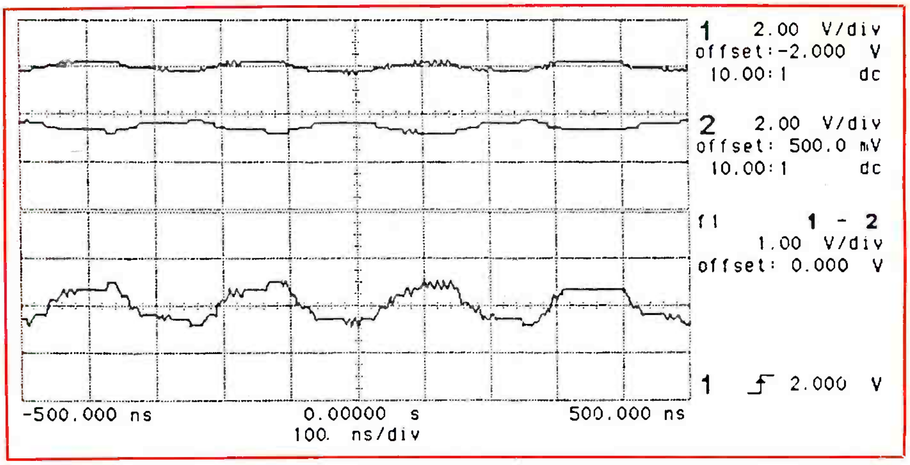


Fig. 2. RX signal transmitted through 300 feet of AT&T No. 2061 cable at 4M bits/second.

an IBM Model 80 network server. This filter was attached for two functional reasons: (1) To slow down rise-time of the signal pulse so that it attenuates the high-frequency leading-edge components of the pulse for FCC emi compliance; and (2) To provide impedance matching between the UTP cable (97 ohms) and output port of the NIC (150 ohms).

Basic functionality of the cable under test was proven when phantom current from the Model 80 token-ring NIC (Network Interface Card) engaged the relays in the MSAU and the sign-on procedure completed without error. Signal snapshots were taken on the TX and RX pairs of each cable under test to show transmission qualities of a cable.

Illustrated in Fig. 1 and Fig. 2 are the RX signals measured at the media filter on a 4M-bit/second token ring. The RX signal represents the effects of 600 feet of cable on the TX signal sent by the PC, a practical worst-case scenario. This is assumed because the TX signal from the PC goes into the cable through the MSAU (as a totally passive device, it provides no signal regeneration) and then backs up to the RX pair in the cable attached to the PC. Figure 2 shows the RX signal measured at the AT&T 2061, while Fig. 1 shows the RX signal measured on Belden 1154A.

As you can see, both signals have very similar levels of degradation. Careful observations of these signals reveals that the Belden cable signal has a peak-to-peak amplitude that is approximately 0.25 volt greater than the AT&T cable signal. This is so because the resistance of the AT&T cable is slightly greater than that of the Belden cable.

Either of these cables would be a good media choice for a 4M-bit/second token-ring network, provided they are installed in a manner consistent with the guidelines I will be discussing later.

The signal snapshots shown in Fig. 4, Fig. 5 and Fig. 6 were taken on a 16M-bit/second token-ring LAN. Methods and procedures used for this test were the same as those for the 4M-bit/second test conducted earlier. The only difference is that the token-ring NIC was set up for 16M-bit/second operation.

Note that IBM (one of the original designers of the token ring) does not support 16M-bit/second token-ring networks over UTP. However, several equipment vendors advertise 16M-bit/second token rings using UTP. What they do not promote, naturally, are the many caveats and limitations that must be followed to make 16M-bit/second token-ring networks operate over UTP media. Some of these unstated precautions are outlined later on.

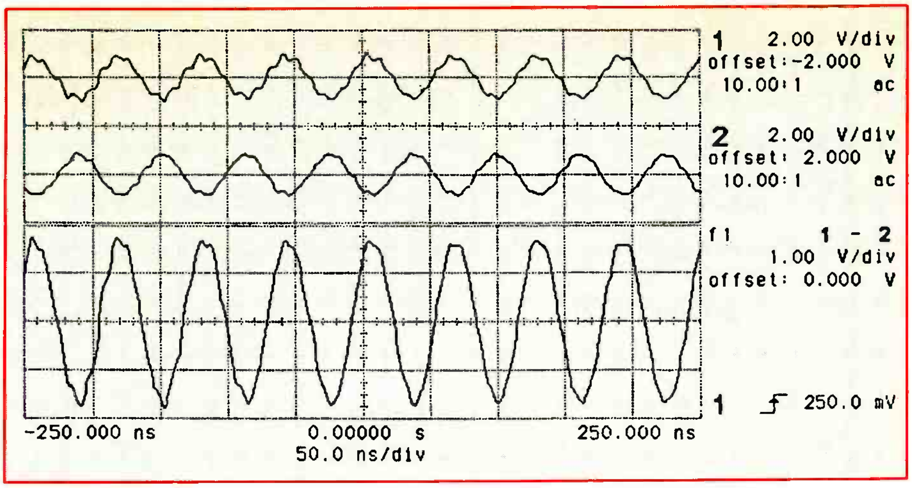


Fig. 3. TX signal from 16M-bit/second token-ring station into 300 feet of AT&T No. 2061 cable.

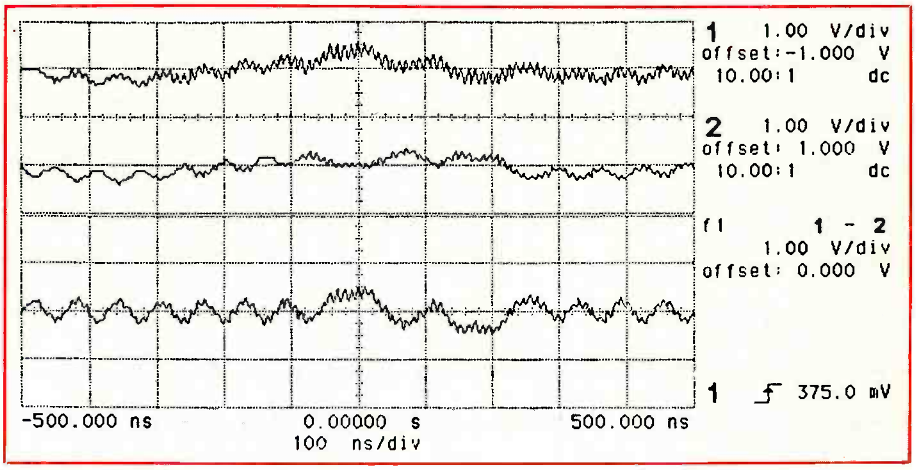
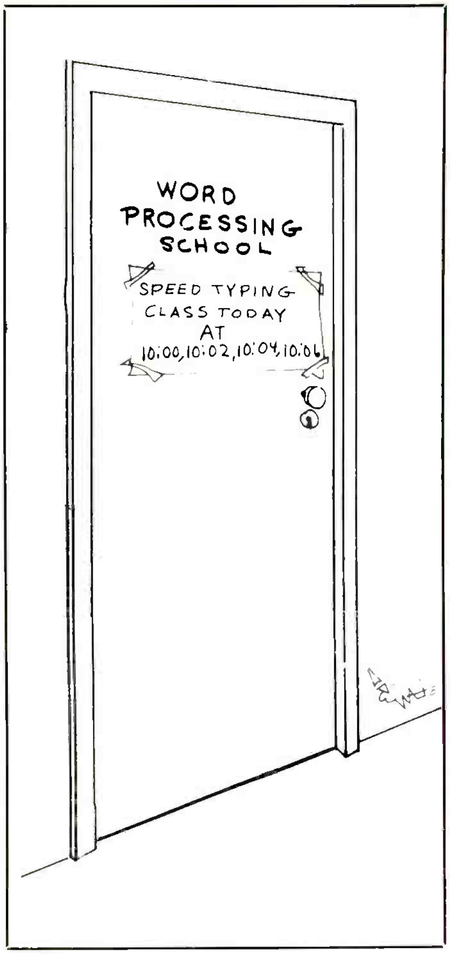


Fig. 4. RX signal through 300 feet of AT&T 2061 cable at 16M bits/second.

The results of this test demonstrate why these caveats are important. Shown in Fig. 3 and Fig. 4 are the RX and TX signals that were measured on the AT&T 1061/2061 cable. Comparison of the two signals reveals the extreme degradation in signal quality that occurs when the 16M-bit/second signal was transmitted through this cable. The RX signal (what the PC would see as "data") is barely discernible over the background noise.

The IBM Model 80 computer was able to engage the MSAU relays and become a working part of the network. But do not let this mislead you. These signals were measured under highly controlled, near-ideal conditions, and only a marginal amount of the signal level remained. You can see that if the quality of the cable, its connections and the installation methods are less than perfect, or if the cable were subjected to such environmental conditions as rfi or decay, the cable may not operate reliably, if at all. Satisfactory operation of the entire system would be at risk.

No RX signal is returned to the PC through the Belden 1154A cable, as shown in Fig. 5 and Fig. 6. The tests revealed something even more dis-



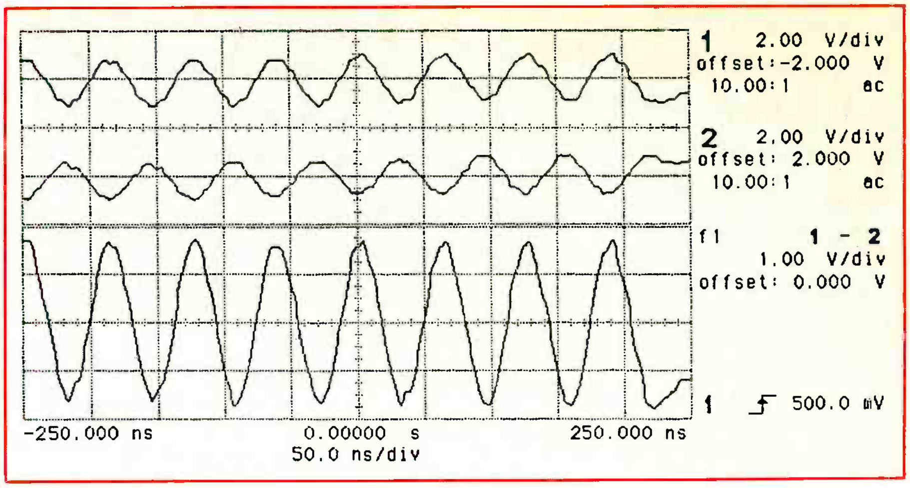


Fig. 5. TX signal from 16M-bit/second token-ring station into 300 feet of Belden No. 1154A cable.

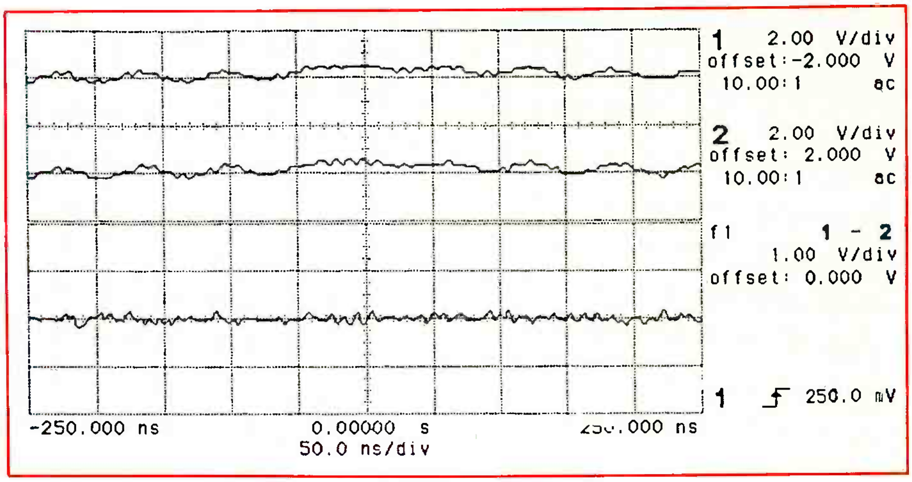


Fig. 6. RX signal through 300 feet of Belden No. 1154A cable at 16M bits/second.

turbing that the signal being completely attenuated by the cable. The PC in this test was fooled into thinking that it was able to join the network, when in fact the cable did not even permit enough phantom current through it to engage the relays in the MSAU.

This "fooled-station" symptom is probably due to high levels of signal crosstalk between wire pairs in the cable. In essence, the PC was talking to itself and thought it was engaged in sessions with other computers on the network. What this means is that, at best, operation of a 16M-bit/second token ring over 1154A cable would be unpredictable or intermittent, both of which are highly undesirable conditions.

"The use of UTP on 16M-bit/second token rings is not a widely viable solution . . . ."

This leads to the conclusion that use of UTP on 16M-bit/second token rings is not a widely viable solution, despite some claims made for this being an easy way out. Too many opportunities exist for things to go wrong. But if it is to be done regardless, only high-grade cables like AT&T's 1061/2061 should be used. And even in this case, installation methods used on the cabling must be strictly controlled. Size of the network should be kept to an absolute minimum as well.

Ethernet Tests

These tests were performed using a Lattisnet Model 2530 department concentrator. A Macintosh with an Etherport IIL card was used as the test station. A small wiring jig with test points was inserted between the Mac and cable connection to the concentrator. The workstation was able to engage the network over both the Belden and AT&T cables. Figures 7 through 10 are signal snapshots taken during this test.

This test reveals comparable signal quality in both tested cables. This is because the specifications for both cables are very similar at 10M bits/second, the speed at which Ethernet operates. Either cable would be a good media choice for 10BaseT star-wired Ethernets, pro-

Ten Commandments of UTP Wiring

For a UTP installation to be a reliable medium for LANs, some installation guidelines should be adhered to. If observed, the following will maximize the transmission characteristics of the cable.

1. Minimize the number of splices and interconnects in a cable used for LANs since each splice or interconnection introduces an impedance discontinuity that contributes to signal attenuation and wave reflections. A maximum of two "in-wall" interconnections is suggested. (An interconnection is any connection, such as punchdown blocks or mass terminations.) Spliceless "homerun" connections are preferred for network cables, especially for 16M-bit/second token rings.

2. Minimize the number of multiple-pair (25-pair) cables used in a LAN avoid problems due to the high level of crosstalk in multiple-pair cables. When using multiple-pair cables, connect a maximum of four 4M-bit/second token-ring stations through a single multiple-pair cable; two 10M-bit/second Ethernet stations through a single multiple-pair cable; one 16M-bit/second token-ring stations through a single multiple-pair cable.

3. Use low-capacitance punchdown blocks, such as Type 110 punchdown blocks, in wiring closets.

4. Use IDC (insulation-displacement connectors) for cable connections to RJ-45 jacks and other interconnect points. Avoid using older screw-down connections that introduce a greater impedance discontinuity in the cable.

5. Make sure attenuation over any length of cable considered for high-speed data transmission is less than 8 dB for a 4M-bit/second token ring, 6 dB for a 10BaseT Ethernet and 4 dB for a 16M-bit/second token ring.

6. Make sure not to stretch the cable when installing it because stretching could lead to pair flips or inconsistencies in the number of twists per foot in the cable. Also, avoid violations of recommended minimum bend radii and other stresses, such as pinched cables.

7. Be highly suspicious of any cabling installed prior to seven years ago if you are considering it as a transmission medium for today's LANs. Extensively test such cabling before considering it as the propagation medium for a LAN.

8. When installing crimp-on connectors, make sure you use the correct type. Most high-speed cable is comprised of solid 24 AWG wires. Bear in mind that there are IDC connectors for both solid wire (less common) and stranded wire (more common). Installing the wrong connector type can lead to intermittent connections between the jack and cable.

9. Make sure that you do not "split" the pairs that carry the RX and TX signals. These signals are different in nature and their propagation is enhanced through a wire pair. Pair splitting leads to increased attenuation and crosstalk and, in worst cases, can cause an inoperative network.

10. All cable installers should familiarize themselves with the standards set forth for LAN installations and adhere to the nature and intent of the documents. You should obtain the following literature and study them to obtain a more complete understanding of wiring standards for commercial buildings where high-speed data networks are to be installed: ANSI/EIA 568/69 and IBM Document No. GA27-3714-4.

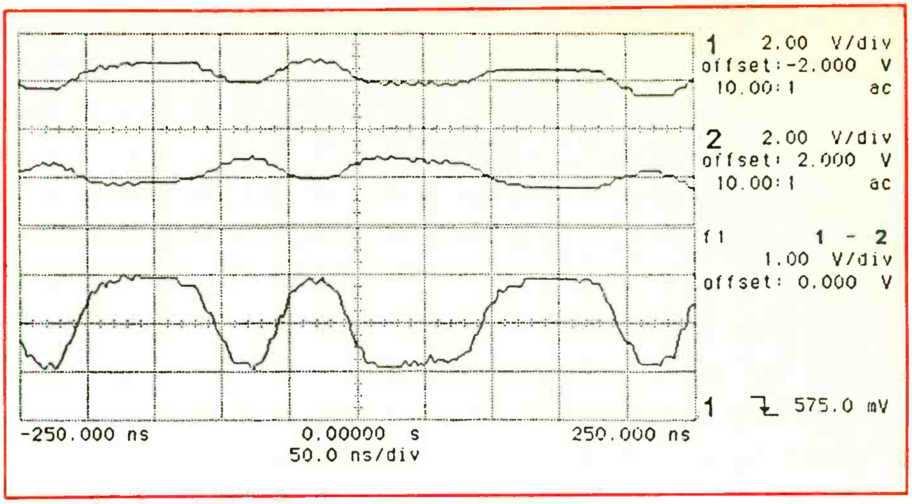


Fig. 7. Macintosh 10BaseT station TX signal into AT&T No. 2061 cable.

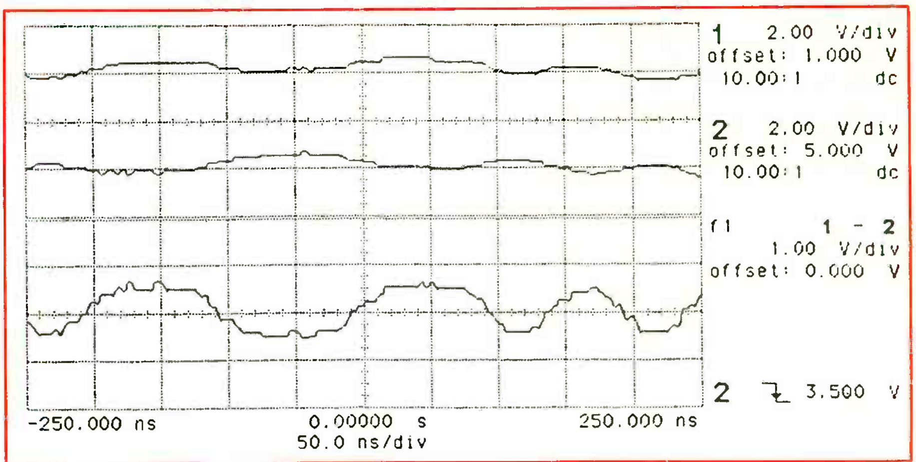


Fig. 8. Macintosh 10BaseT station RX signal through 300 feet of AT&T No. 2061 cable.

vided the installation does not violate any standards or specifications provided by the IEEE 802.3 committee.

Plain Old Phone Stuff

Another test performed was an attempt to get a network station to join a network through pre-installed telephone-type cabling. This cabling was installed eight years ago to then-current standards. The building contractor informed me that the cable went from the wall port to a multiple-drop box in the ceiling. From there it was connected through a multiple-pair cable to a patch panel, where it passed into another multi-drop box that was, in turn, connected through another multiple-pair cable to a patch panel. To make matters worse, there was no consistency in wire pairing. There were multiple pair flips in the line. All told, the 280-foot cable length measured a whopping 18 dB of attenuation.

Multiple attempts were made to have the computer join the network over this cable . . . they failed in every case. This was not surprising, since this installation violated every guideline set forth in LAN cabling standards. Why is this important? It illustrates that real-world cable installations are very suspect for LAN suitability.

Conclusion

Despite what equipment makers may claim about operating a LAN over UTP, there is a lot more to the task than buying the gear and interconnecting it over pre-installed wiring.

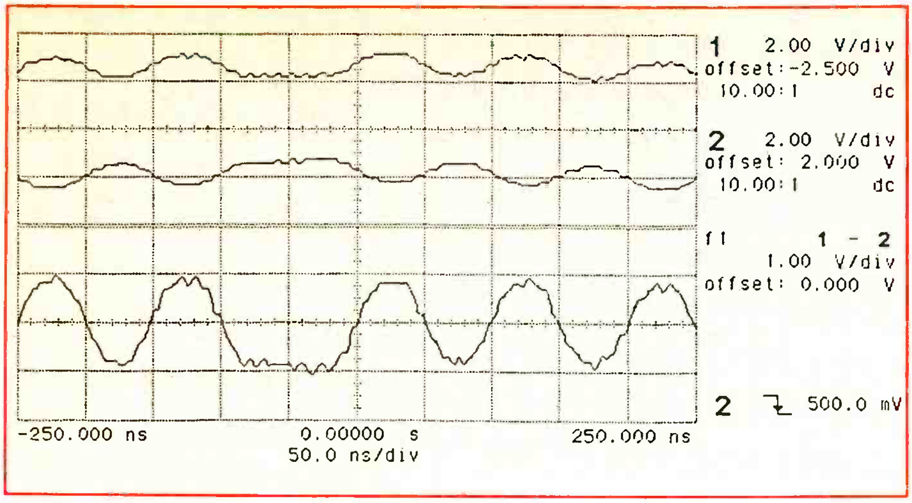


Fig. 9. Macintosh 10BaseT station TX signal into Belden No. 1154A cable.

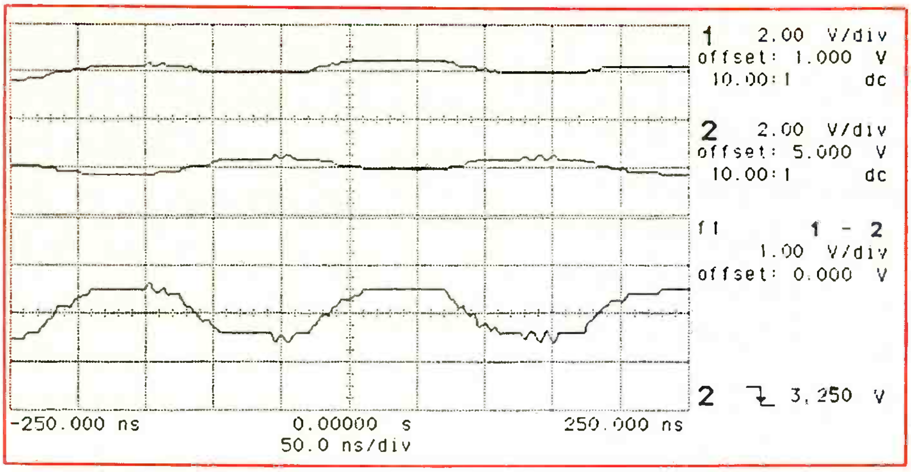


Fig. 10. Macintosh 10BaseT station RX signal through 300 feet of Belden No. 1154A cable.

Most telephone-type wire was not installed with the intention of ever being used as a medium for high-speed data transmission. Though in some cases such an installation might work, it still is not a good idea. Even cable specifically designed for high-speed data transfers must be installed with strict adherence to certain rules or it will not be an effective, efficient media.

While unshielded twisted pairs generally cost about 5 cents per foot, shielded twisted-pair wire, such as IBM Type 1 or Type 2, costs about 60 cents per foot. In turn, coaxial cable is costlier yet, and labor costs are also greater. Interestingly, the AT&T No. 1061 unshielded twisted-pair cable also costs around 60 cents per foot, but it is the best grade in this category, testing out at 20 MHz. Next, at around 5 cents per foot, is Belden's 1154 cable, which is specified at 10 MHz.

In any case, a maximum UTP wire run should never exceed 100 meters (about 33 feet) per lobe. It is best to avoid using existing telephone lines if the building is five or more years old.

In conclusion, many people think little of spending thousands of dollars on network connectivity equipment or servers, but they balk at buying cable and connectors and paying labor costs for a high-quality cable installation. But when you get right down to the basics, the best computers and network operating systems will not give you the performance for which you paid if the cables interconnecting them cannot live up to the task. Remember, a chain is only as strong as its weakest link! ■

Two Microcontroller Boards that Use BASIC

Off-the-shelf SBCs can be easy to work with

Putting together a single-board computer or microcontroller project doesn't have to involve hours spent designing a pc-board layout or using Wire Wrap to assemble a circuit. Nor do you need to be an expert in assembly-language programming. You also don't have to endure multiple cycles of EPROM programming and erasing as you debug your program code.

This month, we look at two "off-the-shelf" microcontroller boards that are easy to program, using BASIC: the BCC52 computer/controller board and the RTC52 processor board, both from Micromint, a company that specializes in small, embedded computer systems. With these boards, you need only add the hardware and control programs specific to your applications. Because they're easy to program, these boards are ideal for experimenting and learning about microcontrollers. With either, you can write a program, try it out in RAM, then modify the program and try again, saving it to EPROM only when you're satisfied with the results.

These microcontroller boards aren't limited to experimenting. According to a Micromint spokesperson, the boards are used commercially for such functions as positioning the bit on an offshore oil-drilling rig, controlling manufacturing processes in a concrete-block plant, controlling mixing and weighing in a food-processing plant and providing off-hours control of lighting and other operations at an airport.

Either board is easily adapted for specific applications and is available for less than $200. The RTC52 is also available as part of Micromint's RTC52-EDS economical development system.

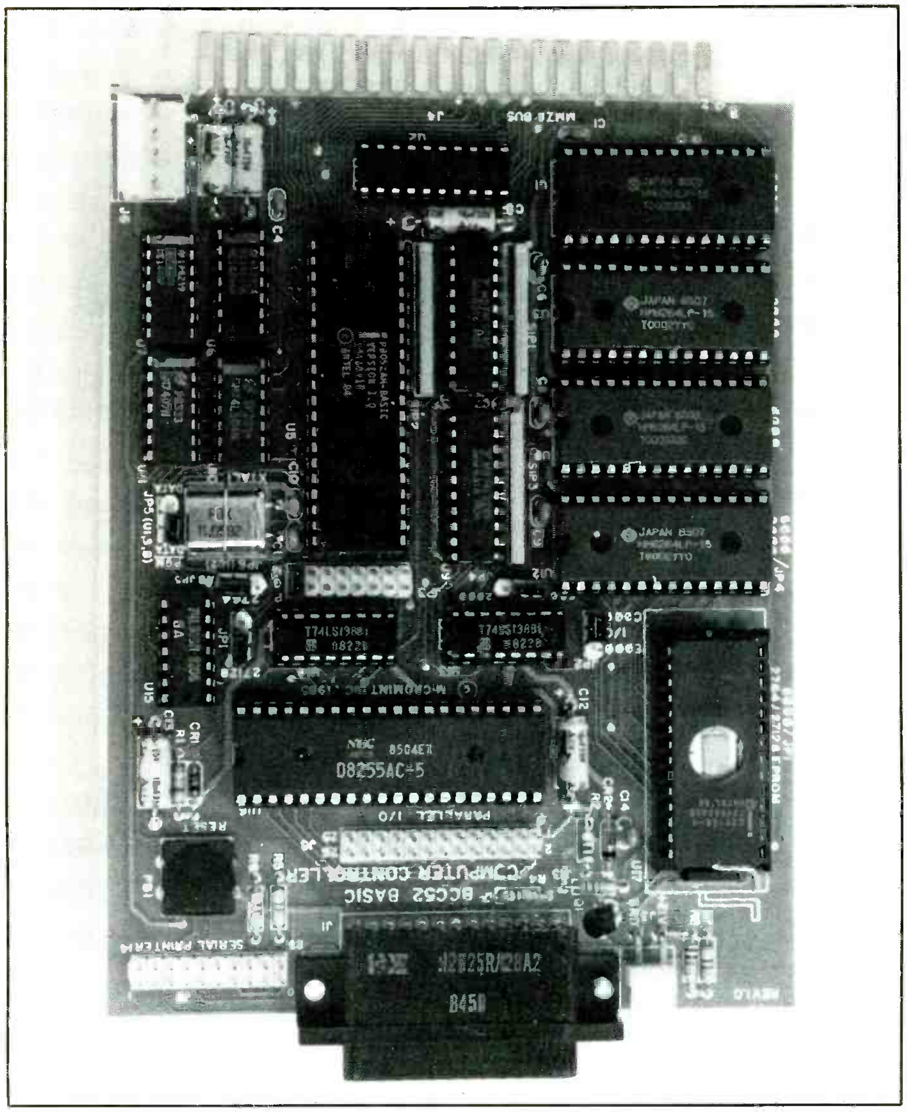


Fig. 1. The BCC52 computer/controller board contains an 80C52-BASIC microcontroller with a BASIC interpreter in ROM. The board also has an 8K × 8 RAM, three 8K RAM/EPROM sockets, EPROM programmer, three eight-bit parallel ports and serial terminal port.

The BCC52 Computer/Controller

First up is the BCC52 single-board computer/controller shown in Fig. 1. The BCC52 contains an 80C52-BASIC microcontroller, a CMOS (low-power) version of Intel's popular 8052AH-BASIC microcontroller IC. The 80C52-BASIC contains a full-featured BASIC-language interpreter in ROM. By connecting the

80C52-BASIC's serial port to the serial port of a computer or computer terminal, you can use BASIC to write, edit, run and store programs in RAM, EPROM or EEPROM.

The BCC52's 4.5 × 6.5-inch board also contains an 8K ×8 RAM, a quick-release socket for a 2764 (8K) or 27128 (16K) EPROM or EEPROM, three additional 8K RAM or EPROM sockets, a serial RS-232 port, an 8255 programmable peripheral interface (PPI) with three eight-bit parallel ports and a serial line-printer port. An 11.0592-MHz crystal provides a timing reference. All ICs are socketed for easy troubleshooting.

Board connections include a female DB-25 connector for the RS-232 port, dual-pin row headers to the parallel and line-printer ports, Molex-type power-supply connectors and an edge connector with data, address and control lines and power-supply connections.

To use the board, you provide the power supplies (+5 volts at 100 milliamperes, +12 volts at 30 milliamperes and −12 volts at 10 milliamperes) and a 3-wire serial cable to your computer or terminal. To store a program in EPROM, you must also provide the EPROM and its programming voltage (+21 volts or +12.5 volts, depending on the EPROM, at 30 milliamperes). Since the board's +12-volt supply is specified with 20% tolerance, you can use the same +12.5-volt supply for it and EPROM programming.

If you store your programs in EEPROM or battery-backed RAM, you don't need a special programming voltage (or an ultraviolet source for erasing).

The BCC52 comes with mating connectors for the power-supply connectors; so making cables for these is easy. You have to buy or make your own RS-232 cable with a DB-25 connector.

From your computer terminal, you can write programs in BASIC, try them out and save them to EPROM. As a terminal, you can use just about any computer with a keyboard, video display and RS-232 serial port. You also need communications software that allows you to send and receive from your serial port. You can use any of the many available modem-communications programs (*Procomm* is one example), or you can use the Basikit software included in the RTC52-EDS discussed below.

Listing 1. Parallel Port Bit Tester BASIC Program

```
100     PHO. "port1= ",PORT1
110     PORT1=PORT1.OR.080H :  PRINT "observe pin 8 high then hit
any key"
120     GOSUB 500
130     PORT1=PORT1.AND.03FH :  PRINT "observe pin 8 low then hit
any key"
140     GOSUB 500
150     PRINT "pull pin 8 high, then hit any key"
160     GOSUB 500 :  PHO. PORT1
170     PRINT "pull pin 8 low, then hit any key "
180     GOSUB 500 :  PHO. PORT1
190     END
500     IF GET=0 GOTO 500
510     RETURN
```

The 80C52-BASIC's BASIC interpreter is similar to other BASICs, with some added commands and operators for use in control circuits and EPROM programming. This example program tests a bit on a parallel port.

To boot the BASIC interpreter, you connect the BCC52 to your serial port, power up the BCC52 and your desktop computer, run and configure your communications software and press the SPACE bar at your computer's keyboard.

On boot up, a sign-on message appears on your video display:

```
*mcs-51(tm) BASIC V1.1*
READY
>
```

When you see this message, you can begin to write, edit, run and save programs using the 80C52's BASIC-52 interpreter. If you've used another version of BASIC (BASICA or GW-BASIC, for example), much of BASIC-52 will look familiar. Listing 1 is an example of a program written in BASIC-52.

Compared to assembly-language programming, BASIC has several advantages. It frees you from having to worry about such chip-level details as stacks, pointers and internal registers, and a single line of BASIC code will do the equivalent of many assembly-language instructions.

Since BASIC-52 is a language *interpreter*, rather than assembler or compiler, programming is interactive. You can write a program at your keyboard and run it immediately, without intermediate assembly or compile steps. This makes it easy to experiment with and debug programs.

BASIC-52 has a simple line editor that allows you to alter your program code and correct typing mistakes. As you type a line, you can delete and make changes, but once you press RETURN or (ENTER), you have to retype the entire line to change it.

A disadvantage of BASIC is its slower execution speed compared to assembly language, though BASIC is quick enough for many applications. If necessary, you can interface assembly-language routines to BASIC for faster execution.

BASIC-52 includes operators for arithmetic, logarithmic, trigonometric and relational functions, along with the logical operators AND, OR, exclusive-OR and NOT. Control structures include BASIC's familiar DO . . . UNTIL, DO . . . WHILE, FOR . . . TO . . . NEXT, GOSUB . . . RETURN and GOTO.

Also included are special commands to select, list, run and store programs in RAM or EPROM. While you're developing a program, you can store it in easily modified RAM. When the program is complete, a single BASIC-52 command stores the final version in EPROM or EEPROM, which save the program even if power is removed.

BASIC-52 allows you to store multiple programs in EPROM, with each program numbered sequentially as it is stored. To run the fourth program in the EPROM, you type ROM4 to select the program and then type RUN to run it. To create a stand-alone system, a special BASIC-52 command programs the EPROM so that on power up, the first program in EPROM runs automatically, without requiring connection to an external terminal.

A BASIC-52 manual (available separately) describes each of the more than 100 commands, operators and instructions in BASIC-52. Micromint's manual is an adaptation of Intel's MCS BASIC-52 User's Manual. The manual's many examples are a good way to get acquainted with the language.

Included with the BCC52 board is a 48-page manual that describes the board's major sections, including processor, address decoding, parallel and serial I/O and EPROM programmer. Also included are descriptions of all connectors and jumpers, information on how to power up the board and configure the PPI chip, complete schematics, a parts list and information on interfacing the many expansion boards available.

The documentation contains much useful information, but it is not oriented towards beginners to microcomputing. It assumes that you are familiar with topics like address decoding, hexadecimal numbers, serial and parallel interfaces and EPROM programming.

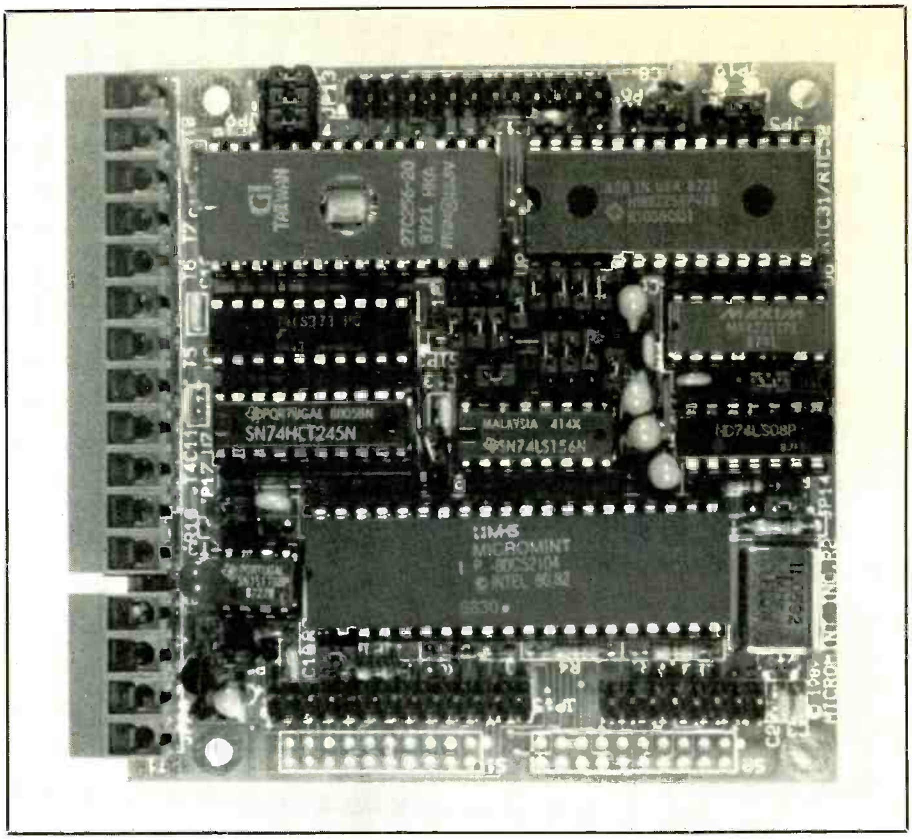


Fig. 2. The RTC52 measures just 3½ × 3¼-inch and operates from a single 5-volt supply. Expansion boards stack vertically on the processor board. Like the BCC52, the RTC52 can be programmed in BASIC.

For example, the BCC52 manual gives the pinout for the DB-25 serial connector and the communications format (eight data bits, no parity and one stop bit), but it leaves it to you to come up with the appropriate serial cable and communications software and to establish communication with your terminal. Since RS-232 interfaces are often confusing—with varying pinouts, numbers of wires, connector genders and communication protocols—a section describing how to find or make the correct serial cable and tips on establishing communication between the terminal and the BCC52 would be helpful.

In addition to the BCC52's manual and the BASIC-52 manual, you'll probably also want to obtain manufacturers' data books for the 80C52 and other major ICs on the board.

Expansion boards are available to extend the functions of the BCC52, using a four- or eight-slot motherboard. Available expansion boards include eight channels of optically isolated I/O (useful for 117-volt interfacing), eight relay outputs, a floppy/SCSI interface, an LCD controller and a prototyping board for adding your own custom circuits.

After reading through the documentation, checking jumpers and making the appropriate cables, my BCC52 powered up and operated without problems. Once the BCC52 is up and running, you can learn a lot about the board by experimenting, trying out programs and observing the results. For example, you can write programs to toggle I/O bits and use a logic probe, voltmeter or oscilloscope to verify that your program is doing what you intended it to do.

RTC52 Processor Board

Micromint's RTC52 controller (see Fig. 3) is a smaller, pared-down version of the BCC52 (though it does have a few features not available on the BCC52). The RTC52 uses the same 80C52-BASIC microcontroller IC as the BCC52, and the board is similar in operation. It includes a serial interface (RS-232 or RS-485) and two sockets for up to 64K of RAM and/or EPROM or EEPROM.

The RTC52 board requires only a single +5-volt supply, since a MAX232 chip generates ±10 volts for the RS-232 interface. The board measures 3.5" × 3.5" ×, or less than half the area of the BCC52.

Screw or quick-disconnect terminals connect to the power supply, RS-485 interface, eight bits of parallel I/O, two interrupt lines and two timer outputs.

Instead of using the traditional motherboard and edge connectors, the RTC52 is expanded by piggybacking boards on top of the processor board. The bottoms of the expansion boards have sockets that plug into dual-pin headers on the board below. This expands the system more compactly and less expensively than using a motherboard.

The RTC52's smaller size compared to the BCC52 is partly due to denser board layout and finer traces and partly due to fewer features being included. Most importantly, the RTC52 does not have the necessary hardware for using the 80C52's EPROM-programming commands. Instead, an applications note from Micromint suggests a couple of options for program storage.

One option is to use the BCC52 board described above as a development system and transfer your programmed EPROMs to the lower-cost RTC52 board. This is cost-effective if you'll be programming many EPROMs for multiple RTC52s.

Another option is to use nonvolatile (battery-backed) RAM instead of EPROM in the RTC52. Nonvolatile RAMs have their own back-up battery and automatically switch to battery power if main power fails. Dallas Semiconductor specifies that its nonvolatile RAMs will hold their data for at least 10 years. A short program (included in the applications note) copies a program to a nonvolatile RAM that is occupying the EPROM socket on the RTC52.

You can use the nonvolatile RAM as permanent storage, or if you prefer EPROMs, you can copy the programmed RAM into a stand-alone EPROM programmer, then re-copy into an EPROM.

For the RS-232 port, instead of the usual DB-25 serial connector, the RTC52 uses a dual-pin header. The manual describes how to make a ribbon cable that connects the header to a standard DB-25 connector. Another serial communications option is the RS-485 interface, which permits up to 32 devices to communicate on a single pair of wires.

The basic RTC52 has no programmable peripheral interface IC for I/O expansion. However, this is available on an expansion board. You must also provide the EPROM and/or RAM ICs for the sockets on the RTC52.

Documentation for the RTC52 is a 22-page manual that includes descriptions of the board and address space, descriptions of all jumpers and a complete schematic diagram and parts list for the board.

Power consumption for the main board is about 30 milliamperes, plus whatever is required for your EPROM and/or RAM.

Expansion boards for the RTC52 include a multifunction board with three eight-bit bidirectional parallel ports, eight-bit, eight-channel analog-to-digital (A/D) converter, eight-bit, four-channel digital-to-analog (D/A) converter and a battery-backed clock-calendar; an eight-channel optically isolated I/O board; a serial and infrared I/O expansion board; and a display, keyboard and X-10 power-line interface board. As with the BCC52, a prototyping board is available for adding your own circuits.

I tested the RTC52 board along with its multifunction board, display board and an LCD module. For a quick test, the manual includes a short program and description of how to connect a wire to cause the RTC52's LED to flash.

I found that the stacking arrangement for expansion boards does, indeed, create a compact system (each board adds ⅝ inch to system height)—in fact, it was a little too compact. Even a conventional ribbon-cable socket connector plugged into the RS-232 header was too tall to allow an expansion board to stack onto the main board. A nonvolatile RAM chip (which has its own socket) caused the same problem. To get around this, you must buy connector adapters that raise the expansion boards slightly or use low-profile components and cable connectors.

The boards' close fit also makes testing and troubleshooting difficult. But you can make ribbon cables to separate the boards for testing.

Each expansion board comes with its own manual that contains a complete schematic, parts list, system overview, set-up information and test programs.

The display board can drive a four- or eight-line by 20-character LCD display, which is available separately. Also included with the display board is a 5¼-inch MS-DOS floppy with test and demonstration programs for interfacing to LCD modules, LEDs, switches, keyboards and keypads, and X-10 interfaces for controlling ac power lines.

I tested a four-line by 20-character LCD module with my display board. The demo program was helpful for quickly testing the display, since it provides all of the module's obscure initialization and control commands. Examining the demo program can also help you understand how to use the module in your own programs.

Documentation for the multifunction board includes convenient short programs for testing the A/D and D/A converters, setting and reading the real-time clock and accessing the parallel ports.

Basikit

A final product relating to the BCC52 and RTC52 is the *Basikit* software from MDL Labs, which is available separately or as part of the RTC52-EDS (Economical Development System). (The RTC52-EDS includes the RTC52 board, an 8K × 8 RAM, the BASIC-52 manual and *Basikit*.)

Basikit comes on two 5¼-inch disks for IBM compatibles. This program simplifies and speeds up programming with the 80C52 (or 8052AH-BASIC) by providing a terminal emulator, a full-screen editor and utilities to convert and manipulate files.

Basikit is menu-driven and includes on-screen help; so it is easy to learn and use. A 45-page manual contains additional information and technical details.

The terminal emulator allows communication between a desktop computer and the RTC52, BCC52 or other 80C52-BASIC or 8052AH-BASIC system. Baud rate and COM1 or COM2 port are user-selectable at rates ranging from 300 to 38,400 bits per second. There is no guarantee that your computer can communicate at the faster rates, but experimentation will tell you how fast you can go. Using an 8-MHz 286 computer, I was able to communicate at 19,200 bits per second.

Basikit's screen editor has two modes: command and edit. In command mode you can write, list, run and edit programs, using 80C52-BASIC's line editor. You can also store programs to disk and read them from disk to the 80C52's RAM.

Edit mode offers more editing options. You can edit any program line (not just the current line) and scroll through a listing on-screen. Neither of these functions is provided by the 80C52-BASIC's simple line editor.

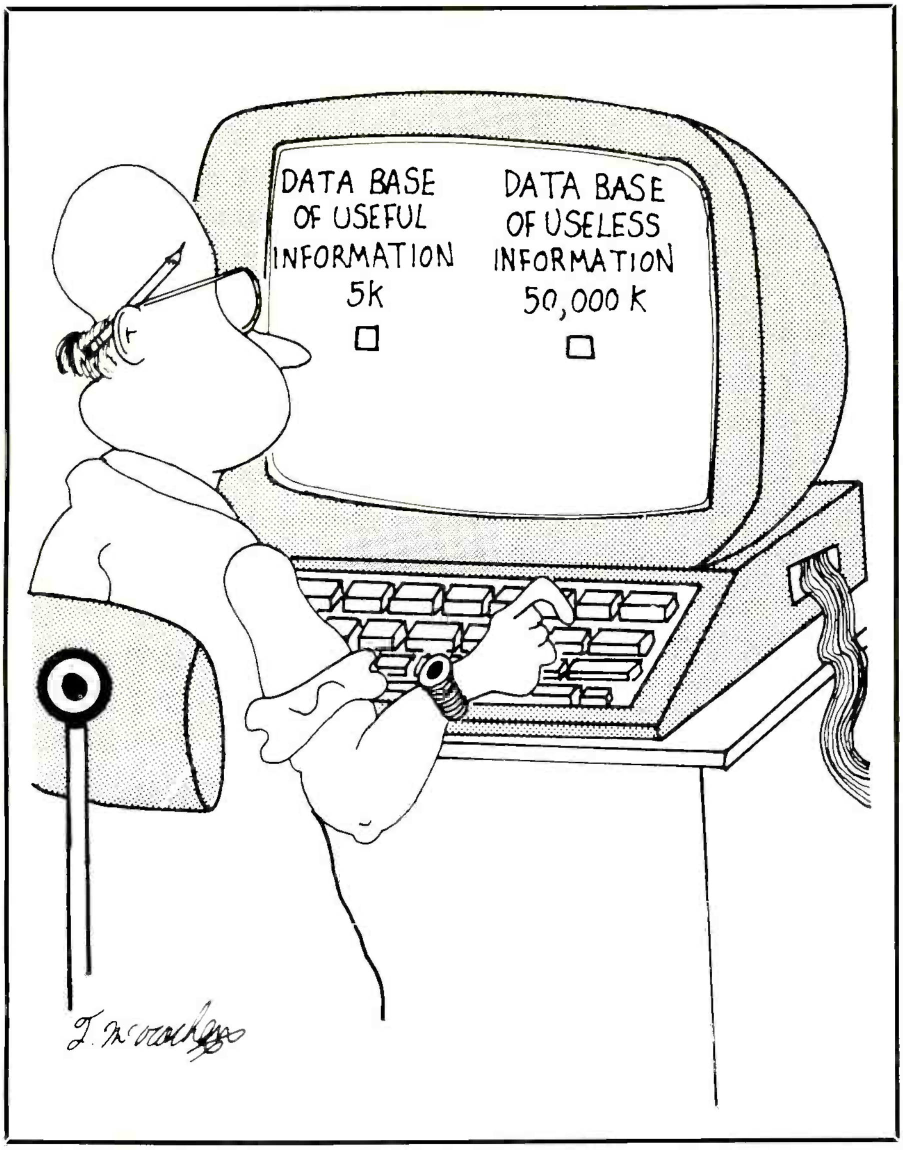
Basikit also has many file conversion and manipulation utilities. *Basikit* will add BASIC-52's required line numbers to a program, and it will compress a file by removing comments and excess spaces, for faster execution and more compact code. A separate source file that includes the stripped comments is preserved.

Other utilities place ASCII hex code anywhere in memory, program nonvolatile RAM and convert among ASCII hex, binary, BASIC-52 and Intel file formats.

You can configure *Basikit* to use either the COM1 or COM2 serial port, although a few computers, including a Zenith XT-compatible that I tried, will not run *Basikit* from COM2. According to MDL Labs, the reason for this is unknown, and the only solution is to switch to COM1.

Some of *Basikit*'s features—such as the terminal emulator and screen editor—can be appreciated immediately. Others, like the file-conversion routines, are most valuable when used with long or complex programs. Either way, you'll probably find something of use in *Basikit*'s many capabilities.

Either the BCC52 or the RTC52 is a good choice if you're getting started with microcontrollers or you want to get a project up and running quickly. The BASIC interpreter makes it easy to experiment with different programs, and expandability is easy, using the available expansion boards or prototyping boards for your own designs. If you prefer to design your own system, Micromint also sells the 80C52-BASIC IC by itself.



Products Mentioned

BCC52 Computer/Controller, $189
RTC52 Processor Board, $139
BASIC-52 Programmer's Manual, $15
80C52-BASIC chip, $25
RTC52-EDS Economical Development System (includes RTC52, 8K × 8 RAM, BASIC-52 Programmer's Manual and *Basikit* software), $199
Micromint, Inc.
4 Park St.
Vernon, CT 06066
1-800-635-3355 (outside CT)
203-871-6170
FAX: 203-872-2204

Basikit Software, $150
MDL Labs
15 Deerfield Rd.
Chappaqua, NY 10514
914-238-0416

Nonvolatile RAM
Dallas Semiconductor
4401 S. Beltwood Pkwy.
Dallas, TX 75244-3292
214-450-0448
FAX: 214-450-0470

Moving On

I welcome your comments, suggestions and questions on topics that relate to designing, building and programming microcontrollers and other small "single-purpose" computers. Send correspondence to me at *ComputerCraft*, 76 North Broadway, Hicksville, NY 11801. For a personal reply, please include a self-addressed, stamped envelope.

Next time: a look at Motorola's M68HC11 Evaluation Board, a low-cost tool for assembling, debugging and evaluating systems using the M68HC11 microcontroller chip with its own eight-channel, eight-bit A/D converter. ■

Jan Axelson

Forrest M. Mims III

Solid-State Power Supplies

Power supplies are usually considered the least-exotic section of an electronic circuit, especially when that circuit uses a microprocessor. Yet, without a power supply, a circuit is completely useless.

Recently, I found that a new kind of power supply could significantly improve operation of a miniature instrument I'd designed and built. This new supply, which uses no transformers, provides ± 15 volts when powered by a 5-volt supply. How this supply is able to provide a voltage increase without a transformer is an interesting topic. Even more interesting are some of the applications for such a supply. Even if this particular supply doesn't solve any of your design problems, one of its cousins might. Read on, and you'll find out why.

A Battery Problem

Recently, I built a miniature instrument that uses an analog divider circuit to calculate the ratio of two optical signals. While this circuit works well, the accuracy of the divider is influenced by the required ± 15-volt supply potentials. My present circuit uses two pairs of 7-volt mercury batteries to give ± 14 volts. As the voltage falls, though, overall accuracy of the divider's output is degraded with time.

There are two ways to solve this problem. The first is to completely redesign the circuit so that it uses a programmable microprocessor or calculator chip. This method permits the ratio of the two signals to be accurately calculated independently of the power supply voltage.

There are two drawbacks to this method. First, is that the signals from the optical detectors are analog. Therefore, the programmable digital circuit must include an analog-to-digital (A/D) converter. Secondly, the programmable approach requires considerably more time to design and program than the simple analog-divider approach. Just designing and making an etched circuit board for a programmable circuit digital takes considerable time, particularly since the board would probably have to have conductors on both sides.

An alternative way to solve this problem is to use a power supply that delivers a regulated ± 15 volts. Ideally, it should be powered by a single miniature battery.

Maxim Integrated Products (120 San Gabriel Dr., Sunnyvale, CA 94086) makes a wide variety of analog ICs. Among them is a series of chips designed for use in various kinds of low-voltage power supplies. One of these chips, the MAX743, provides a regulated ± 15 volts from a 5-volt supply. This chip provides a much simpler solution to the power-supply problem with my instrument than by using a digital approach. Other chips made by Maxim provide various other voltages from low-voltage batteries.

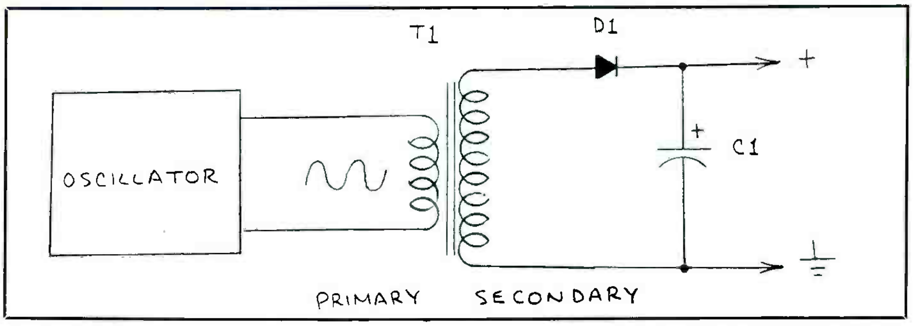


Fig. 1. Details for a basic dc-to-dc converter power-supply circuit that uses a transformer (T1).

No-Transformer Voltage Boosting

The traditional way to boost a voltage is shown schematically in Fig. 1. Transformer *T1* has two windings, one of which has more turns than the other. If an ac voltage is applied to the winding with fewer turns (the primary), a greater ac voltage appears across the winding that has more turns (the secondary). This voltage can be rectified by *D1* and filtered (smoothed) to dc with *C1*.

You can easily make a working version of the Fig. 1 circuit using a 555 timer chip or similar oscillator to drive the primary of a 6.3-to-117-volt transformer. Be sure to use a diode and capacitor rated for the appropriate output voltage. Also, be aware that a circuit like this can easily produce a few hundred volts. Therefore, use caution.

While the principle is less obvious, a single winding of a transformer or choke can also provide a voltage boost. Consider a pulse of current applied across a coil. When the flow of current is suddenly stopped, a much greater voltage than that across the coil is induced into the turns of the coil by the collapsing field. The resulting current spike can easily have an amplitude of hundreds of volts, even when only a few volts is applied.

This phenomenon is why a reverse-biased diode is often placed across the coils of relays. The diode provides a

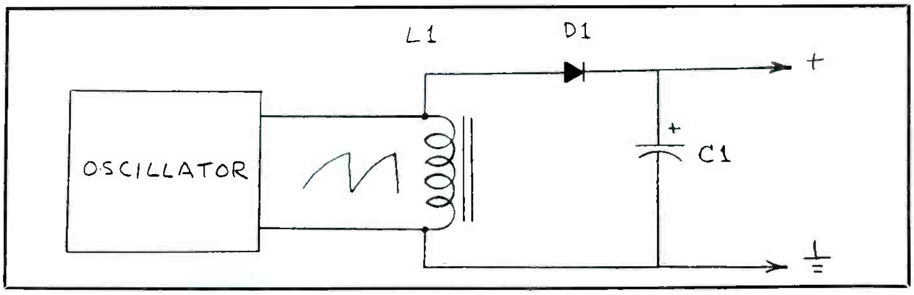


Fig. 2. Details for a basic dc-to-dc converter power-supply circuit that uses a choke (L1).

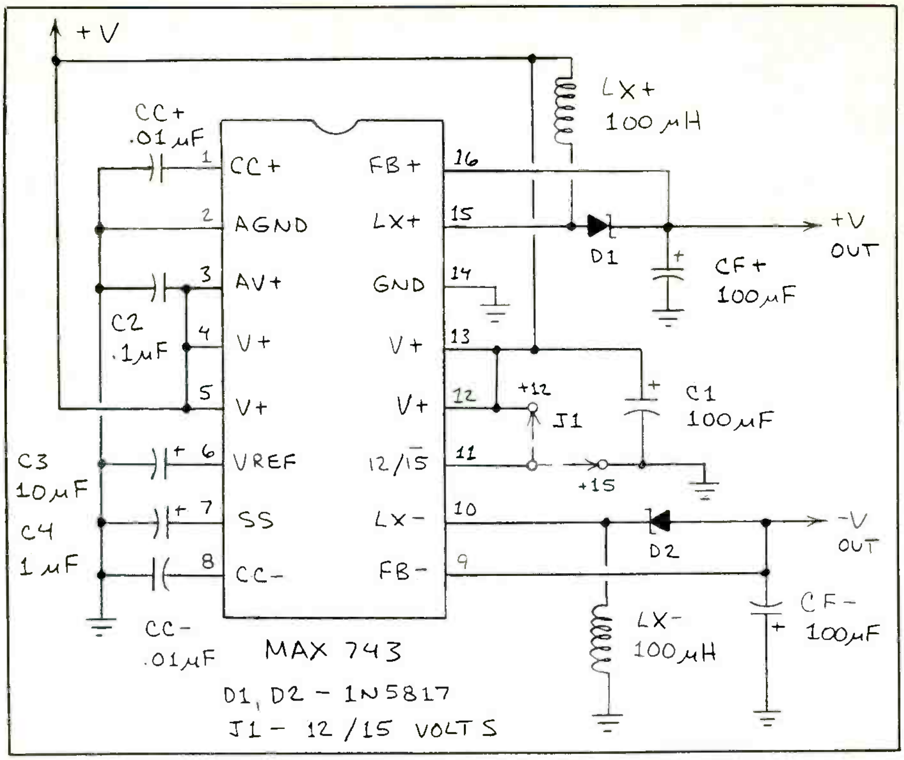


Fig. 3. Schematic of a working −15-volt supply made with a MAX743.

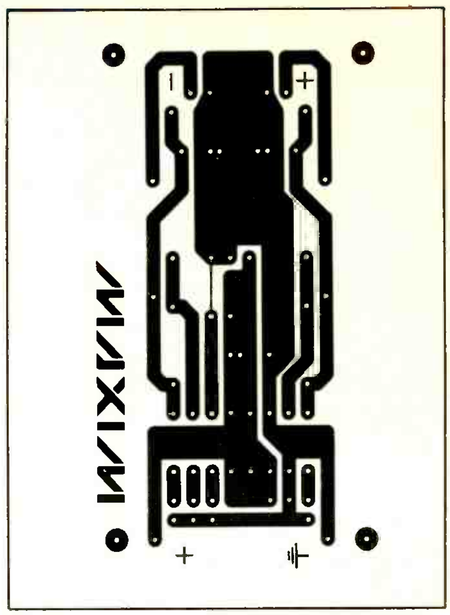


Fig. 4. Actual-size etching-and-drilling guide for a printed-circuit board for the MAX743 recommended by Maxim and used here with permission.

short-circuit path for the voltage spike that's generated when current stops flowing through the relay's coil. Without the diode, the voltage spike might flow through the wires leading to the relay coil and damage the relay's driver circuit.

One early version of a transformerless high-voltage supply is known as the ringing-choke power supply. The idea behind this circuit is to supply a pulsating flow of current to a choke coil. The pulses can have a slow rise time, but they should have a fast fall time. A capacitor (*C1*) is connected across the coil's terminals through a diode (*D1*), as shown in Fig. 2. Each time the current momentarily ceases to flow, a voltage spike passes through the diode and is stored in the capacitor. The diode keeps the capacitor from discharging through the coil. The output from the circuit is a direct current with a ripple value determined by the size of *C1*.

Apparently, the ringing-choke supply was named after the hum produced by the oscillating current applied across the choke. These supplies can be both small and efficient. One I built to power a tiny Geiger counter produced an equally tiny audible hum and several hundred volts from a 1.2-volt nickel-cadmium cell.

Power Supply Chip

The ringing-choke principle can be applied to the design of modern IC dc-to-dc converter power supplies. For example, the MAX743 is a 16-pin device that functions as a dc-to-dc converter with a dual-polarity output of either ±12 or ±15 volts. This chip provides a maximum load current of up to 100 milliamperes in the ±15-volt mode.

Both outputs of the MAX743 are regulated independently of each other to within ±4% of their rated output voltage over the chip's specified range of operating conditions. The chip provides a power conversion efficiency of from 75% to 82% for most loads. A built-in thermal shut-down circuit prevents overheating and possible damage to the chip.

An oscillator inside the MAX743 requires several external components. Since the oscillator is laser-trimmed for a precise frequency of 200 kHz, external trimming components aren't required, and different chips can be used with the same external components to provide predictable operation.

Figure 3 shows how the MAX743 connects to external capacitors, diodes and inductors to form a working power supply. Jumper *J1* permits the output from the circuit to be selected as either ±12 or ±15 volts.

Diodes *D1* and *D2* must be 1N5817 (Fuji No. SE014) or 1N5802 Schottky devices or equivalent. Note that the positive and negative outputs each has its own inductor and associated capacitors. The inductors can be made by winding 30 turns of No. 30 insulated wire on a Magnetics 58238 ferrite core. Or they can be purchased ready-made from Gowanda Electronics Corp. (1 Industrial Pl., Gowanda, NY 14070).

MAX743 Evaluation Kit

Though you can assemble the circuit shown in Fig. 3 on a solderless breadboard, best results are obtained if you assemble it on a printed-circuit board, the actual-size etching-and-drilling guide for which is shown in Fig. 4, and wire it according to Fig. 5.

If you don't have the time to duplicate the recommended pc board, you can do as I did and order an MAX743EVKIT evaluation kit from Maxim. The kit, which costs $20 postpaid, includes the board and all components needed to assemble the complete supply. Also included in the kit are additional components for a pair of optional Pi filters that reduce the noise level at the two outputs to less than 2 millivolts peak-to-peak. (These filters aren't shown in Fig. 3) Besides saving you the time needed to find the parts and the trouble to make the board, the kit saves the difficulty of ordering the 1N5817 Schottky diodes and the inductors. Whether you order the kit or proceed on your own, be sure to request a copy of the MAX743 application note. This note contains essential information about component values and other important facts.

You can assemble the MAX743 evaluation kit in less than half an hour. Though the kit doesn't include an IC socket, I decided to use one, just in case I

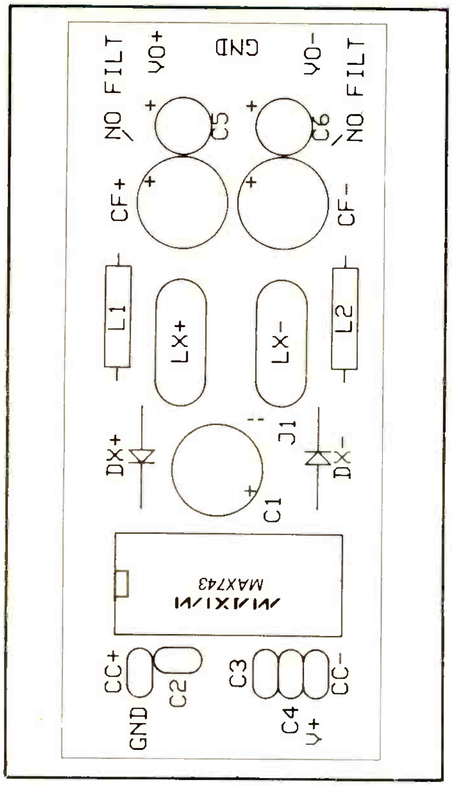


Fig. 5. Component layout diagram for pc guide shown in Fig. 4. The space for C4 is not used with the evaluation kit.

damaged the MAX743 as I was evaluating and testing the board. The socket also permits the chip to be removed while components are installed or replaced.

Assemble the kit by following the parts-placement diagram shown in Fig. 5 or in the MAX743 ap note. Assembly will be easier if you first install the smallest components. After all components are installed, connect some lengths of insulated hookup wire to the power-supply inputs and the voltage outputs. Figure 6 is a photo of an assembled version of the kit.

Before applying external power to the circuit, double check all components to make sure each is installed in its correct location and is properly oriented. Also, make sure that the output voltage of the power supply doesn't exceed the maximum allowable rating (+6 volts in the ±15-volt mode).

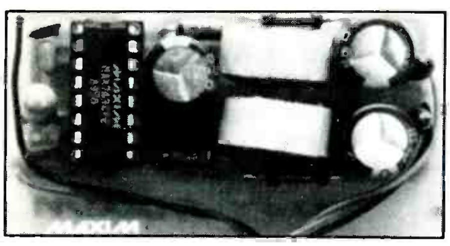


Fig. 6. An assembled MAX743EVKIT that delivers ±15 volts when powered by a single +5- to +6-volt supply or battery. (Photograph courtesy of Maxim Integrated Products).

Connect a dc voltmeter or a multimeter set to the dc-volts function across the +15-volt output and circuit ground and apply power to the circuit. Then check the −15-volt output. The circuit I assembled provided outputs of +14.90 and −14.92 volts with no load.

Repeat these tests with a 180-ohm load resistor (supplied with the evaluation kit) across each output. This resistor will drain 83 milliamperes from each side of the supply, which is equivalent to a power consumption of 1.25 watts per channel. Nevertheless, even with this relatively high drain, the outputs of the circuit I assembled were +14.78 and −14.79 volts, or better than 99% of the no-load voltage level. As you can see, this circuit provides excellent performance and uniformity between outputs.

Since I intended to use this circuit in a battery-powered application, I was curious to determine the minimum supply voltage that would give a ±15-volt output. With no load, the circuit I built delivers a stable ±14.9 volts down to a minimum supply potential of around 4.2 volts. In short, the circuit is ideally suited for operation from a 6-volt battery.

Operating Precautions

Several operating precautions must be observed when using the MAX743. A short-circuit between CC+ and CC− may damage the MAX743. Therefore, when testing the pc version of the circuit, be sure to place the board on an insulating surface that's free of bits of wire, solder and metal. Also, be sure to observe the power-supply maximum voltage ratings (+7 volts for the ±12-volt mode and +6 volts for the ±15-volt mode). Exceeding these ratings may damage or destroy the MAX743.

Remember that maximum load current decreases from the maximum permitted of 100 milliamperes when the temperature of the chip rises above around 60 degrees Celsius. *Never* plug the MAX743 into or remove it from its socket when the power supply is connected. Also, never solder or try to change components when the circuit is powered. Finally, the output filter capacitors must be connected when the chip is operated.

Other Maxim Devices

While I am prepared to power the circuit described at the beginning of this column from a small 6-volt battery, the prospect of using only one or two penlight cells to get ±15 volts is intriguing. This possibility can be made real by means of one of the MAX654-658 family of Maxim dc-to-dc converter chips. The MAX655EVKIT is an evaluation kit that contains a pc board and all components needed to assemble a 5-volt supply powered by a pair of AA cells. Figure 7 is a photo of an assembled version of this kit. The $20 price for this kit seems a bit excessive in view of the reduced number of components it contains compared with the MAX743EVKIT.

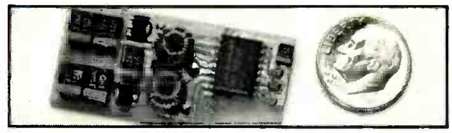


Fig. 7. An assembled MAX655EVKIT that delivers +5 volts from two AA penlight cells. (Photograph courtesy of Maxim Integrated Products).

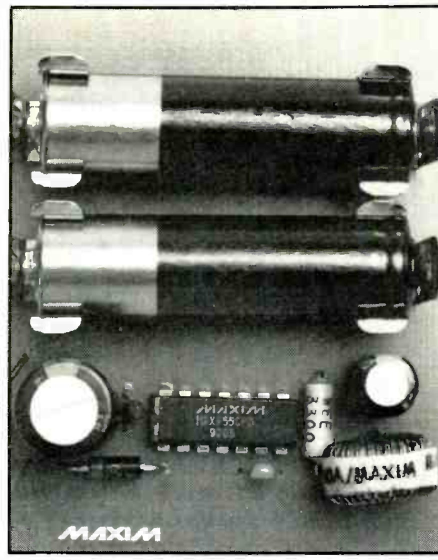


Fig. 8. A miniature ±15-volt MAX743 power supply made from surface-mount components. (Photograph courtesy of Maxim Integrated Products).

The idea of powering my circuit from one or two inexpensive penlight cells is intriguing. But the additional board will take up lots of space. Therefore, it might be best to use a more costly 6-volt battery and keep the size of the instrument down.

Going Further

The MAX743 evaluation kit weighs only slightly more than an ounce when assembled. If that's too heavy for your application and/or if you want the smallest possible size, Maxim makes a surface-mount version of the MAX743. Figure 8 is a photo of a surface-mount ±15-volt supply that uses this tiny version of the MAX743. As you can see, the circuit is only slightly larger than two dimes placed side by side. Apparently it's very difficult to find surface-mount inductors for this supply. If an evaluation kit becomes available, I'll let you know. ■

Joseph Desposito

A High-Performance 80386 Chip Set, New Floppy-Disk Controller, World's Fastest DRAM, Programmable Clock Generator and an AC Suppresser

This time around, we lead off with a discussion of the features of a high-performance chip set for 80386 computers from Suntac USA in San Jose. Then it's on to a DRAM that its maker, NMB Technologies, claims is the world's fastest; the newest member of the NEC family of floppy-disk controllers; and a programmable clock generator that provides multiple frequencies from a single IC. We finish up with a 1,000-volt surge suppresser that takes up only 1.25 square inches of pc-board real estate.

i80386 Chip Set

Suntac USA (2107 N. First St., Suite 370, San Jose, CA 95131) has a chip set that's fully compatible with the IBM PC/AT. It offers increased performance in a compact package for i80386 systems that utilize i82385 cache controllers.

The Suntac ST62CS30-A chip set, which supports 25- and 33-MHz clock speeds, was designed using the latest CMOS technologies for high-density mounting and low power consumption. A single Suntac chip set can be used to create a high-performance desktop, laptop or notebook computer.

At the heart of the four VLSI (very-large-scale integrated) chips that make up the set is the ST62CS30-A Address Bus Extender. This chip provides the READY and HOLD signals to the CPU and cache controller, and a 24-bit address latch for the i82385 pipeline operation. Additionally, it contains the i80387 and Weitek 3167 interface and the turbo circuits.

The remaining chips in the set have the following features and functions: The ST62C301-A Data Bus Extender contains a 32-bit data latch and data buffers that support the posted write function of the i82385. This chip also acts as the interface between main memory, 16- and 8-bit AT buses and i80386. The ST62C251-A system Bus Memory Controller controls operation of the AT bus at 8 MHz and is completely independent of the i80386 clock speeds of 25 and 33 MHz, which allows for various access times of DRAM and ROM BIOS. The ST62C303-A controls the address bus in DMA cycle and the B-port and outputs the i80386 address bus to the expansion slot address bus to synchronize timing with that of the AT bus clock. Internally, this last chip includes two 82C37 DMA controllers, two 82C59 interrupt controllers and one 82C54 timer controller.

Additionally, the Suntac chip set includes: two- and four-way page-interleaved memory operation that supports up to 16M of high-speed memory; 1M to 16M of local DRAM, fully accessible by DMA; quick CPU reset and Gate A20 for OS/2 optimization; in-circuit, tri-state test mode; and support for LIM EMS 4.0. Information and pricing for the ST62CS30-A chip set is available from Suntac USA.

Currently the fourth largest manufacturer of chip sets in the world, Suntac USA (a subsidiary of Japan's Sun Electronics Corp., a leading international manufacturer of electronic products) develops computer chip sets used in the manufacture and design of personal and laptop computers.

World's Fastest 1M DRAM

NMB Technologies' (9730 Independence Ave., Chatsworth, CA 91311) new AAA-1M300 series 1-Mbit DRAM is claimed to be the world's fastest CMOS DRAM at 53 ns. The new high-speed 1M device is offered in 1M × 1 and 256K × 4 versions. Both versions are specified to have maximum access times of 53, 60 and 70 ns. Read/write cycle times are as short as 100 ns. The high-speed design permits direct memory access with 16- and 20-MHz microprocessors, eliminating the need for cache memory and improving system performance.

The AAA1M300 is available in enhanced-page mode with page mode read/write cycle time of 40 ns. Operating potentials range from 4.5 to 5.5 volts and temperatures from 0 to 70 degrees Celsius. Power consumption for the new 53-ns, 1M DRAM is 400 mW when powered from a 5.0-volt dc source.

The 100-ns read/write cycle time permits designers to create zero wait-state systems utilizing 20-MHz microprocessors, without having to resort to complex interleaving or caching schemes. Tests of 20-MHz 386SX systems and 53-ns DRAMs conducted by the company suggest a 25% increase in MIPS, compared to a dual-bank interleaving technique using 80-ns DRAMs.

Pricing for the new 1M DRAM is in the $5-per-unit range in quantities of 10,000.

NEC Floppy Disk Controller

A new IBM PC-compatible CMOS floppy-disk controller is available from NEC Electronics Inc. (401 Ellis St., P.O. Box 7241, Mountain View, CA). The μPD-72064 is a highly integrated solution for space-critical designs. This controller supports the complete PC/AT register set and standard data rates. It has been enhanced for multitasking applications.

This is the newest in a line of controllers from the company that introduced the industry-standard μPD765A/B and the μPD72068. The μPD72068 was the forerunner of the new chip, offering a high-performance digital phase-lock loop. This feature is also included in the μPD72064, providing analog level performance without the need for external components or making adjustments.

Software compatible with the μPD-765A/B, the new μPD72064 contains upgrades that ensure overrun detection to eliminate the possibility of data corruption in multitasking environments. Because it is pin-compatible with other leading FDCs, it provides performance improvements without costly redesign.

The μPD72064 features on-chip clock generation, selectable write pre-compensation, host-interface registers for the PC/AT and a high-performance DPLL data separator that eliminates the need for maintenance adjustments.

High-current drivers and Schmitt receivers provide direct interfacing to the drive, and standard data-transfer rates are supported on one crystal (250K and 500K bps, MFM). A power-saving standby mode makes the chip well-suited to portable applications. A block diagram of the device is shown in Fig. 1.

The μPD72064 FDC is available in 44-pin PLCC packages at $4.80 each and 52-pin QFP packages at $4.40 each, both in quantities of 10,000 or more units.

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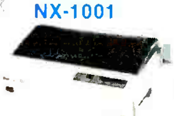

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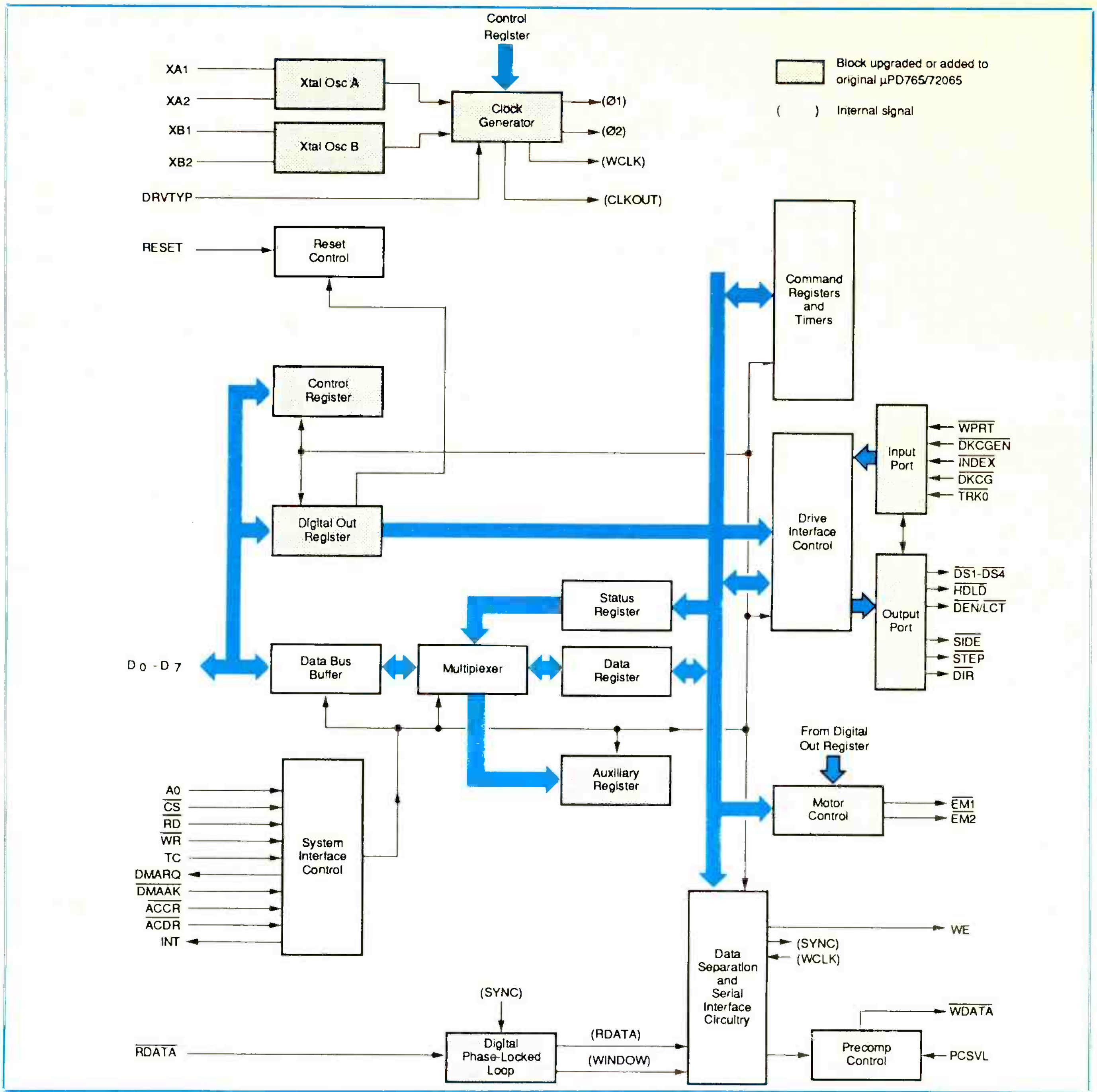


Fig. 1. Block diagram of NEC's µPD82064 floppy-disk controller chip.

CA 95052) has a pair of high-frequency programmable clock-generator chips based on the principle of frequency synthesis and phase-locked loop.

These devices use frequency synthesis to generate a variety of output frequencies for computer-system timing from just a single reference frequency. The DP8531 and DP8532 Programmable Clock Generators are targeted for enhanced graphics and mass-storage applications in personal computers.

The DP8531/8532 have sufficient frequency range to produce the timing signals required for both low- and high-resolution graphics systems. The DP8531 can be programmed on-the-fly via a four-bit bus to generate virtually any frequency from 0.78125 MHz to 160 MHz. Most conventional clock generator ICs have a maximum usable frequency of only about 45 MHz. Because DP8531/8532 chips are fabricated in BiCMOS, the devices can provide both true TTL and differential ECL outputs. ECL logic levels are often desired for high-speed applications in the 80-to-160-MHz range.

The DP8532 is a ROM-masked version that can select any of eight frequency options pre-programmed at the factory.

The DP8531/8532 produce output clocks when driven from an external reference input, either a 1- to 40-MHz crystal oscillator or a TTL source. Both devices can be genlocked to an external TTL source by using the dual phase detector functions on the chips. The devices use frequency-synthesis and PLLs (phase-locked loops) to generate fully programmable clock output frequencies.

In applications that require multiple clock frequencies, the DP8531/8532 devices can reduce component cost and increase reliability over conventional timing-generation schemes in two ways. One is by operating from a single reference crystal to create all of the required frequencies, replacing multiple crystal oscillators. The second is by using the programmable clock generator with an inexpensive reference frequency crystal to replace expensive, high-frequency ECL crystal oscillators.

Graphics boards, which often contain a processor, memory and video DAC (digital-to-analog converter), require separate system, pixel and load clocks. The DP8531/8532 generate all clock outputs from a single, low-frequency crystal, eliminating the need for a pixel clock crystal oscillator.

Non-graphics applications can also benefit from the multi-frequency capability of the clock generators. One such use is in zone-bit recording (ZBR) applications that pack more data on hard disks. By varying the clock input on disk data synchronizers, designers can change the read/write rate at different zones on a disk, thus using the space more efficiently.

Due to their high-frequency operation, PLL ICs are sensitive to layout and wiring variations on a printed-circuit board. To simplify the design task, National Semiconductor has created an evaluation board (DP8531EB) that permits designers to observe how the clock generators perform when properly installed on a printed-circuit board.

Apple Computer already uses the DP-8531 in its recently introduced graphics adapter boards for Macintosh displays, and Maxtor uses the chip in ZBR hard-disk applications.

The DP8531V programmable clock generator is available in a 28-pin PLCC for $25 each in 100-piece quantities.

AC Suppresser

Amber Industries' (P.O. Box 790712, Dallas, TX 75379) AI-025 and AI-025-CM are designed to suppress a 1,000-volt transient to within 1 volt of the ac sine wave (60 dB). This feature satisfies the surge withstand capabilities of IEEE 587 categories A and B (ANSI C64.21). Both models utilize only 1.25 square inches of board space (1″ × 1.25″) and are, therefore, ideal for mounting on printed-circuit boards. These devices not only cure spikes, but also fill short-term notches in ac power. Model AI-025 is a four-pin device that protects for normal mode only. The AI-025-CM is a five-pin device that protects both normal-mode and common-mode.

Zeos International's Notebook 286

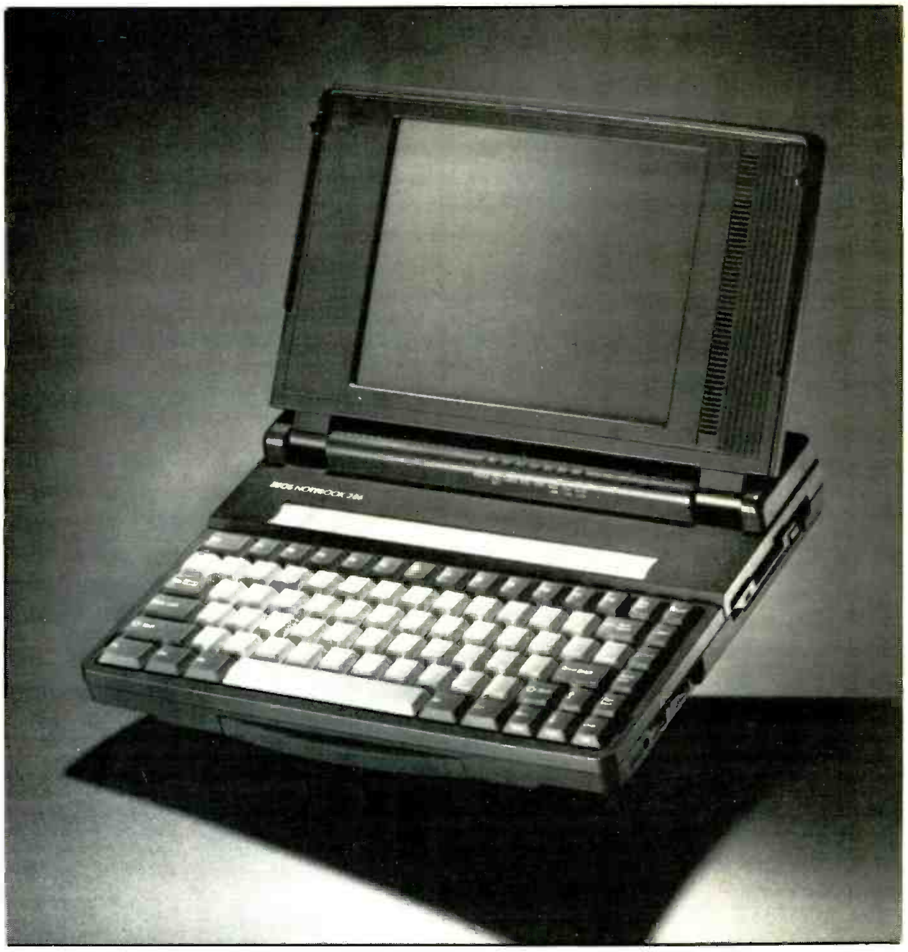
One of the joys of writing this column is the sheer volume of things I get to look at. I don't always write about everything I review, but act as sort of a filter, talking about those things I liked most. However, there's a down side to the job; I sometimes inadvertently miss a company I meant to mention, or when a column is running very long, I spend less time on a company than I had intended to.

Before I get to this month's "meat," I'd like to update several previous columns for you. In the January issue, I discussed a number of CD-ROMs for the Macintosh. While I mentioned the Bureau of Electronic Publishing as a source, I forgot to mention Wayzata Technology, a company whose catalogs I've been getting for some time now. Wayzata is a publisher, rather than a distributor, and CDs can be ordered both directly from the company and a number of other companies, such as the Bureau. At the present time, 22 titles are listed, including public-domain collections of games, reference disks for Apple programmers and a variety of image collections. My favorite title (though I haven't seen the CD) is *About Cows*. Although my own interest in cows doesn't extend much beyond a Porterhouse steak with baked potato, this $39 ROM has extensive bovine information and even digitized pictures.

Wayzata's catalog also has more conventional Mac titles, like the *1990 CIA World Factbook*, that I'll be looking at in a future column. The company's telephone number is 800-735-7321, and its catalog is free. If you have a Mac with a CD-ROM drive (or you're thinking of adding a drive to your Mac), give Wayzata a call.

In my last column, I mentioned Voyetra Technologies somewhat in passing while reviewing Brown-Wagh's Sound Blaster card. This has a built-in 11 voice FM synthesizer, and Voyetra has a special version of the $69.95 SPjr sequencer that lets you take full advantage of this synthesizer. What I didn't have room to mention, though, is that the Application Programming Interfaces (APIs) that Voyetra includes with the Sound Blaster board are making some waves of their own in the industry.

Voyetra's Multimedia APIs are used by a number vendors, including IBM in its *Storyboard Live!* package, to provide MIDI-based sound control to presentation software. Voyetra is one of the best-known companies in the computer-music field, and its product line includes three levels of sequencer software, several PC-oriented MIDI interfaces, Mpc, an IBM version of Interactive Software's "M" package I reviewed here several years ago and even complete packages that include an IBM-compatible interface card, sequencer software and, if you desire, a MIDI keyboard. Its catalog makes interesting reading. If you're involved in computer music (or even just considering it), write or call for a copy (Voyetra Technologies, 333 Fifth Ave., Pelham, NY 10803; 914-738-4500).



Zeos Notebook 286

I have a love/hate relationship with laptops. I love the idea of being able to get work accomplished when I have to travel or to be able to computerize parts of the many presentations and talks I give every year, but I hate having to lug a PC with me. I usually travel with a carry-on and garment bag. This gives the airlines less of a chance to lose my luggage, and a 15-pound (or even a 10-pound) PC is often the straw that breaks this particular camel's back, especially if my flight is a connecting one, with a half mile between arrival and departure gates.

Recently, I've taken to either foregoing the portable completely or using United Parcel or Federal Express to do my carrying for me. This considerably light-

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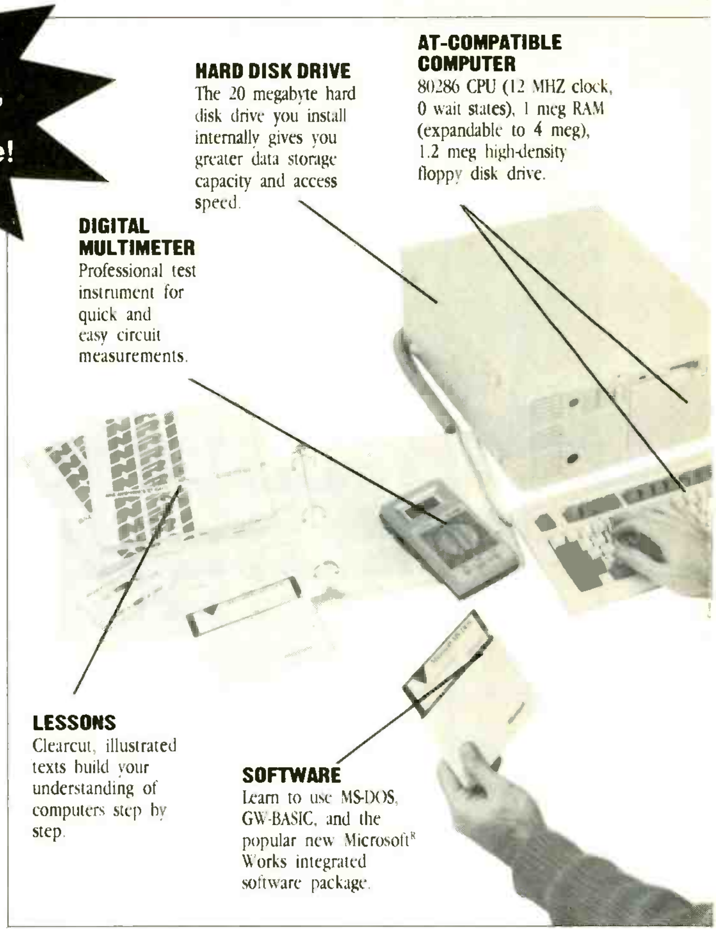

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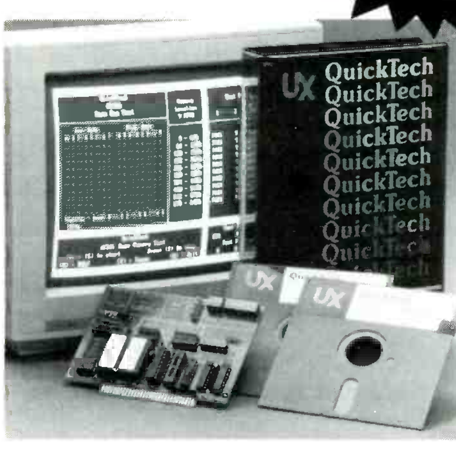

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City/State/Zip

Accredited Member, National Home Study Council 4-051 ens the load on my back, but it puts more of one on my wallet.

Compaq's LTE/286, which I reviewed a while back, provided a viable solution while I had it. At its hefty asking price, it had to go back to Compaq after the end of the loan period. However, the Zeos Notebook 286 I've been playing with lately gives me all of the features of the LTE/286, with a few extras thrown in, at a price I just might be able to talk my company into going for.

Zeos International is a mail-order firm that has become quite well known in the last several years. I reviewed its $1,400 386SX desktop system in this column a while back and was very impressed at the value it provided. The Notebook 286 only serves to reinforce this impression.

Portable PCs are becoming the hot system to own. They let you easily (or not so easily, depending on size and weight) take your work along with you, whether across the country, to and from work, or upstairs at home, when you don't want to sequester yourself in your downstairs office. The form factors of these systems have stratified into three fundamental types over the years.

Lunchboxes, patterned on Compaq's popular Portable II and Portable III systems, are the largest and heaviest. In the 20-pound range, these systems usually aren't battery operated, but they often provide expansion slots for standard peripheral cards. Next come the familiar clamshell-style laptops. These are hinged in the middle of the case, with screen on top and keyboard on bottom. Many clamshells will run for several hours on a built-in rechargeable battery, are available in 286 and 386 CPU versions and often weigh between 12 and 17 pounds.

The latest, and fast becoming the most popular class of laptop, however, is the notebook. This is a clamshell-style PC that's approximately the same size as a three-ring notebook. Many models offer VGA-resolution LCD displays and weigh about 7 pounds or so with built-in rechargeable battery installed.

Notebook PCs make a lot of sense. They're small enough to fit into a briefcase or other carry-on, and at 7 pounds, light enough to consider taking on a long trip. Until now, their main disadvantage has been cost. Compaq, NEC, Toshiba and others all have notebooks, and these systems are generally in the $3,000-and-up price range with a hard disk.

Not so with the Zeos Notebook 286. For a reasonable $1,995, you get a 12-MHz 80C286 CPU, 1M of RAM, a 1.44M 3.5-inch floppy disk, 20M IDE hard disk, backlit LCD display with VGA resolution and a decent 82-key keyboard. All this comes in a well-made case that measures 12.3"W × 10"D × 2"H and weighs just 7 pounds.

The $1,995 price doesn't include MS-DOS, but it does include a battery and ac power supply/recharger. The operating system is available separately for $119, or as part of a number of packages with other options. Package #1 includes the Notebook 286, an upgrade to 3M of RAM, a very nice custom-fitted nylon carrying case, a battery charging stand and extra battery and MS-DOS 4.01 with GW-BASIC. This gives you the capability of charging the extra battery while using the system on battery power and costs $2,495, which represents a $186 savings over the options if purchased separately. Package #2 (priced at $2,895) upgrades RAM to 5M (the system's maximum) and adds an internal 2,400-baud modem with MNP Class 5 error correction.

The unit I received for review was the base system, but it included MS-DOS and the carrying case. Even if you don't go for a package, the $79 carrying case is a good deal. It's custom-designed for the Notebook 286 and has separate pockets that accommodate the charger, an extra battery and even a half-dozen floppy disks. The padded shoulder strap makes it easy (and fairly comfortable) to carry long distances and adds about a pound to the total weight.

As with many notebook-style systems, the Zeos can't support add-on peripheral slots. There's just no room for them in the densely packed case. However, it does have a proprietary slot for an internal 2,400 baud modem, a video out port to which a standard color VGA monitor can be connected and serial and parallel I/O ports. If you aren't using the serial port for a mouse, a pocket modem, available from a variety of vendors, can be attached to this port, as can several vendors' packet fax boxes.

Zeos' backlit LCD screen is excellent. Many of the laptop LCDs I've seen lately have had uneven color across part of the screen. The Notebook 286's screen is clear, crisp and easy to read. There are adjustments for brightness and contrast, which enable the screen to be used in any lighting situation. I did experience a slight bit of cursor ghosting when running *Windows* 3 with a mouse. This is common, though, on LCD displays. Because of the panel's slow switching speed, when compared with a standard CRT, or even gas-plasma display, every LCD panel I've ever seen exhibits this ghosting to some degree, and Zeos' was less than many other similar systems. The LCD panel is capable of supporting 32 shades of gray, which can be mapped to colors with a utility program Zeos includes with the system.

I'm a bit less impressed by the keyboard. As notebook keyboards go, it's okay. It has a pleasant feel, but as with just about every laptop this size, it features a numeric keypad embedded within the standard keyboard. You access this keypad by pressing a special Fn key located at the bottom left of the keyboard. This is a pretty much standard feature with notebook PCs, but it's an annoyance if you must perform a fair amount of numeric input.

Its Phoenix BIOS lets you set various power-conservation functions to prolong battery life. These include a screen backlight power-down after a predetermined time (which you can alter), as well as a similar feature that powers down the hard disk between accesses. I generally turn off these power-conservation features because the applications I run perform disk access fairly often, and when I'm using word processing (my primary application), I often pause between writing sections of text and find it annoying to have the screen go dark just as I'm about to resume typing. With the power-conservation options disabled, I've averaged between 1¾ and 2¼ hours on a charge. The battery recharges while you're using the system on ac power, again a common feature, but one I appreciate.

I freely admit that the last couple of years have spoiled me somewhat. Both of the PCs I usually use at work and at home are 386 systems. A 12-MHz 286's performance now seems somewhat snail-paced to me, especially when running *Windows* 3. Yet the Zeos Notebook 286 is an easy PC to like. It's well-made (the basic system is OEM'ed from Sanyo), light in weight, yet with both floppy and hard disks and a megabyte of RAM, it's still powerful enough for many of the tasks I want to get done while traveling. And the price is hard to beat.

Zeos also offers a 16-MHz 386SX version of the Notebook for $2,295. I haven't tested this system, but on the surface, it seems to make a bit more sense for *Windows* or heavy spreadsheet applications and isn't really much more expensive.

The Zeos isn't perfect. I'd love to see a port to plug in a standard keyboard, and a second serial port would let me use both a serial mouse and a pocket modem/fax board. But at less than $2,000, the price is right, and it's a terrific value for what it does give you. ■

Product Mentioned

Zeos Notebook 286
Zeos International, 530 Fifth Ave. NW
St. Paul, MN 55112
800-423-5891

0.1-μF disk capacitors (2)
0.001-μF disk capacitor

Wire the circuit according to Fig. 10 on any convenient breadboarding system or on the solderless breadboarding section of your *Modern Electronics* Prototyping Station. When you're done, carefully check all wiring. Bear in mind that if you incorrectly wire the power supply, you may destroy the op amp.

Set the input sensitivity of your scope to 5V/div. and select the DC input mode to allow the scope to record dc as well as ac responses.

Set the horizontal timebase to 1 millisecond per division.

Set the trigger mode to normal and trigger slope to + to cause the scope to trigger on the positive-going edge of the incoming signal.

Connect the scope to the − input of the 741 op amp and set the function generator for a 10-volt p-p (two vertical divisions on the scope screen or display), 100-Hz triangular wave.

Record you results in the user plot space provided.

Now connect the scope to the output terminal of the 741 and note the output waveform. Compare the duty cycle of the signal with the theoretical illustration. If you're using a single-channel scope, the input display won't be present. However, as an exercise plot, you can overlay your display in the correct position in the user plot space provided.

We'll now analyze the saturation characteristics of the 741 op amp. Remember that the outputs can't swing all the way to the ±12-volt power-supply rails because of the saturation characteristics of the transistors used in the output stages. To Illustrate this, connect your scope to +VCC and then −VCC terminals and record the voltages on your plot. They should be close to ±12 volts. Now reconnect the scope to the output of the 741 and note that the peak-to-peak outputs are less than ±VCC.

• *Slew-Rate Test.* The effect of slew-rate limiting is always present. However, it's observed better when displaying higher frequencies. For this test, do the following:

Set the horizontal timebase of the scope to 10 μs/div.

Set your function generator for a 10-kHz signal at the same 10-volt p-p signal as before at the inverting input of the op amp.

Connect the scope to the output terminal of the 741 and note that the output waveform is actually sloping. It was also sloping in the previous experiment but it wasn't noticeable because you were viewing a lower-frequency signal. The 741 is rated to provide a slew rate of less that 0.5 μs/V of output change. This means that with a 20-volt change in output voltage, it will take at least 10 μs for the output to change polarity.

Plot your response and compare it with the Texas Instruments specifications sheet shown in **Fig. 11**.

Using the Op Amp As an Amplifier

Now we'll look at applying negative feedback to the basic op amp. Doing this reduces the gain from about 200,000 to levels ranging from less than unity to a few hundred times. You'll learn how to calculate gain and input impedances for both inverting and noninverting designs and will be able to predict the maximum undistorted output levels as a function of frequency and load resistance. You'll also observe how the common-mode rejection mode varies with frequency and how the small signal risetime compares to slew rate.

Basic op amps that have gains of 200,000 and more aren't practical for use as ordinary small-signal amplifiers. However, it's easy to employ negative feedback between the output and inverting input terminals to reduce gain to manageable levels. Feedback can be adjusted for a wide range of gains and can be used in both inverting and noninverting modes. The only problem with putting it to use is learning how to read the specifications and to interpret the host of interacting characteristics. For example, maximum output voltage is a function of frequency as well as load resistance; CMRR isn't a constant, but a function of the common-mode frequency; frequency response is a function of the gain selected; small-signal characteristics are different than large-signal characteristics. The question is: How does one make sense of all these interactive specifications?

Fortunately, most manufactures present the data the same way. We'll use Texas Instruments' specifications sheet for the μA741 to explain

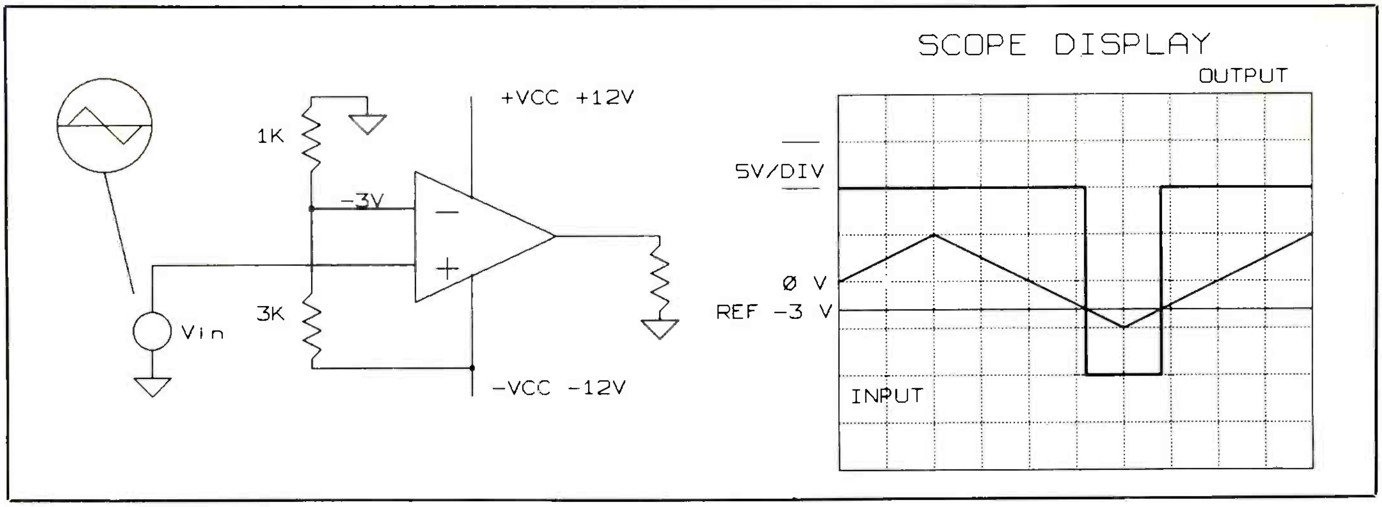

Fig. 9. Details of a noninverting negative-reference comparator circuit.

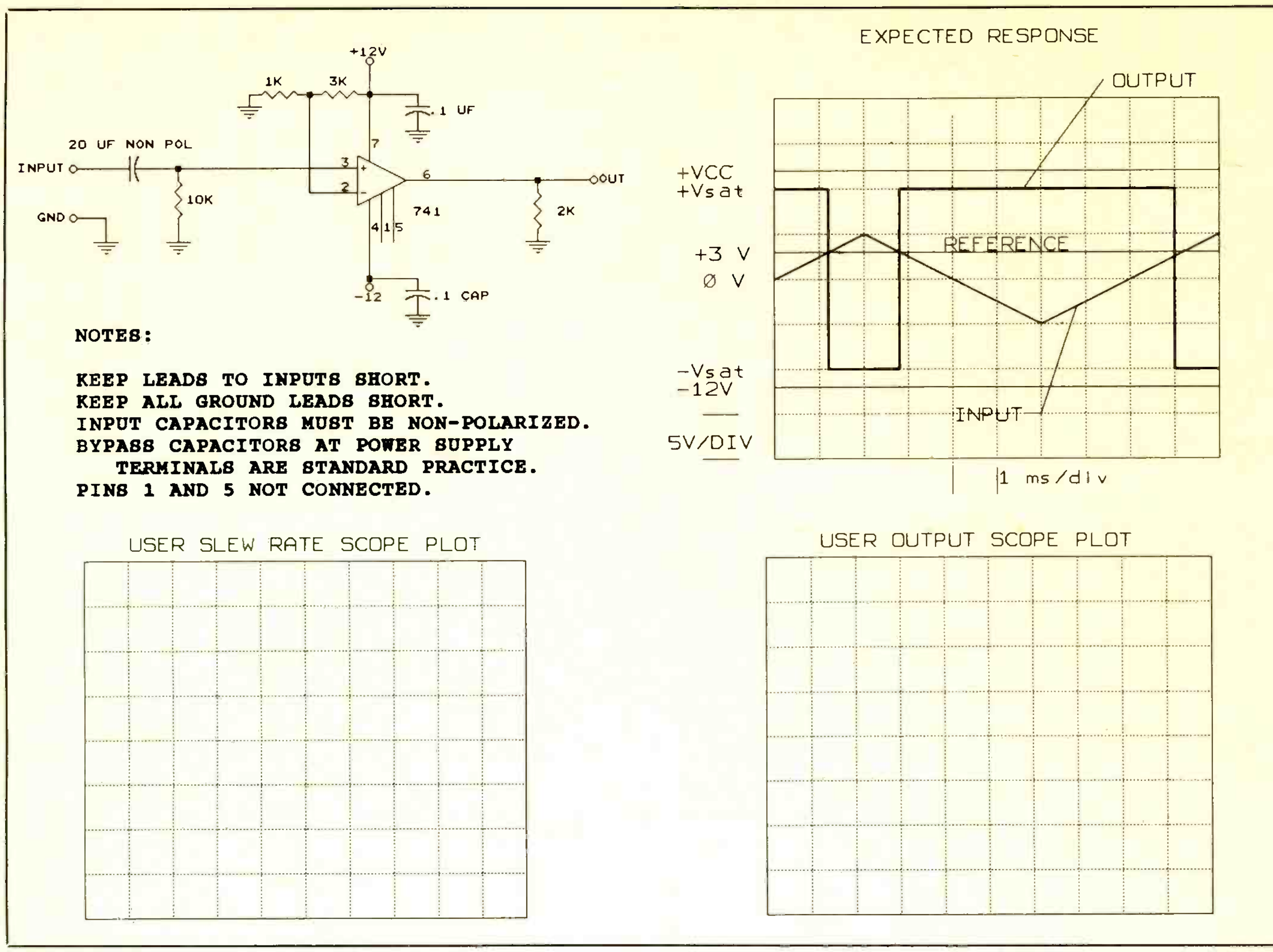

Fig. 10. Schematic details of a positive-reference inverting comparator (upper-left) you build and upon which you perform experiments. Plot the results obtained on the appropriate grids shown at the bottom and compare them with the composite expected responses shown at the upper-right.

how the specs apply to design situations. We'll assume that the dynamic characteristics are similar for the inverting and noninverting modes. TI chose to measure risetime, overshoot and slew rate in the noninverting emitter-follower mode (see **Fig. 12**). Other manufactures may use different configurations; so be careful when reading spec sheets.

• *Input Offset Adjustments.* The input offset null circuit **(Fig. 2)** allows the designer to compensate for unbalances in input amplifiers and differences in user circuitry. For example, if a very-large-value resistor is used to terminate the input of a noninverting input, the slight input bias current through the resistor will develop a dc voltage between the noninverting input and ground. When amplified, this voltage will cause the output to have an offset voltage. The offset can be set to zero by using the circuit shown in **Fig. 2**.

Input bias current is also sensitive to the free-air temperature **(Fig 4)**. If the output offset is to be super-critical, compare units that have lower input bias currents. Some FET designs like the Analog Devices 843 have less that 1 nA input bias current, which is 0.001 that of the 741.

• *Output Range Considerations:* Looking at **Fig. 5** and **Fig. 6**, you can see that the both the choice of load resistor and the frequency determine the maximum peak-to-peak output voltage. If the load is less than 2,000 ohms **(Fig. 5)**, peak-to-peak output drops rapidly. A 200-ohm load permits only about 10.5 volts peak-to-peak output before distortion occurs.

Now look at **Fig. 6**. Notice that the maximum output curve falls off very rapidly after 10 kHz. Note, too, that this curve is presented using a 10,000-ohm load resistor. You can assume that things get worse if the load resistor gets much smaller. In cases like this where it's permissible to use lower loads, the designer must bench test the device to develop his own data or contact the manufacturer for additional data.

Be sure to compare your high-frequency output design requirements with this curve. For example, if you need 5 volts peak-to-peak at 100 kHz, this device won't be up to the task. If all your frequencies are below 10 kHz, the device will produce 28 volts peak-to-peak.

• *Supply Voltage considerations.* **Figure 7** reveals that open-loop gain is a function of supply voltage. Open-loop gain with a ± 15-volt supply voltage is 200,000. It drops to about 60,000 if the supply used is on-

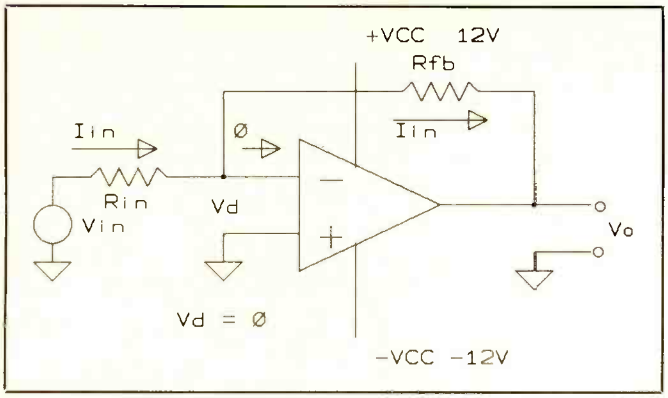

Fig. 11. A circuit you can use to calculate the gain of an inverting amplifier.

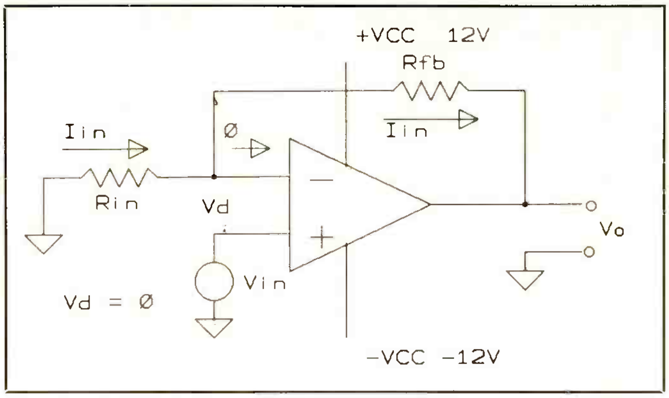

Fig. 12. A circuit you can use to calculate the gain of a noninverting amplifier.

ly ±5 volts. Data presented in **Fig. 5** and **Fig. 6** are also related to supply voltage. If you use the device less than ±12 volts, you should develop your own data for output voltage range and frequency response.

• *Frequency Response.* The open-loop gain *versus* frequency relationship is shown in **Fig. 8**, which shows that the gain below 5 Hz is 200,000 and drops off to unity at 1 MHz. It would appear, however, that maximum peak-to-peak output is almost zero at 1 MHz, making the use of this device at this frequency academic.

When we apply feedback, gain is reduced at all frequencies. Feedback is less at higher frequencies, so its effect at high frequencies is less. A 741 set for unity gain starts to droop a few dB at 60 to 70 kHz. Again, this is established on the bench. Consequently, design with op amps is an art as well as a science. Thus, all designs must be prototyped and carefully documented.

• *Common Mode* versus *Frequency.* Common-mode rejection ratio is also frequency-sensitive. The curve in **Fig. 9** indicates that CMRR at 1 MHz is less than 20 dB, which is less than 10:1. It's better than 60 dB (1,000:1) at 5 kHz. Again, if all you're concerned with is 60-Hz hum, this is a great device to use. However, if leads are close to a CPU or other digital circuit, this chip may not be suitable. As an example, the AD 843 has 40 dB of rejection (1,000:1) at 1 MHz. As you can see, you may have to do some spec-sheet shopping to get the right op amp for your design.

• *Transient-Response Considerations.* The last curve we'll evaluate is for small-signal risetime. The slew rate indicates that the output can rise at a 0.5-μs/volt change in output voltage. This could be interpreted that it takes only 0.05 μs for a 0.1-volt change in output, which is true when large signals drive the inputs. However, if you use the amplifier as a small-signal linear device, risetime will be limited to about 0.4 μs for only a 20-millivolt output. So you must be careful to distinguish between overdriven saturated conditions, as when used in comparators, and the small-signal linear operation that exists in low-gain amplifier design.

Feedback

Adding feedback to the inverting op-amp circuit consists of adding resistor R_{fb} from the output to the inverting input and placing resistor R_{in} in series with the input, as illustrated in Fig. 11.

Calculating gain is a straightforward procedure if you make a couple of assumptions. One is the voltage drop across the inputs (V_d) is 0, the other that the current into the inputs of the op amp is 0:

$$I_{in} = E_{in}/R_{in}$$
$$E_{in} = I_{in} \times R_{in}$$

Since there's no input current into the op amp inputs, current through R_{fb} must equal I_{in}. If voltage $V_d = 0$, $V_o = I_{in} \times R_{fb}$.

Closed-loop gain is expressed by:

$$A_{cl} = V_o/V_{in} = (I_{in} \times R_{fb})/(I_{in} \times R_{in}) = R_{fb}/R_{in}$$

Therefore, gain is simply the ratio of the value of the feedback resistor divided by the value of the input resistor.

Input impedance is R_{in} because V_d is 0.

All remaining circuit specifications are essentially defined by the parameters discussed earlier and can be estimated by consulting the manufacturer's specification sheet.

Using the same assumptions as above for the noninverting op-amp circuit, you can see that:

$$V_{in} = I_{in} \times R_{in}$$
$$V_{fb} = I_{in} \times R_{fb}$$

Closed-loop gain is calculated using the following formula:

$$V_o/V_{in} = I_{in}(R_{fb} + I_{in} \times R_{in})/(I_{in} \times R_{in})$$
$$A_{cl} = 1 + R_{fb}/R_{in}$$

Keep in mind that the gain for the noninverting amplifier configuration can't be less than 1.

The input impedance looking into the noninverting input is infinite because the current into the device is zero. With the current not being 0 for a 741, you obtain an input impedance of 2 megohms. Input impedance for the AD843, on the other hand, is 10^{10}, or 10,000-million ohms.

Coming Next Month

Next month, we'll discuss building an inverting amplifier that has a gain of 5 and an input impedance of 50,000 ohms. You'll measure gain, risetime, frequency response and output levels as a function of frequency and compare your results with those expected from the specification sheet for the 741 op amp.

so, thoroughly clean the enclosure and make sure it's completely dry. Then use a spray enamel to paint it. Spray on two or three covering coats, allowing each coat to thoroughly dry before spraying on the next.

When the paint has completely dried (preferably for 24 or more hours), loosely mount the circuit-board assemblies to the floor of the enclosure and mount the potentiometer controls and rotary switch on the control panel and place a pointer-type control knob on the shaft of each. Rotate the control knob of each potentiometer in turn over its entire travel and note if the stop points are symmetrically located to either side of the central axis. If not, adjust the positioning of the controls until the stops are symmetrical and tighten the hardware. Repeat with the positions for the rotary switch.

Once you have the potentiometers and switches properly positioned, remove the control knobs from their shafts and use a dry-transfer lettering kit to label the panel, referring to the lead photo for details. When you're done, use masking tape to protect the controls and switch as you spray two or three light coats of clear acrylic over the entire panel to protect the lettering. Allow each coat to dry before spraying on the next.

Mount the meter movement, POWER switch and binding posts in their respective locations on the control panel and the fuse holder on the rear panel. If there's a connector on the output cord from the power supply, clip it off and discard it. Separate the conductors a distance of about 5 inches and then strip ¼ inch of insulation from both conductors. Tightly twist together the fine exposed wires in each conductor and sparingly tin with solder. Pass this end of the cord through the hole you drilled for it in the rear panel of the enclosure and tie a strain-relieving knot in it about 1 inch from the separation.

Connect the leads of a dc voltmeter or multimeter set to the dc-volts function across the output leads of the power supply and power up the supply. Determine the polarity of the conductors and mark them accordingly. Power down the power supply.

Now, referring to Fig. 5, finish wiring the circuitry. Use appropriate lengths of hookup wire for each interconnection, and strike off each conductor run as you make it. Make absolutely certain that each connection goes to the appropriate lug on the circuit-board assemblies and off-the-board components.

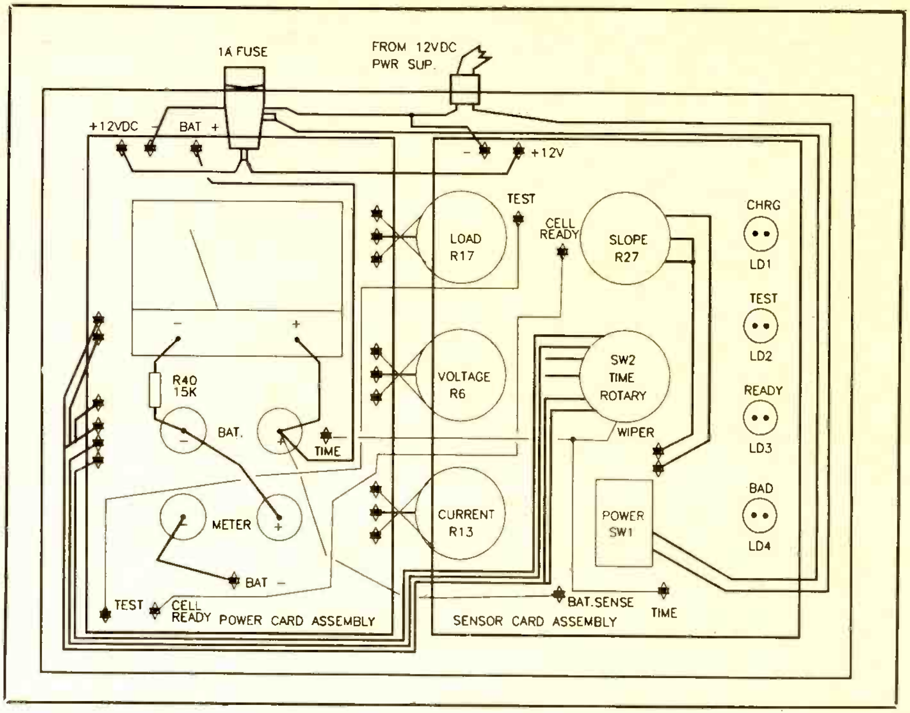

Fig. 5. Overall wiring details for interconnecting all components that make up the Super-Charger.

Leave installation and connection of the light-emitting diodes for last. When you arrive at this point, make sure to observe the polarity markings on the bases of the LEDs. There should be a flat on the "skirt" around the base of each LED, which usually identifies which of the two leads goes to the cathode. In some cases, lead length can be used as a polarity indicator.

If you aren't sure of LED polarity, connect the LED in series with a 1,000-ohm resistor across a 12-volt dc power source and note if it lights. If it does, the lead connected to the + side of the supply is the anode and the other lead is the cathode.

If any LED fails to light, reverse its connections to the power supply so that it does so that you can determine polarity. As you determine the polarity of each LED, clip its cathode lead to a length of ½ inch and form a small hook in the stub.

Having determined the polarity of each LED, slide a 1-inch length of small-diameter heat-shrinkable tubing over the ends of the LED wires coming from the sensor card. Crimp and solder the cathode wire to the cathode lead of *LD1* and repeat for the remaining LEDs.

Next, clip the anode leads of the LEDs to a length of ½ inch and form a small hook in the stub of each. Then crimp and solder the cathode wires coming from the sensor card to the respective cathode leads of the LEDs. Slide the tubing up over both connections for all LEDs until they're flush with the bottoms of the LED cases and shrink into place.

Use chassis clips to mount the LEDs in their respective locations in the front panel. Alternatively, you can press-fit the domes of the LEDs directly into the holes if you made them small enough for this. If you go the latter route, any LED that fails to remain in place can be secured with a small drop of plastic cement.

When you're done wiring the project, neatly dress all wiring. Use small plastic cable ties or waxed lacing cord to collect the wiring into neat bundles, as shown in the completed project pictured in Fig. 6. Then tighten the mounting hardware for circuit-board assemblies.

Preliminary Tests

Connect the common lead of a dc voltmeter or multimeter set to the dc-volts function to any convenient point that's supposed to be at ground potential. Place a fuse in the fuse holder. Then, with no DIP ICs plugged into the sockets on either circuit-board assembly, plug the power supply into an ac outlet, and set the POWER switch to ON.

Touch the "hot" probe of the meter to pin 16 of the *U1* and *U2* sockets and pin 8 of the *U3* sockets and to pin 1 of *U5* on the power-card assembly. In all four cases, you should obtain a reading of +5 volts.

Touching the "hot" probe of the meter to pin 16 of the *U1* and pin 3 of the *U4* sockets should yield readings of approximately +12 volts on the sensor-card assembly. Your reading at pins 4, 10, 12 and 14 of the *U3* sockets on the sensor-card assembly should be +5 volts.

If you fail to obtain the proper reading at any one or more points in the circuit, power down the project and rectify the problem. Do not proceed until you obtain the proper readings in all cited locations and are certain that your wiring is correct.

When you're certain that everything is okay, power down the project and plug the ICs into their various sockets. Make certain each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets. Then place an Ni-Cd battery in an appropriate battery holder and connect an ammeter (preferably using the ammeter function of a digital multimeter), in proper polarity, between the negative side of the battery holder and the BAT. NEG. connection on the power card.

Before you power up, make absolutely sure your meter is in the proper mode. Otherwise, you can damage your meter, especially if it's accidentally set to the resistance function.

Set the charging VOLTAGE, CURRENT and LOAD controls to MINIMUM. Power up the project and note if the voltmeter on the control panel indicates a small voltage. If it does, adjust the charging VOLTAGE control slowly clockwise to a point about 50% beyond the rating of the battery. You can estimate this setting of the control. Fully counterclockwise is the minimum of 1.2 volts; fully clockwise is about 11 volts. The voltmeter will probably indicate actual battery voltage, regardless of the setting of the charge VOLTAGE control. This is due to the current-limiting action of the current circuit.

While monitoring your DMM, slowly adjust the charging CURRENT control clockwise. As you do this, you'll observe that the current begins to increase. For initial testing, use about 100 mA of charge current.

At this point, the Super-Charger will be charging the battery. To check out the test phase of the charging cycle, you need patience! The project charges the battery for several minutes before it begins its first test. When the test phase is entered, the green CHARGING LED extinguishes and the yellow TESTING LED illuminates. Watch your battery ammeter, which should be indicating a negative number and represents load current in milliamperes.

Quickly adjust the LOAD control to obtain a reading of approximately 100 milliamperes. Set the SLOPE control fully clockwise. After a few seconds, the project should resume the charging phase.

Set the TIME switch to the 0.5-hour position and let the unit run for about 30 minutes. After the Super-Charger times out for 30 minutes, it will light the BAD LED. You may have to re-time this cycle several times and adjust the value of timing capacitor *C2* on the power card until you get close to 30 minutes (±4 or 5 minutes should be close enough). You can either try several different 2.2-μF capacitors until you obtain

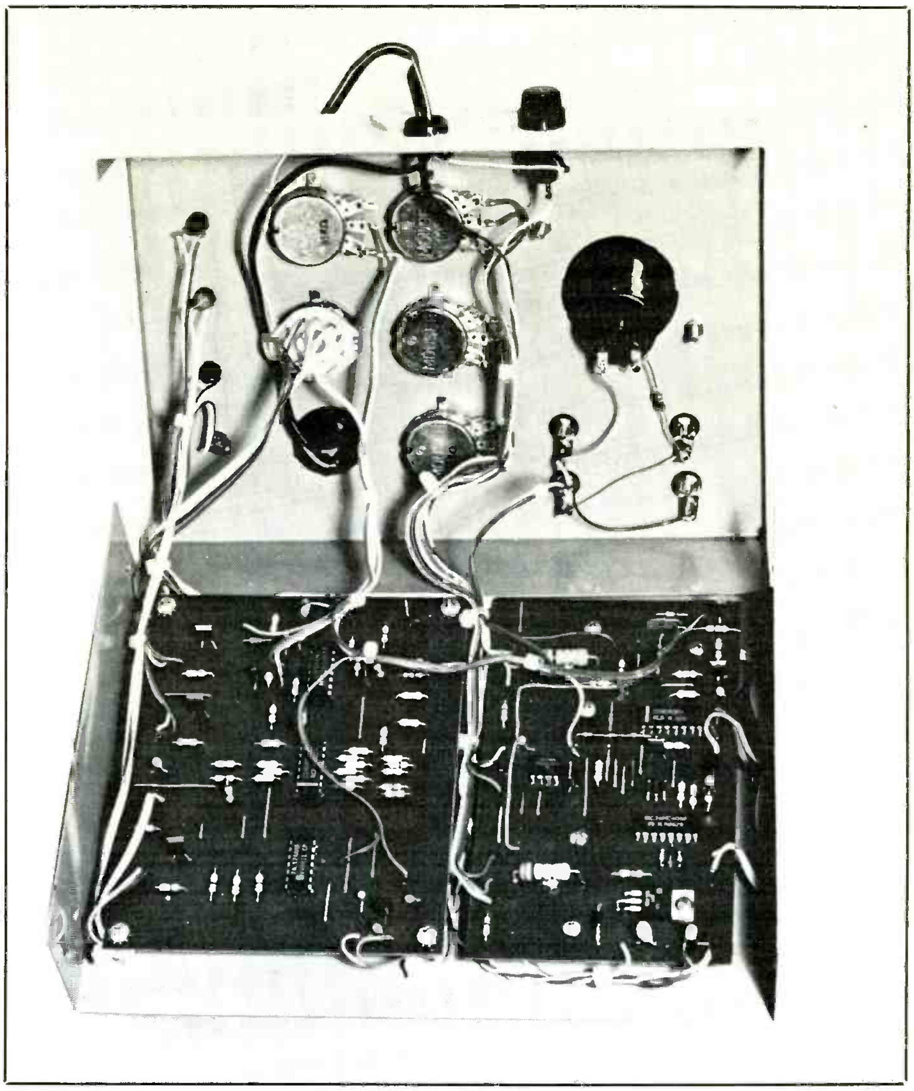

Fig. 6. Interior view of completed Super-Charger prototype.

one that's close, or you can try changing timing the values of *R3* and *R4* to obtain proper calibration.

To calibrate the timebase, move to the final slope test. Start charging once again by switching power, but this time set the SLOPE control fully counterclockwise. After a few minutes, the Super-Charger enters its test phase as usual. However, this time, charge the battery enough to pass the minimum slope test. Rather than returning to the charge mode, the unit should light the GOOD LED, indicating a charged battery.

Using the Project

Super-Charger is a very flexible battery-charging device. If you don't know much about Ni-Cd battery characteristics, start reading up on the subject. This project allows you to pick and choose among the various charging methodologies. Some people feel that charging Ni-Cd batteries should be done at low charging currents for extended periods of time. Others feel that greater charging currents can be safely used for shorter periods of time.

It's up to you to experiment with Ni-Cd cells and batteries and the Super-Charger to determine optimum charging performance. There are now available "rapid charge" Ni-Cd cells and batteries that can tolerate much greater charging currents than heretofore. Obtain as much information as you can on Ni-Cd batteries from manufacturers. While I don't know that it's necessary, I never leave my Super-Charger unattended. If a cell or battery or the project behave unpredictably, I'm always ready to intervene. You should also always remove cells and batteries from the battery holder when fully charged. If you don't, the voltmeter built into the project can eventually run them down.

It should be possible for you to "up-scale" your Super-Charger to accommodate larger-capacity batteries. A larger power supply would be in order, as would be larger heat sinks and even semiconductors with greater power-dissipating capability. If you use the Super-Charger wisely and safely, it will provide you with a reliable and versatile Ni-Cd battery charging system for years to come! ■

 (from page 12)

Math Equations For Word Processors

K-Talk's *MathEdit* 2.0 creates typeset-quality math equations that can be easily imported into word-processor documents. It is compatible with *WordPerfect, Word, WordStar, MultiMate, PageMaker* and other programs that can import TIFF, PIX or EPS graphics.

Users see their equations as they are being created, and all commands are visible onscreen. *MathEdit* requires DOS 2.11 or later, a graphics-compatible word processor, 400K RAM, a hard disk and a graphics-compatible monitor. Price is $199.

CIRCLE NO. 29 ON CARD

Technical Support Software expanded the capability of its HP Driver Disk to support the HP DeskJet for the mathematical typesetting program, *EXACT*. *EXACT* is a RAM-resident program that cooperates with a user's word processor to permit creation of complex mathematical expressions in a WYSIWYG environment. The program is compatible with the latest versions of *WordPerfect, Word, WordStar, MultiMate, Displaywrite, Samna* and most other PC-based word processors. Drivers are available for all common dot-matrix and laser printers. Depending on the number of fonts loaded, *EXACT* requires from 64K to 128K of RAM. The company provides a free demo disk that allows users to test the compatibility with their word processors.

CIRCLE NO. 26 ON CARD

Hand-Held Printer

The Syntest (Marlboro, MA) SP-401B battery-powered hand-held thermal printer allows users to produce quiet, low-cost hard-copy output anywhere. Housed in a rugged aluminum case, the SP-401 measures 5.7"D × 4.5"W × 3.1"H and weighs only 4.13 lbs. Featuring 40-column print technology and a replaceable Ni-Cd battery pack, the SP-401B has an enclosed paper supply. The battery allows it to print up to 7,000 lines of text between charges. A multinational character set, Barcode 39 and IBM graphics capability are built in. Input interfaces include RS-232C, 20 mA and Centronics parallel. $410 in OEM quantities.

CIRCLE NO. 27 ON CARD

Enhanced Laptops

Sharp's MZ-200 and MZ-250 laptop computers are enhanced versions of the popular 100 series. Both models feature 10" 640 × 400 high-definition back-lit, triple supertwist CGA LCDs with four shades of gray. Measuring only 11.1" × 11" × 2.3", these models weigh in at 8.8 pounds. The MZ-200 has dual 1.44M 3.5" floppy-disk drives, while the MZ-250 has a single floppy and a 20M hard disk. Both units use a 10-MHz 8088-compatible CPU.

Options include color/mono-chrome CRT interface, a second serial port, an external 5.25" floppy-disk drive, 1,200- and 2,400-bps modems, 768K EPROM card and carrying case. The MZ-250 lists for $2,499, the MZ-200 for $1,999.

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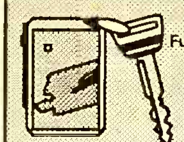

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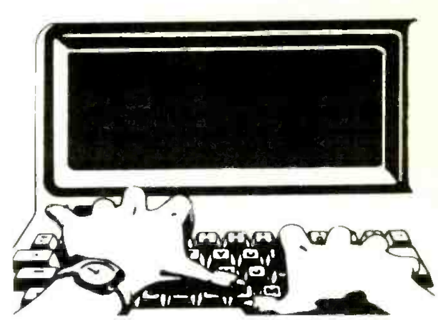

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Links: The Challenge of Golf

Golf enthusiasts who own personal computers can rejoice. Finally, there's a golf game wherein the trees, greens and other scenery all look real. The game is called *Links* from Access Software.

Access Software has helped move ahead the computer-game market with its cutting-edge use of digitized graphics and sound. *Links* is another step forward for games, especially golf simulations. As a whole, the game sports useful features that make it very enjoyable to play.

Graphics display is the first noticeable feature as the game starts. The digitized 256-color images are near-photograph quality. Terrain and sky, green and sand all look convincingly real. When the on-screen golfer winds up and takes his shot, swing and snap are perfectly fluid. Digitized sound reports the sharp click as the golf ball takes off on its flight.

These remarkable graphics are not enjoyed without a price. As computer gamers know, detailed graphics demand processor time and can be slow to manipulate. When loading graphics from one scene to the next, the length of waiting time can become significant even when using an average-speed '386 computer with a fast video card. The first thing that helps solve this problem is installing the game on your hard drive. Don't even think about playing from floppies! Another thing that helps is to have 3M of extended memory for the game to use. When doing so, an extended memory manager must be installed, such as Microsoft's HIMEM or Quarterdeck's QEMM386. The game can also use expanded memory, but extended memory runs faster.

The simulation aspect of *Links* is equally impressive. The player has control over virtually every aspect of the game. Difficulty levels can be set from Beginner to Professional. Beginner level is designed for children and is very forgiving of poor technique. The higher levels, especially Professional level, demand accuracy in timing, power, hook and slice. Varying terrain, wind strength and wind direction all have an effect on the roll and flight of the ball.

Player tendencies toward hooking or slicing can be compensated for by adjusting settings for Draw and Fade. Furthermore, the scene at any particular green can be viewed from top or can be rotated and looked at from various angles. This helps to better size up terrain conditions for a good shot. And, if you find yourself in a difficult situation, you can pick up your ball and place it somewhere else. This does, however, incur a stroke penalty.

Additionally, players can make such finer adjustments as swing plane, stance, ball position and the six different types of club face. Serious golf enthusiasts will greatly appreciate these advanced features plus the fact that the game adheres to USGA rules.

Access Software is busy designing a variety of golf courses to go with the game. Bountiful Golf Course in Utah, the first of a line of new courses, is already available. New courses will add variety to the game.

Links is a brilliantly executed golf simulation that is fun for the beginner, yet challenging to the experienced golfer. Its advanced graphics, digitized sound and player features put it far ahead of other golf simulations. It is an excellent simulation that celebrates the look, feel and beauty of real golf. ■

Bird's Eye View

Links, $59.95
Championship Course #1, $9.95 (Registered Users Only)
Access Software
4910 W. Amelia Earhart Dr.
Salt Lake City, UT 84116
800-800-4880
Requirements:

Memory	640K, Extended, Expanded
Graphics	VGA, MCGA
Sound	RealSound, AdLib, Sound Blaster, Msound, IBM Speech Adapter
Controllers	Joystick, Mouse

Evaluation

Documentation	Good
Graphics	Excellent
Learning Curve	Short
Complexity	Medium
Play Length	Medium
Playability	Good
In Brief:	Successful golf simulation with excellent graphics. Recommend a fast computer with extended memory for optimum performance.

Samples of dazzling graphics for Links: Main Menu; Using the grid to get a feel of the course terrain; Lining up a shot.